‘Subtle’ Technology:
Design for Facilitating Face-to-Face Interaction for Socially Anxious People

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Submitted in partial fulfilment of the requirements

for the Degree of Doctor of Philosophy

Statement of Originality

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April 20, 2018

Abstract

Shy people have a desire for social interaction but fear being scrutinised and rejected. This conflict results in attention deficits during face-to-face situations. It can cause the social atmosphere to become 'frozen' and shy persons to appear reticent. Many of them avoid such challenges, taking up the 'electronic extroversion' route and experiencing real-world social isolation. This research is aimed at improving the social skills and experience of shy people. It establishes conceptual frameworks and guidelines for designing computer-mediated tools to amplify shy users' social cognition while extending conversational resources. Drawing on the theories of *Social Objects*, 'natural' HCI and unobtrusive Ubiquitous Computing, it proposes the Icebreaker Cognitive-Behavioural Model for applying user psychology to the systems' features and functioning behaviour.

Two initial design approaches were developed in forms of Wearable Computer and evaluated in a separate user-centred study. One emphasised the users' privacy concerns in the form of a direct but covert display of the Vibrosign Armband. Another focused on low-attention demand and low-key interaction preferences – rendered through a peripheral but overt visual display of the Icebreaker T-shirt, triggered by the users' handshake and disguised in the system's subtle operation. Quantitative feedback by vibrotactile experts indicated the armband effective in signalling various types of abstract information. However, it added to the mental load and needed a disproportionate of training time. In contrast, qualitative-based feedback from shy users revealed unexpected benefits of the information display made public on the shirt front. It encouraged immediate and fluid interaction by providing a mutual 'ticket to talk' and an interpretative gap in the users' relationship, although the rapid prototype compromised the technology's subtle characteristics and impeded the users' social experience.

An iterative design extended the Icebreaker approach through a systematic refinement and resulted in the Subtle Design Principle implemented in the Icebreaker Jacket. Its subtle interaction and display modalities were compared to those of a focal-demand social aid, using a mixed-method evaluation. Inferential analysis results indicated the subtle technology more engaging with users' social aspirations and facilitating a higher degree of unobtrusive experience. Through the Icebreaker model and Subtle Design Principle, together with the exploratory research framework and study outcome, this thesis demonstrates the advantages of using subtle technology to help shy users cope with the challenges of face-to-face interaction and improve their social experience.

Acknowledgements

The idea behind this research originated while I was working on the Queen Mary Innovation and placement projects at R&D lab, Lean Mean Fighting Machine. It was then developed through discussion with my supervisors Dr Matt Purver, Dr Akram Alomainy, and advisor Prof Pat Healey during my research at Media Arts Technology (MAT) programme and circuit experiments in Electronics Teaching Lab. I'd like to thank Matt for his support given towards the completion of this thesis during his sabbatical leave. Also I'd like to thank Jennifer Murray, Jonathan Winfield, Dr Nick Bryan-Kinns, and Prof Simon Dixon for their assistance in the thesis submission.

I wish to express my sincere gratitude to the examiners Prof Sarah Kettley and Dr Tony Stockman for their time and invaluable guidance towards the improvement of this thesis.

This work would not have been possible without the commitment of all the shy people who participated in the studies. I would like to thank my friends Anusaya Sutan-Tanon, Berit Greinke, Doon MacDonald, Hilda Walsh, Netnapis Kittivorapattara, Pushka Antoniades-Walsh, Richard Kelly, and especially Irene Antoniades and Sam Duffy. My thanks also to my family who provided support in so many ways.

Above all, I would like to express my appreciation to Delia Weeks who has always been there for me and has supported me in every way, who always took me out to galleries and the Heath to clear the mind when the writing became muddled.

I dedicate this research to my mother Wilaiwan Thaa-wara, for her friendship and unwavering devotion and encouragement, who taught me to overcome adversity, and never lost confidence in me. She would have been delighted to know the thesis has been bound.

This research is funded by RCUK under the Digital Economy Doctoral Training scheme, through MAT programme, EPSRC Doctoral Training Centre EP/G03723X/1.

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List of Abbreviations

corr. – Correlate (p. 194)
CMC – Computer-mediated communication (p. 24)
F2F – Face-to-face (p. 12)
EQ – Empirical question set for a specific study (p. 173)
HCI – Human-computer Interaction (p. 3)
IBJ – Icebreaker Jacket (p. 157)
IBT – Icebreaker T-shirt (p. 128)
NHST – Null-hypothesis significance test (p. 106)
no-soObj – No social-object meeting mode (p. 170)
NUI – Natural User Interface (p. 52)
PST – Practical significance test (p. 107)
PWM – Pulse-width Modulation (p. 116)
QA – Question-answer number in a questionnaire (p. 147)
RFID – Radio-frequency Identification (p. 137)
RQ – Central research question (p. 6)
RCT – Randomised-controlled trial (p. 99)
SAD – Social Anxiety Disorder (p. 12)
SIAS – Social Interaction Anxiety Scale (p. 94)
SO – Social Object (p. 6)
SPA – Social-proximity application (p. 26)
SW – Social weight (p. 76)
TAP – Technology-assisted psychotherapy (p. 22)
vs. – Versus (p. 177)
WBAN – Wireless Body-area Network (p. 114)

Chapter One

1. Introduction

1.1. The Problem

Shyness is a common experience that can be triggered by unfamiliar social settings. Almost everyone, at least occasionally, is inclined to feel socially anxious at some stage in life (Leary & Kowalski, 1997) but shy or socially anxious persons, experience it more frequently and to a greater degree. For them, the anxiety can have negative consequences on psychological well-being that affects work and day-to-day interaction with others, especially in the age of technology-mediated and online social networking.

The affluence of technology has expanded the possibility to connect with others and to avoid some social challenges during in-person communication (Lu et al., 2011). For shy users, these benefits can come at a cost, i.e., the sense of real-world isolation (Pittman & Reich, 2016), low self-esteem (Widyanto & Griffiths, 2011) and limited practice of handling anxiety in face-to-face situations (Pierce, 2009). As a result, it limits the opportunities to improve social cognition and conversational skills in-person – the apparent effects of social anxiety exhibited by shy users.

Computer-mediated communication tools have expanded the ‘everywhere’ (Greenfield, 2006) nature of online information into the real world. It is common for social network sites to provide context-aware applications in mobile communication devices and accelerate new connections among zero-acquaintance users, who are in defined proximity of one another. The technology also lends itself to forceful and dynamic expression of the need for new contacts. Despite facilitating extrovert interaction models (Chalmers, Fitzpatrick, Scott, & Wakeman, 2008), this type of technology often comes equipped with high attention-demand user interfaces (e.g. screen, on-screen keyboard, button and cursor). Its ‘in-your-face’ (Clark, 2003) features are built in ways that do not fade into the background of the user’s life or work. Adopting such technology as a tool for real-world social interaction, the interpersonal skills and experiences of the socially adept tend to flourish, whereas of the shy person become marginalised. Shy individuals are more reserved and concerned with privacy. They need time to adjust to unfamiliar situations and are careful with the disclosure of personal information. Their social nature gives them the appearance of being reticent, showing a preference for low-cognitive demand and unobtrusive technology.

Bearing in mind the increasingly pervasive nature of social technology and recent records of people suffering from social anxiety (Australian Psychological Society, 2010; National Collaborating Centre for Mental Health UK, 2013; Pilling et al., 2013) being more widespread and prevalent in Western society than first thought, it seems that more consideration should be given to shy people’s communication prerequisites. The situation is complicated by cultural forces that equate a forceful, self-expressive and loquacious personality as a path to success while shyness is sometimes looked upon as a sort of deviant behaviour that needs to be ‘cured’ (Scott, 2006); In this cultural climate where technology is a driving force for speeding up the pace of everyday life, people seem to become intolerant more quickly and lose patience with others.

The marginalisation of shy users and their needs is adopted as the research problem and looked at from two viewpoints. Firstly the personal view of the researcher who has experienced shyness first-hand and observed friends and colleagues dealing with the same difficulties and frustration in social situations. The issue seems to be neglected by the approach of currently available social technologies driven by prevailing cultural demands. Secondly, seen from the perspective of a researcher in Human-computer Interaction (HCI) and its subfield Ubiquitous Computing, it points to a lack of research emphasis on the possibilities of using technology to facilitate understanding and improvement in the social behaviour and experience of shy users. Subsequently, the knowledge transfer in practices of end-user and commercial sectors becomes limited.

These views identified the social limitations of shy users and the burdening aspects of technology to their social interaction, as matters that needed to be examined within the unexplored areas of HCI and ubiquitous computing research. Furthermore, it might lead to forming a new approach and useful methods to minimise the challenges of social interaction for shy users when using technology in this context.

1.2.Motivation

Shyness exists within the conflict between the desire to belong or be part of a group and the fear of scrutiny and rejection (Clark, 2005; Clark & Wells, 1995; Rapee & Heimberg, 1997). Nonetheless, many shy people attempt to overcome social barriers by acting ‘outwardly’ to become ‘successfully shy’, as Carducci’s (Carducci, 2000, p. 6) survey found. A number of these respondents reported having tried different methods, including ‘electronic extroversion’, to tackle the anxiety, specifically to the way it affects their fear and social behaviour. In a similar light with this finding, sociologists, like Susie Scott (2006; 2007), Christopher Lane (2007) and Susan Cain (2012), provide some positive perspectives on shyness, such as, it can (if promoted constructively) influence the person to become sensitive, thoughtful and reflective to the social situation. Scott’s (2006, p. 134) view, for instance, present the personality trait as a ‘socially intelligible response’ to a sociocultural demand and an exhibit of the desire for being part of a social group and the self-representation for the team effort. In support of her view, Scott cited Thomas Szasz’s argument of shy people that are ‘... capable of thinking sociologically about their condition, even if those around them are not’. Drawing these constructive opinions together with Carducci’s (Carducci, 2000, p. 6) seminal survey results, it implies that shy people understand the nature of social anxiety and its impact, and that they are willing to learn ways to cope with the cultural demands towards the improvement of their social interaction skills.

It confirms that shy people, having the desire to socialise, are willing to try new ways to overcome social interaction stress, despite being fearful and sensitive to unfamiliar social settings. This is one of the motivations for this research, to place this overarching topic in HCI and ubiquitous computing – the research fields with limited contributions to this particular topic. This factor is reinforced by the vantage point of combining two Ubiquitous Computing perspectives. One is Mark Weiser and John Sealy Brown’ (1995) vision of *calm computing*, where computational tools and applications are designed to inform, not overwhelm. Technology should assist but not become a ‘pervading influence’ (Abowd & Mynatt, 2000) on everyday life. Another is Yvonne Rogers’ (2006, p. 406) *engage agenda* with the objective for users to participate in an activity that they currently find challenging, in a constructive manner. Going beyond merely assisting users in their background environment, technology should enable their pursuit of existing needs, and in ways they already know, so that it is possible for them to achieve what they have considered difficult or impossible to accomplish. Incorporating these two perspectives into building an artefact for facilitating social interaction suggest that, the technology could be deployed as an 'effective tool' (Clark, 2003; Dourish, 2004b) enabling shy people to engage with others (through it) in a more appealing and meaningful way.

1.3.Research Aim

The aim is to explore how computer-mediated tools can assist shy users' social interaction, with the specific goal to develop a new approach and methods to enhance their social behaviour and experience. Listed below are the objectives to support the research aim:

- Literature search to form a descriptive understanding of how social anxiety manifests and affects individuals, and the impact of interaction models of currently available social technology
- Develop a model-based approach to conceptualise system features and functioning behaviour of a novel social aid, and validate the model based on shy[1] users' feedback
- Define and implement 'subtle' characteristics in the development of a novel social aid, and empirically assess its usability and user experience, comparing with those of the non-subtle based on socially anxious[2] users' feedback

[1] The intended users of the proposed interaction model and user interface. The term refers here to the self-report shy participants in Pilot II study who found themselves meeting with strangers in social environments challenging.

[2] The term refers here to the self-report socially anxious participants in Final study. Their social anxiety degree can range from mild to severe on the social phobia continuum (Chavira, Stein, & Malcarne, 2002; McNeil, 2001; M. B. Stein, 1999). Here, the shy trait or socially-anxious personality is placed at the lower end of the continuum, while the opposite pole is avoidant personality disorder. People in the latter group tend to avoid participating in social events altogether and fall outside the scope of this research.

- Generalise key advantages of the subtle characteristics towards forming a design principle for subtle technology.

These research objectives are discussed in the following section through the two central research questions (RQs) formulated in regards to shyness and the use of subtle technology to enhance the interaction of socially anxious users.

1.4. Central Research Questions and Approaches

It is well documented that shy people have a desire to engage in conversation (Colle et al., 2017), although initiating and maintaining it being the major challenges for them caused by the fear of potential disapproval or rejection from conversation partners (Bryant & Trower, 1974; Carducci & Klaphaak, 1999). In the presence of someone or a group with whom they are not familiar, shy people tend to become reserved by turning their attention to self-assessment and threat-monitoring, away from the interaction partner. This is when their conversational resources dry up and the social atmosphere turns 'frozen'.

Along with the constructive views given by the sociologists (section 1.2) on the social nature of shy people, sociology literature also provides the theory of *object-central sociality* (Knorr-Cetina, 1997). It explains how a shared artefact can be designed as a *social object* (SO) and given specific qualities, how SOs can influence a rapid relationship and conversation among strangers in various ways (Simon, 2010). The fundamental capacity of an SO is in their ability to draw users' attention, diverting direct attention between participants onto itself and easing the attentional stress, and in some cases, anxiety that exists when meeting someone unfamiliar. This SO ability appeared to be promising proposition for relieving the anxiety shy users experience in social interaction. However, when considering the unusual degree of their social anxiety and the way they manage attention within a social situation, it remained unclear how helpful a regular SO could be. Such considerations led the initial stage of this research to form the first central research question:

RQ1: How can a social object be used to aid the social interaction of shy users?

Inherent in this question is the assumption that not all SO qualities are adequate if the object is to be used exclusively to aid the socialising nature of shy users. This assumption requires understanding the way socially anxious individuals think and behave, as well as the available cognitive-behaviour approaches and techniques. Although providing alternative tools or methods to existing therapeutic practices is not the objective of this research, looking at the focus and effective methods used by professionals in the field clearly will benefit the current research that approaches the topic from a technology-driven perspective. The scope of HCI and its related subjects are broad and extensive and needs to be narrowed down to the relevant information appropriate to the intricate nature of the prospective users' problem. As such, the assumption requires the understanding of the intrusive features and system behaviour of in-your-face technology that may add to or escalate users' anxiety.

Through the process of reviewing literature in social psychology, sociology, HCI, ubiquitous computing and interaction design, it arrives at a research decision to undertake the 'natural' approach to designing social technology. This approach has been drawn, partly, from the embodied views of cognition (Kirsh, 2013) and interaction (Dourish, 2004b) in relation to sharable-tool uses, and by which the users' 'how-to' and 'why' knowledge comes naturally, and their existing skills and expectations unconsciously comply.

Central to the natural approach is the unobtrusive themes of computer-mediated user interfaces (namely *peripheral*, *intuitive* and low social-weight displays) – considering that focal-demand technology can add to cognitive overload in the user and hence, social anxiety. Applying these themes to low-cognitive and low-key user interaction techniques (namely *peripheral*, *subtle* and *implicit* interaction models) led to formulating the concept of 'subtle' technology – the computer-mediated social tool expected to assist socially anxious users in ways not impeding their social cognition and skills, and the usual social routines.

Peripheral user interfaces are traditionally thought of as less efficient than those designed for focal-attention demand. As peripheral attention of users plays a crucial role in making subtle technology exist and behave in ways it is intended for, it is essential to assess how and to what extent the subtle characteristics can advance users' social performance and experience. This requirement led to forming the second research question:

> *RQ2: What are the key advantages of facilitating social interaction with subtle technology?*

Introducing a new tool in situations where users already find challenging, its advantages need to be worthwhile for them to adopt. It should not require users to develop new specialist techniques for communicating with the system, not adding apparent psychological and physical efforts – the main design approach taken by the current research. Further insight is given by a comparison between the characteristics of a subtle and non-subtle social tool. It is hypothesised that the subtle would to be superior on account of its features that engage the users' existing cognitive behaviour and social skills, the functioning behaviour and manifestation that do not compete with user attention within the social routine, and offering low-key and low-cognitive operation.

These RQs are integrated into the research aim – to explore the possibility of computation-mediated artefacts and novel methods in supporting the social interaction of shy people, and thus leveraging their social intent, skill, and understanding.

Regarding the subject being in a research field that has not been extensively examined, and the research questions that imply qualitative and quantitative enquiries are equally important, this research adopts mixed method approach with an exploratory-sequential model (Creswell & Plano Clark, 2017) to design and conduct research activities in response to the research objectives (section 1.3). The model consists of three research phases running in order, namely *exploration*, *development* and *generalisation*. Finalised through the last phase, the research outcome is expected to suggest the way forward in designing a new social aid in respect to the demands and preferences of users who are prone to social interaction anxiety. Accordingly, it may turn their social situation into a more encouraging 'interface' that bridges their existing desire for social interaction and the anticipation of a positive outcome. Ideally, this subtle approach may enable the users to engage in social settings in a more fulfilling manner, and lead them to a new and positive perception about social situations and their own social abilities.

1.5.Thesis Structure

This thesis structure reflects the order of research activities conducted in the three sequential phases. Following the current introductory chapter, chapters 2 and 3 present the outcome of research *Phase I*. Its exploration starts with qualitative data collection and analytical processes, conducted through a literature review presented in chapter 2. Each of its three sections provides the theoretical and contextual background to the three research subtopics: Shyness and Technology (section 2.1), Natural Approaches in

Human-Computer Interaction (section 2.2), and Unobtrusive Interaction Styles and User Interfaces (section 2.3). Each section completes with a discussion of its analytical findings that contribute in part to the assumptions for RQs. Sub-questions for the research were formulated as well as discarded as the body of the reviewed literature grows and are set out in the research methodology: Exploratory Sequential Mixed-Method, presented in chapter 3. Here, the approach, methods, and conceptual tools (namely Icebreaker Cognitive-Behavioural Model and Design Principle for Subtle Technology) applied to experimental studies are discussed.

Phase II activities and outcomes appear in chapters 4 and 5. Knowledge from analytical findings during the first phase was applied in the development of computer-mediated instruments (namely Vibrosign Armband and Icebreaker T-shirt prototypes) and evaluation tools (namely questionnaires) used in two experiments. The armband, presented in chapter 4, is the result of applying a covert design approach to user interface, evaluated by six vibrotactile experts in Pilot I study. The study outcome (section 4.3) showed the vibrotactile display to have a negative impact on user mental load that outweighed the benefits and thus led the research to a different design approach, focusing on the design for peripheral attention. The t-shirt, presented in chapter 5, was equipped with a peripheral display and interaction models, evaluated by 11 self-report shy participants in Pilot II study. User feedback was collected through a qualitative-based questionnaire and video-audio recordings. The outcome (section 5.3) of descriptive analysis validated the Icebreaker model (section 3.3.1) and the meaning of subtle technology – central to its representation qualities and interaction techniques to initiate conversation between the co-users. This knowledge provided the answer to RQ1 and helped to set the assumption for RQ2 with several subtle characteristics formulated as the Design Principle (section 3.3.2).

Phase III activities and outcomes can be found in chapters 6 and 7. Chapter 6 is a discourse on conceptual and technical design elements to gain a deeper understanding of subtle characteristics through the refinement of the Icebreaker prototype: Icebreaker Jacket with a subtle-peripheral display used as a subtle social object in the Final study. Its usability and user experience were compared to a non-subtle social aid (subjected to the characteristics of a non-subtle social aid) and assessed by nine self-reported socially anxious participants who gave quantitative and qualitative feedback through a during- and post-test questionnaire. Justification on the descriptive and inferential statistical results (section 6.5) indicated various advantages of the subtle characteristics in facilitating social interaction, in response to RQ2 and as validation of the subtle design principle (section 3.3.2). Chapter 7 provides the final conclusion where all the main findings from previous research activities were synthesised to refine the validity of the proposed design principle for subtle technology (section 3.3.2). It ends with a discussion of the overall contributions and limitations of the study, and suggests areas for future work.

1.6. Associated Publications and Demonstrations

1.6.1. Publications

- Khaorapapong, N., & Purver, M. (2012a). An Assistive Device for Shy Users in Face-to-Face Communication (pp. 1–3). Presented at the Doctoral Consortium at 16th Annual International Symposium on Wearable Computers.
- Khaorapapong, N., & Purver, M. (2012b). Designing Unobtrusive Interfaces to Increase Naturalness of First Time Face-To-Face Interaction. Presented at 16th Annual International Symposium on Wearable Computers.
- Khaorapapong, N., & Purver, M. (2012c). Icebreaker T-shirt: a Wearable Device for Easing Face-to-Face Interaction (pp. 1–1). Presented at the Demo session of 16th Annual International Symposium on Wearable Computers.
- Khaorapapong, N., Purver, M., & Cox, D. (2013). Augmenting Real-world Social Networking with Vibrotactile Display. Proceeding of the 7th International Conference on Tangible, Embedded and Embodied Interaction, 1–8.

1.6.2. Demonstrations

- Live demonstration of Vibrosign Armband, the 7th International Conference on Tangible, Embedded and Embodied Interaction, Fab Lab, Barcelona, 2013
- Live demonstration of Icebreaker T-shirt, Innovate UK, London, 2014
- Live demonstration of Icebreaker Jacket, Wearable Technology Show, London, 2015
- Live demonstration and discussion of Icebreaker Jacket, Digital Drop-in, Victoria and Albert Museum, London, 2015

Phase I

Chapter Two

2. Theoretical and Contextual Background

This chapter establishes the argument of the thesis, through a focus on specific elements from three related research areas. The first area provides background information on social anxiety, technologies used to alleviate it, and the concept of social objects. The second area presents theoretical foundations related to natural approaches to understanding user experience and social interaction through computational technology. The third area is a review of existing interaction models and concepts of user interfaces that have the potential to facilitate face-to-face (F2F) interactions for shy people.

2.1. Shyness and Technology around Sociality

There has been a debate about the terminologies ‘shyness’, ‘social phobia’, ‘social anxiety disorder’ (SAD), and avoidant personality disorder (APD) since the mid-1980s. The counterargument started when the American Psychological Association introduced social phobia as a mental disorder in DSM-III. Inspired by the British Psychological Society’s public criticism, an Open Letter[3] namely ‘DSM-5 reform effort’ (Kinderman, Allsopp, & Cooke, 2017) was signed in 2011 by more than 15,000 health professionals from over 50 nations (Robbins, Kamens, & Elkins, 2017), calling on the APA to lower diagnostic thresholds for multiple disorders – including social anxiety disorder – while DSM-5 was being prepared. The proposed revision reflects the professional and public disapproval of physiological states being overly diagnosed as mental illnesses that could

[3] https://www.ipetitions.com/petition/dsm5/ Retrieved July 13, 2018

result in unnecessary harmful treatments with psychiatric medication and the mislabelling of people, such as the shy. Why is it worrying if shyness is overly pathologised? Kinderman et al (2017) argue, people with such a personality trait can improve their social wellbeing without undergoing treatments (Kinderman et al., 2017), even though 25 million of new antidepressant prescriptions were issued in 2001 to Americans and Europeans who experienced some forms of social anxiety after the announcement of DSM-III (Lane, 2013). Nonetheless, the DSM-5 reform effort resulted in DSM-5 (American Psychiatric Association, 2013) describing shyness as a common personality trait; non-pathological by itself that only becomes SAD when its associated conditions interfere with day-to-day activities.

The previously mentioned terminologies and different interpretations inform our understanding of social anxiety under investigation in this research and are fundamental to the conceptualisation and development of a technology, the potential benefits to users and the scope of user needs. Through the continuum approach of social anxiety, this section seeks to advance the understanding of the origins, nature and development of shyness and its effects. It also examines the impact of technologies used among socially anxious people and researchers in cognitive-behavioural and technology-mediated therapies. Lastly, the knowledge about object-central sociality, as informed by sociology literature, informs how specific kinds of objects can be used to reduce interactional stress between people while encouraging a rapid form of social functioning.

2.1.1. Understanding Shyness

To address the initial contradictions in terminologies describing unpleasant emotional states that involve social situations, it is important to note that social phobia (in DSM-III) was renamed as SAD (in DSM-IV) to denote broader and more generalised states of fear associated with this disorder (Dalrymple & Zimmerman, 2013; Lane, 2013). Nonetheless, the features for identifying relationships and diagnostic boundaries between shyness, social phobia, and APD remain unclear and undefined. Researchers have to date relied on two approaches: the heterogeneity and the continuum of social anxiety. The heterogeneity approach sees these conditions are sub-clinical with having overlapping symptoms and sharing fearful situations (Beidel & Turner, 1999; Chavira et al., 2002; Heiser, Turner, & Beidel, 2003). These conditions do not necessarily differ in degree of severity (Heiser, Turner, Beidel, & Roberson-Nay, 2009). For example, people with APD who avoid specific situations can exhibit other preferences for social sharing (Colle et al., 2017).

They may be willing to interact under certain circumstances – which people with social phobia would avoid altogether.

Another perspective views social phobia and APD as forms of shyness that manifest itself more severely (McNeil, 2010; Stein, 1999), with a greater range of social skill deficits and avoidant situations (Herbert, Hope, & Bellack, 1992; Zimbardo, 1981). This model places the three conditions on a social anxiety continuum, with mild-to-average shyness at the lower end, social phobia in between and APD at the highest point (Chavira et al., 2002). While regarding the latter two as subclinical conditions, this approach holds the hypothesis that shyness is a common personality trait found in most people (Chavira et al., 2002; Dalrymple & Zimmerman, 2013; Heiser et al., 2009; Henderson, Gilbert, & Zimbardo, 2014), who are predisposed to timidity, self-consciousness or embarrassment (Crozier, 2002) when their desire to socialise conflicts with the fear of being scrutinised (Dalrymple & Zimmerman, 2013; Heiser et al., 2003).

This research adopts the continuum approach to understanding shyness, especially with regard to the point at which cognitive 'negativities' and attentional bias escalate (Meidlinger & Hope, 2014). The latter plays an important role in differentiating shyness from SAD. Nonetheless, these impairments increase the likelihood of shyness developing into social phobia or APD (Chavira et al., 2002). Although shyness is presented in this thesis as a non-clinical condition, the understanding of its manifestation and persistence, presented as followed, is drawn on cognitive behavioural models of social anxiety and therapies. In particular, the models are those featured in the two seminal literature, namely Clark and Wells (1995) and Rapee and Heimberg (1997), and their associated cognitive-behavioural-theraphy (CBT) interventions that are central to appropriating client's attention towards positivity in social functioning.

Manifestation and Maintenance of Social Anxiety

Several cognitive behavioural models of social phobia, such as Clark-Wells (Clark & Wells, 1995), Rapee-Heimberg (Rapee & Heimberg, 1997), Moscovitch (Moscovitch, 2009) and Hofmann (Hofmann, 2007), have been proposed in line with the DSM-5. The Clark-Wells and Rapee-Heimberg models posit that deficits in attentional focus are central to the manifestation and persistence of social anxiety (Wong, Gordon, & Heimberg, 2014). A recent meta-review shows these two models are fundamental to the most efficacious CBT interventions for SAD (Mayo-Wilson et al., 2014). In addition, both models demonstrate social anxiety in ways as being receptive to available concepts and design principles of Human-computer Interaction (HCI) and ubiquitous computing. Further discussion of other models can be found in an in-depth discussion (e.g. Wong et al., 2014) and meta-review (McKenna, 2013) of SAD.

The core features emphasised in the Clark-Wells model are a strong desire to engage in social situations with high-efficacy, and the perception of oneself as lacking in the ability to do so. Such a perception about the self is not necessarily valid; shy and socially phobic individuals rated themselves less capable of handling social situations than they actually were (Heiser et al., 2009; Melchior & Cheek, 1990; Wong et al., 2014). Either influenced by failed experiences in the past, negative self-perception or rapid assumptions about potential rejection in the new situation (Melchior & Cheek, 1990; Miers, Blöte, Heyne, & Westenberg, 2014), the anxiety in individuals is heightened by self-focused attention (Kley, Tuschen-Caffier, & Heinrichs, 2012; Norton & Abbott, 2016). When social anxiety is triggered and maintained as illustrated in the Clark-Wells model (Figure 1), individuals become preoccupied by their internal cues – monitoring own cognitive and somatic symptoms and assessing own behaviour. Subsequently, they become locked within a closed negative cycle, which put their social 'self' forward as the object central to the engagement.

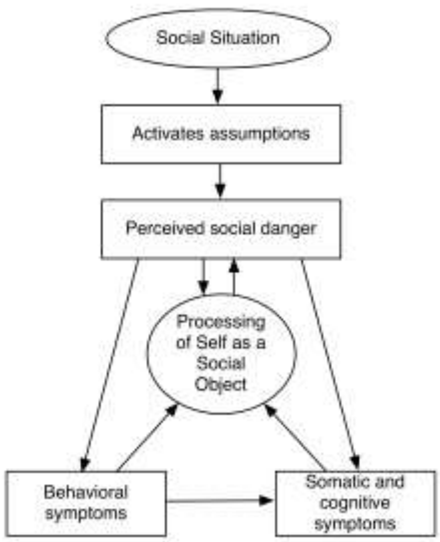

Figure 1: Clark and Wells' cognitive model of social phobia. Excerpted from Clark (2005, p. 195).

Attention pays a key role to indicate the difference between shyness and SAD. As suggested by Clark-Wells model, for which it places *'Processing of Self as a Social*

Object' as a central component that draws the person's attention back and forth within a *vicious circle*. This loop causes people with a greater degree of anxiety to shift their attentional focus inward to search for internal cues. By assessing their own behaviour, negative thoughts and fearful bodily states excessively, people with SAD and APD fail to monitor social events like shy people do. The former are unlikely to break free of the *vicious circle* while the shy pay more attention to the details of social situations (Stopa & Clark cited in Clark & Wells, 1995; Melchior & Cheek, 1990) owing to their desire to be socially accepted. This explains why shy people have a better chance to recognise the possibilities and adapt behaviour to engage with the situation more constructively.

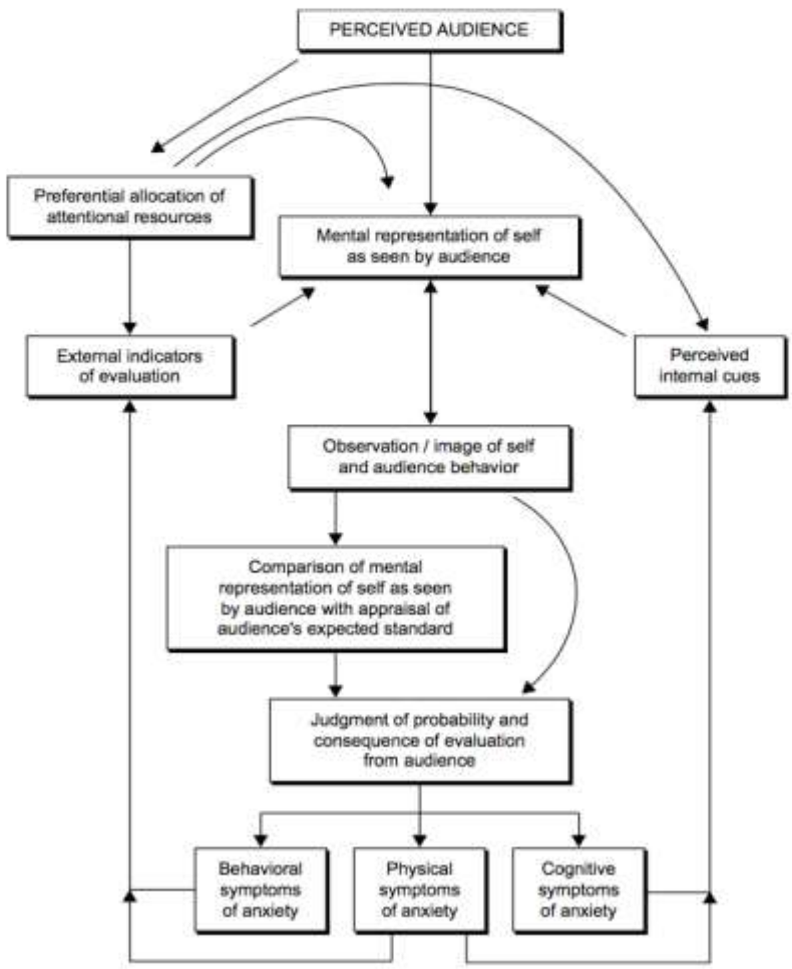

Figure 2: Rapee & Heimberg's cognitive behavioural model of social anxiety. Excerpted from Heimberg et al. (2010).

The Rapee-Heimberg model (Figure 2) follows on from Clark-Wells in similar vein, particularly in its spectrum of anxiety, but emphasises that the model itself should be applied to the entire range despite shyness not being considered a mental illness like the more severe conditions on the continuum (Rapee & Heimberg, 1997). Like Clark-Wells, the Rapee-Heimberg model places the conflict between the need for social acceptance and negative beliefs about one's social ability at the heart of social anxiety. It also describes social anxiety as a condition maintained by the processing of 'self' as the social object. However, the Rapee-Heimberg model posits that socially anxious individuals perceive others as critical of their social abilities. This perception sets a high standard for one's own performance and for positive evaluation by others. The anxious individuals hence are inclined to overestimate the required effort, risk factors and the severity of failure in social situations.

Having such a tendency and negative belief about one's own social performance creates a perceived discrepancy between own social abilities (as seen by others) and the assumption of others' expectations. As a result, the anxious person's attention is fixated on the internal assessment of the self, always searching for signs of negative evaluation and rejection by the social group (Judah, Grant, Lechner, & Mills, 2013). This threat vigilance, together with self-monitoring, incline the person to experience the self from a passive perspective (Clark, 1999b) and to disengage from the social situation that may expose the self to possible risks. Consequently, they become trapped in the *vicious cycle* – a similar negative loop described as the *vicious circle*[4] in the Clark-Wells model. This reflects the fundamental idea of both models that emphasise the self-focused cognitive processes as central to the maintenance and escalation of social anxiety (Clark, 2005; Clark & Wells, 1995; Rapee & Heimberg, 1997).

Impact of Attention Deficits on Social Cognition and Mental Capacity

Excessive self-preoccupation is not only an underlying characteristic of the severe conditions on the social anxiety continuum (Koyuncu, Çelebi, Ertekin, Kök, & Tükel, 2016) but also of shyness (Buss, 2013; Melchior & Cheek, 1990). In Melchior and Cheek' study (1990), self-reported shy individuals tended to spend most of the 6-minute conversation time with a stranger on examining their own behaviour and experience, agonising about the way they might appear to others. This attentional bias leads the

[4] These two terms: '*vicious circle'* and '*vicious cycle'* are used interchangeably from this point in the thesis.

individual to ‘selective attention deficits’ (Cheek, Melchior, & Carpentieri, 1986; Clark, 2005; Clark & Wells, 1995; Steinman, Gorlin, & Teachman, 2014) – by not paying sufficient attention to the interaction partners (Melchior & Cheek, 1990), positive social signals (Clark, 2005; Miers et al., 2014; Taylor, Bomyea, & Amir, 2010) and constructive components ‘useful’ to engage in social situations.

Attention deficits influence negative concepts about self and social situations, hence hinder social cognition – a mental factor pivotal to effective social performance (Frith, 2008; Gkika, Wittkowski, & Wells, 2017; Norton & Abbott, 2016). The theory and concepts of social cognition have been explored in many research fields (such as social psychology, philosophy of mind, and cognitive psychology) with different emphases on the relationships between humans and their social world. In cognitive psychology, social cognition refers to a set of cognitive processes enabling us to understand others and our relationships with them (Frith, 2008). It enables our social information processing and guides our social interaction (Riva & Mantovani, 2014). In other words, social cognition plays a key role in our ‘successful’ experience of in the social world (Frith, 2008). MacLeod:2004vv}. According to the Clark-Wells model, the negative bias in highly social-anxious individuals limits their cognitive abilities to anticipate a constructive social outcome that restricts their cognitive behaviour to adopt the *we-mode* of interaction – the state in which a participant of a successful joint action considers and allows their and the others’ intention (shared goals, knowledge and belief) to enhance the action and evolve through the shared experience (Frith, 2012; Tuomela, 2006; van der Wel, 2015).

Negative cognition limits attentional resources (Fredrickson, 2001) and significantly undermines the person’s effort to achieve constructive social goals and interaction (F. R. Goodman, Doorley, & Kashdan, 2018). Socially anxious people regulate fear and other components of anxiety through the self- and threat-monitoring processes. Managing such negative traits puts a strain on the working memory (Judah et al., 2013; Vytal, Cornwell, Arkin, & Grillon, 2012) by competing with normal interaction routines, and placing excessive mental demands on the person’s attentional resources. This explains why individuals who experience social anxiety are likely to suffer cognitive overload during a social situation (Berggren, Richards, Taylor, & Derakshan, 2013; Judah et al., 2013). Such overload, in turn, makes them easily distracted and fixated on negative aspects of the social situation. A recent study shows that the higher the cognitive load on the working memory of socially anxious individuals, the more difficult it is for them to disengage from social threats. (Berggren et al., 2013; Judah et al., 2013). Subsequently, the load may give rise to increased anxiety (Najmi, Amir, Frosio, & Ayers, 2015; Vytal et al., 2012). Nonetheless, Vytal and colleagues' study (2012) showed the interplay between anxiety and cognitive load relies largely on the amount of attention each task demands. In designing parallel tasks to improve the social performance of anxious people, finding a balance between the number of tasks and the degree of required concentration is, thus, crucial to managing their attention.

Cognitive Behavioural Therapy for Managing Attention

Cognitive-behavioural therapy is the most common method currently studied in SAD research (Bandelow et al., 2015), and believed to be more effective and durable (Beidel, Turner, & Morris, 2000; Scaini, Belotti, Ogliari, & Battaglia, 2016) in reducing anxiety than many other approaches, such as relaxation therapy (Montero-Marin, Garcia-Campayo, López-Montoyo, Zabaleta-Del-Olmo, & Cuijpers, 2018), pharmacology (Mayo-Wilson et al., 2014), behavioural treatment (Beidel & Turner, 2007a) cognitive therapy alone (Donald, Abbott, & Smith, 2012; Wong et al., 2014). Several CBT techniques were first introduced into SAD by Heimberg and colleagues in the early 1990's (Beidel & Turner, 2007b), such as exposure to stimuli, cognitive restructuring, self-help and social skills training (Hambrick, Weeks, Harb, & Heimberg, 2003; Heimberg, 2002). In line with the Clark-Wells and Rapee-Heimberg models, exposure incorporated with attention bias modification technique is a recent intervention but becoming well established (Hakamata et al., 2010; Ollendick et al., 2018). It is widely used to counter nonconstructive thoughts and behaviour by decentralising clients' attention away from negative self-related aspects (self-attention bias) and threats (clue-attention bias). Presented in recent systematic reviews, treatments that focus on changing attentional processes during exposure do not only reduce social anxiety (Fistikci, Saatcioglu, Keyvan, & Topcuoglu, 2015) and self-focus attention (Kley et al., 2012) but also improve rational thoughts on self-related concepts (Gregory & Peters, 2017; Hulme, Hirsch, & Stopa, 2012).

Exposure with an attention training approach has both limitations and benefits to socially anxious clients regarding the stimuli used in the training process, such as threatening facial expression (Ollendick et al., 2018), challenging speech (Ahn & Kwon, 2018), and social mishap (Fang, Sawyer, Asnaani, & Hofmann, 2013). Exposure exercises are usually conducted through simulation and exposure to fears commonly encountered by clients in social situations (Heimberg, 2002). The clients are assisted to endure or disengage from threats by diverting their attention to positive stimuli, and thereby to remain cognitively and behaviourally active in the social exchange. However, to fully engage in the given situation is a fundamental requirement of the attention modification approach (Heimberg, 2002) which remains a difficult stage for socially anxious people to reach being already in a state of fearfulness. Training their attention to circumvent threats is, therefore, less common (Klumpp & Amir, 2010) because it tends to trigger an instant rise in anxiety, rather than seizing control (Foa & Kozak, 1986). This is evident in a recent study by Aderka and colleague (2013) who found the fear and anxiety in participants with social avoidant behaviour increasing above the pre-treatment level during the first 8 of 14 weeks treatment, although no increase found from week 9^{th}. Nonetheless, the effects of training to disengage from threats, when successful, have much greater impact than no training (Heeren, Reese, McNally, & Philippot, 2012; Klumpp & Amir, 2010; Schmidt, Richey, Buckner, & Timpano, 2009). A substantial improvement is evident in Schmidth and colleagues' (2009) study in which social anxiety traits in all participants (44) were eliminated after an 8-session treatment with a lasting effect of 4 months.

Compared to attention training away from threats, diverting attention towards positive (Boettcher, Andersson, Carlbring, on behalf of the SOFIE-13 research group, 2013; Boettcher, Berger, & Renneberg, 2011; De Voogd, Wiers, Prins, & Salemink, 2014) and/or non-threatening (De Voogd et al., 2014; Klumpp & Amir, 2010; Lazarov, Pine, & Bar-Haim, 2017), particularly stimuli that involved positive self-cognition (Gregory & Peters, 2017; Hulme et al., 2012; Li, Tan, Qian, & Liu, 2008), have been reported more effective in reducing self-focus and attentional bias. Hulme and colleagues (2012) used a structural interview to elicit positive and negative self-imagery in participants with high and low social interaction anxiety (Mattick & Clarke, 1998). They found that while holding a positive self-imagery, participants could substantively strengthen self-esteem (Kernis, 2005) – a psychological feature lacking in individuals with social anxiety (American Psychiatric Association, 2013) – which helped to buffer their thoughts from the negative anticipation of socialising outcome. However, given positive stimuli can produce greater effects in participants with lower anxiety. Li and colleagues (2008) reported a similar result on comparing the degree of social interaction of two groups of socially anxious individuals for which the training group was exposed to positive stimuli.

Their anxiety reduced significantly within a 7-day treatment, compared to the controlled group.

Modification of attention in CBT can produce more positive results when combined with social skills-training, given that socially anxious people tend to limit their own social experience. In line with Stopa and colleagues' (2009; 2010) view about the self as a complex matter; many interventions provide social-skills training and demonstrate greater possibilities to improve self-related processes in socially anxious individuals. Skills training can enhance the changes in cognition and behaviour both in laboratory and existing social situations (Scaini et al., 2016). The latter is noted more challenging to the treatment process, owing to the highly variable nature of social environments and how individuals usually perform within them (Beidel & Turner, 2007a). Although incompetence in social behaviour is known to be less detrimental to social performance than cognition deficits in socially anxious individuals (Wong et al., 2014), merely diverting their attention away from excessive monitoring of the self and associated negative cues may be inadequate.

Social anxiety evolves over time and involves incompetence in interpersonal skills. Despite the intrusiveness (Veale, 2003) and overarching goals (Meidlinger & Hope, 2014) of the exposure-to-threat techniques, CBT techniques that are in line with Clark-Wells and Rapee-Heimberg models have demonstrated to improve cognitive and behavioural traits in people with social anxiety. What these successful techniques share is the aim to appropriate their attention and effecting behaviour and facilitate the social-cue processing in a constructive way.

This subsection explores social anxiety through cognitive-behavioural models and therapeutic approaches to social anxiety. The knowledge path may seem to contradict the adoption of the social anxiety continuum hypothesis that regards shyness as a common personality trait, which can be improved, if needed, without treatments. However, as a mild condition on the continuum, shyness can develop into social anxiety and avoidant personality disorders. Considering how cognitive-behavioural professionals put these conditions under control by indicating irrational thoughts and modifying nonconstructive behavioural patterns in the individual is, therefore, fundamental to the understanding of how the anxiety shy people experience during social situations is manifested and maintained.

Acquiring the above knowledge is not intended towards any production of a substitute or complementary tool to CBT research and practices, but to gain insight into the nature of the prospective user of the proposed technology (chapters 4, 5, 6). Specifically, it helps to understand why cognitive deficits in these individuals occur and how the deficits are maintained and can be prevented from escalating into a more severe condition. Subsequently, it helps to specify the scope of HCI modalities and ubiquitous interfaces of technologies to investigate (sections 2.2 and 2.3), in particular, those that prioritise the user's attention resources as something to be preserved for the focus of their ongoing activities within the given social context, and those that are suitable to provide useful information with the least interference to their social cognition, performance, and preferences. In addition, this knowledge helps to narrow down the possibilities and limitations of technology used in the field of social anxiety, as explored in the next subsection.

2.1.2. Impact of Technologies on Socially Anxious Users

Technological advances are changing psychotherapy practice and research, and the ways in which shy people strive to initiate and maintain social ties. Exploring the cognitive-behavioural approaches used by professionals to treat social anxiety, this subsection looks into the impact of technologies on social anxiety from the perspectives of researchers and practitioners in technology-assisted psychotherapy (TAP) and socially anxious users attempting to circumvent the demanding nature of interpersonal communication with the use of everyday social technology. These two topics are discussed in light of the interaction modality of technology – one of the pillars underpinning the research fields in which this thesis resides – and its main features determining the psychological effect of social technologies. In addition, given the rise of online social networking that prospers new technology-mediated relationships among unknown users, the author further examines the aspects of a virtual community that bind unknown users together at such a rapid pace. Lastly, the concept of object-centred sociality is presented to help understand these virtual phenomena and to inform how technology can be modelled to help initiate an immediate social interaction in an in-person environment.

Technology-aided Psychotherapy

The digital technology and communication infrastructure have been developing exponentially over the last two decades. This puts mental-health interventions on the path of a ‘technology-inspired revolution’ (Imel, Caperton, Tanana, & Atkins, 2017, p. 385), but the traditional format, namely F2F support, remains an indispensable aide. Like many aspects in mental-health treatments, social-anxiety applications benefit from these changes, especially in the mode of interaction between client and interventions. Seen in TAP, these modalities range from accessing simple electronic forms of therapists’ feedback and online content through mobile phone applications (Miloff, Marklund, & Carlbring, 2015; Stolz et al., 2018) to receiving complex virtual-reality (Brahnam & Brooks, 2014; Kampmann et al., 2016; Yuen et al., 2013) and immersive-environment (Krijn et al., 2004; Moller, Bal, & Potwarka, 2014; Morina, Brinkman, Hartanto, & Emmelkamp, 2014) treatments.

TAPs delivered online are becoming more popular because the Internet and smartphones disseminate widely into people’s day-to-day activities, replacing some parts of F2F sessions, thus reducing Tailoring treatments for individuals are more cost-effective and convenient than the traditional F2F format. There has been a number of studies comparing Internet-based TAP and F2F therapies, but recent meta-reviews (Andersson, Cuijpers, Carlbring, Riper, & Hedman, 2014; Carlbring, Andersson, Cuijpers, Riper, & Hedman-Lagerlöf, 2017) indicate neither of the two having significant advantages over the other. The reason why F2F treatments still holds much prominence is that socially anxious people tend to experience feelings of isolation (Baumeister & Leary, 1995) and low self-esteem (American Psychiatric Association, 2013), hence, benefit from the sense of belonging, self-validation and mutual support found in an interpersonal environment (Barkowski et al., 2016).

The advent and success of *blended* care reflect the importance of F2F features in mental-health care, as a recent meta-review shows (Erbe, Eichert, Riper, & Ebert, 2017). *Blended* care is a form of TAP that retains F2F support with computer-assisted processes partially the time (Wright et al., 2002) and cost of in-person therapy. However, its optimum benefit is in the design possibilities it offers for personalisation as Wentzel and colleagues’ study (2016) shows. As a result of the study, in line with van Germert-Pijnen and colleagues (2011), they propose *Fit for Blended Care*, a design framework for making the features of technology and content of treatment relevant to the needs, characteristics and existing physical and cognitive skills of individuals. They further state that the underlying mechanism of *blended* care is the integration of information and communication technology into daily routines in collaboration with F2F features that cannot completely be replaced. While technology can provide non-linear ways (van Gemert-Pijnen et al., 2011) and personalised locations for information access, F2F provides opportunity and encourage individuals to make use of real-world social resources (Donkin & Glozier, 2012; Gerhards et al., 2011).

The mechanism and approach of *blended* intervention support design thinking to conceptualise and situate aiding technologies within a F2F context, and in ways open to the complex and intricate issues of socially anxious individuals. These individuals often have entrenched and persisting fears of social interaction elements that lead to a lack of social-skill practices (section 2.1.1). Underestimating the importance of F2F components can, therefore, limit the benefits of the intervention. Such examples are seen in TAPs only focusing on the innovation of the technology or intervention itself, such as videoconferencing (Backhaus et al., 2012; E.-L. Nelson, Barnard, & Cain, 2003) and AI-based conversation with an online robotic interlocutor (Riek, 2016). These applications can provide real-time F2F contact, but at the same time, create a 'psychological distance' (Suwita, Böcker, Mühlbach, & Runde, 1997). Other examples are immersive exposure treatments such as Cave VRs (Krijn et al., 2004) and head-mounted displays (Morina et al., 2014). Despite adverse side effects and the uncomfortable experience of strangeness these applications impose on the users (DeLucia, Harold, & Tang, 2013), they can facilitate an engaging user interaction with the system and a sense of being with a therapist- or group-avatars, yet lack the 'real' sense of human presence [5] and connectedness. Facilitating real-time and F2F engagement within an in-person context, the interaction model of technological aid is likely to optimise individuals' real-world sense of belonging, and promote the dependency on and the improvement of their own abilities to rapport, interpret and respond to both verbal and nonverbal cues. This is in line with the approach of the current thesis, while overlooked by many available social technologies.

Everyday Social Technologies

The choice of a social technology is based on various factors, including its interaction modality. Socially anxious people have preferences for computer-mediated communication (CMC) technology (Pierce, 2009; Sheeks & Birchmeier, 2007; Tokunaga

[5] referred to an experience of 'being' in a simulated place (Witmer & Singer, 1998), as different from therapeutic presence – the underlying quality of Carl Rogers' person-centred therapy (Throne, 2003) – as referred to the therapist's state of being completely in the moment with the client on physical, emotional, cognitive and spiritual level (Geller & Greenberg, 2012).

& Rains, 2010) because its features and services allow them to avoid many of the challenging aspects of F2F communication. Examples are instant messaging, emailing, online and mobile social networking and blogging, all being communication channels that facilitate hyper-personal interaction models (Walther, 2011) and uninhibited effects (Suler, 2004). This makes users appear more confident than when they communicate in F2F situations (Harwood, Dooley, Scott, & Joiner, 2014). One of the most appealing benefits of this model is the sense of anonymity and invisibility it offers by way of a digital shield. Coordinating with the asynchronous communicative norm of CMC, the shield gives users a sense of control (Suler, 2004) and saves cognitive capacity for composing or posting messages (Suler, 2004) instead of interpreting common cues and responses in an in-person environment. Behind CMC mediums, users can, therefore, optimise their self-representations (Ebeling-Witte, Frank, & Lester, 2007; Gonzales & Hancock, 2011; Walther, 2011) and mask undesirable physical and anxious appearances (Chan, 2011; Parks & Floyd, 1996). Considering this, CMC technologies can reduce the anxiety commonly experienced in F2F interaction and make social interaction more rewarding.

CMC offers reduced cues and an identity-definable environment at the expense of real-world social wellbeing. This less-anxiety provoking communication model makes it more appealing than F2F for the shy since their fear of social outcome does not diminish the desire to socialise. Some literature (Pittman & Reich, 2016; Sheeks & Birchmeier, 2007; Song et al., 2014) indicates its positive impact on this user group because it allows for expressing a certain degree of “true-selves”, enhancing positive self-concept and self-esteem (Valkenburg & Peter, 2011), and/or rapid initiating and nurturing of satisfying relationships. Some others provide the opposite perspectives, particularly the perceived anonymity the user takes as a form of social compensation. In turn, the user becomes less engaged with the physical presence (Favotto, Michaelson, & Davison, 2017) and limits the opportunities to improve in-person social strategies (Caplan, Williams, & Yee, 2009). Following their seminal survey on the patterns and consequences of Internet involvement on shy users, Carducci and Klaphaak (1999) argued that the allure of anonymity turns shy users into *digital* extroverts and escalates their feelings of awkwardness in F2F interaction. Sharing this perspective, more recent studies (Chan, 2011; Li, Chang, & Chiou, 2017; Pierce, 2009) found that sociality through CMC technology and networking websites can gradually weaken user desire for F2F communication, while increasing the anxiety and likelihood of real-world activity withdrawal. Furthermore, Li et al’ (2017) study revealed the negative associations between the frequency of social-network website usage and the appreciation of offline social situations; more frequent users found it more difficult to realise and process positive information in social activities they participated in 'real' life. Pursuing sociality online made it harder for shy users to overcome the challenges of F2F social situations.

Information resources become useful to real-world relationships when it is accessible from anywhere. Embedded in CMC devices, social proximity applications (SPAs) take advantage of ubiquitous and context-aware computing to make social networking sites and user information accessible locally, and without compromising their sensitive information other than that made publicly online. In addition to strengthening social ties among online members in the real world, these applications introduce new relationships among strangers based on their geographical proximity, profiles and preferences (e.g., *Facebook*[6], *Foursquare*[7], *Google+*[8], *Instagram*[9] and *LinkedIn*[10]). Drawing on the electronic propinquity theory (Korzenny, 1978), SPAs can create the experience of psychological closeness leveraged from the user's perception of their related locations. This can enrich social involvement among strangers (Walther, 2011) and accelerate connections. Nonetheless, SPAs can stand as a communication barrier to socially anxious users, owing to the nature of the introductory property and interaction model of hosted devices.

The drawbacks of SPAs (Puttaswamy & Ben Y Zhao, 2010; Xu et al., 2011; Shuang Zhao et al., 2018) using proximate co-locations as the main introductory criterion can be perceived in two aspects. The first issue is reflected in the lack of information richness the applications can provide. Drawing on Edward Hall's (1990) Proxemic Theory asserting that the smaller the distance between people is, the greater the chance of personal involvement and intimacy becomes, it nevertheless remains unlikely that strangers will initiate new contacts based on close proximity, unless they are pursuing new romantic dating opportunities (Finkel, Eastwick, Karney, Reis, & Sprecher, 2012). Having context-aware computing in their fundamental operation, location-based social applications can harvest many other properties on the ground of proximity; other

[6] https://www.facebook.com/mobile/ Retrieved: August 9, 2018.
[7] https://foursquare.com/download Retrieved: August 9, 2018.
[8] https://developers.google.com/+/mobile/android/ Retrieved: August 9, 2018.
[9] https://www.instagram.com/?hl=en Retrieved: August 9, 2018.
[10] https://mobile.linkedin.com/ Retrieved: August 9, 2018.

examples include orientation patterns, similar previously visited points of individuals and/or actions performed at specific points (Chen & Abouzied, 2016; S. Greenberg, Marquardt, Ballendat, Diaz-Marino, & Wang, 2011; Schellekens et al., 2015) and social context of the location (Ville Antila, 2012; Waga, Tabarcea, & Fränti, 2011). The second issue, inherent in the nature of the co-location property, is that it does not make explicit the user's intention to interact (Lawrence & Payne, 2004). It requires the user to take an active role in initiating a connection. This is evident in an early example of a SPA embedded in a custom-made device, *Jabberwocky* (Paulos & Goodman, 2004; Urban Atmospheres, 2004) to explore the concept of familiar strangers (Milgram, 1977; Paulos & Goodman, 2004) turning co-location of users into a social cue while retaining the users' anonymity. Users' relationships are informed merely by the public spaces they daily co-use and visit. Although the co-locations can facilitate some degree of familiarity, unacquainted individuals introduced in this manner may find their relationships difficult to process in a meaningful way.

Another drawback of SPAs can be found in the cognitive and physical demands of their hosting devices. CMC technologies, such as smartphones and mobile personal computers (tablets), are common tools for networking through SPAs. Modern devices are equipped with multifunctioning user interfaces, aiming to offer rich display aesthetics and degrees of *direct manipulation* (Fitzmaurice, Ishii, & Buxton, 1995; Hutchins, Hollan, & Norman, 1985). Despite claims of being intuitive to use, these devices still hold some similar features to traditional WIMP[11] user interfaces, which require intricate motor controls (Starner, 2002). Their operations tend to demand existing user knowledge, skills, and proactive engagement in terms of cognition and physical actions (Blackler, Popovic, & Mahar, 2010; Britton, Setchi, & Marsh, 2013; Hurtienne & Blessing, 2007a). Eyes, hands, fingers and brain coordination at multi-screen operations are unavoidable and can become attentional stretching processes (Brewster, Lumsden, Bell, Hall, & Tasker, 2003; Brown, Brewster, & Purchase, 2006). Regardless of the attention required for maintaining the ongoing interaction with people in the physical environment, the attention of SPA users is split between the requirements for precisely manipulating the device interface, comprehending application features and interacting with other users. All these tasks are competing for the user attention and can cause deficits of cognitive resources.

[11] Windows-Icon-Menus-Pointers for traditional user interfaces.

Deficiency in attention resources has long been a primary concern for mobile applications in HCI (Starner, 2002). Researchers in complex-task completion have proposed several approaches regarding the use of commercial CMC devices (Jimenez-Molina & Ko, 2015; Motti & Caine, 2016; Oulasvirta, Tamminen, Roto, & Kuorelahti, 2005) to eliminate the interference of user tasks on their attentional resources. Of particular interest to this literature-review part is when user attention is taxed by physical and cognitive tasks of a mobile application. The attention, being already fragmented, becomes even more stretched when the condition of use involves social goals and time-space organisation. Oulasvirta and colleagues (2008; 2005; 2007) suggest several solutions to easing these tensions, such as making sure the personal space, namely user interaction with the device, is socially registered and accepted in the physical setting of the social context; prioritising tasks that are socially engaged at the local environment – in particular, ones that strongly influence cognitive withdrawal from other tasks; and minimising task duration. Other researchers suggest using playfulness to facilitate non-stressful perception of location information (Ali, 2011); and personalising application services to regulate its obtrusiveness to the user mind (Gil, Giner, & Pelechano, 2011), particularly ones that require proactive and spontaneous provisioning (Jimenez-Molina & Ko, 2015).

The pervasiveness of context-aware social technology can facilitate local social interaction among strangers without compromising their privacy. However, many features and characteristics of these everyday social technologies, as discussed above, are designed with cognitive-competent and extrovert-interaction models (Chalmers et al., 2008) that work well for self-expressive and gregarious-minded users. For shy people, low on cognition resources and social skills, this technology seems counterproductive for integration into their environment and to encourage social engagement in a non-intrusive and non-provocative manner.

Objects Central to Sociality

Making online conversation is less stressful than in-person because it revolves around objects of communication. The risk of judgement is more directly related to these objects and not the communicators themselves, and therefore helping their conversations to be more relaxed and prosperous. To discover what makes some social networking sites go viral and others to fail, a social engineer Jyri Engeström (2005) examined the communication mechanisms of online communities. He found that those built around a network of shared objects (e.g. Flickr.com, Facebook.com and Instagram.com) can create heavy usage and may even lead to some form of addiction. In contrast, those formed on site members' profiles (e.g. LinkedIn.com [12]) did not gain as much popularity. Underpinning the success of high-traffic sites is the share-ability (including being available for modification and redistribution) of the central objects of communication (McLeod, 2017), such as a photo, video or diagram. Dialogues grow out of these shared processes and attach to many objects that are often taken or ‘tagged’ beyond closed circles of friends (I. McDonald, 2009). These objects become so-called social objects (SOs) inviting strangers with a common interest in a specific social activity to contribute to the narrative; and act as a resource for communication. This implies that a SO does not itself prompt the sharing, but does so in cooperation with people’s desire to search for and share meanings, which is fundamental to social interaction.

Individuals have different capabilities of social sharing, which is also affected by the communication models. Social sharing refers to the human ability to engage in collaborative actions in order to meet a mutual objective. Although this ability is weak in most socially anxious people, shy people display a greater willingness to engage in these actions. Colle and colleagues’ (2017) conducted a clinical study on the degree of in-person social sharing of people with social anxiety. As expected, the results showed that the fear of being judged by others restricted the participants’ impulse to participate in joint actions. The unexpected result was that, unlike people diagnosed with the greater degree of social anxiety, shy people are not always reluctant to participate in a conversation. In certain circumstances and with specific people, they exhibit a strong intention to engage in a F2F conversation and share its meaning. Consequently, the more their shared experiences, the greater their chances of forming and maintaining social relationships. However, the sense of social sharing in the real world, even though influenced by SOs, is far more challenging for socially anxious communicators than what they experience online. The cause of this difference is in the user interaction models. Without the interfaces of the CMC and Internet, users can find it difficult or impossible to disguise their identity, avoid the potential risk of being judged, or mask the dispositional effects of anxiety. Prior literature shows limited interest in easing the F2F interaction of socially anxious people with SOs. This leads the following discussion to serve two

[12] This analysis was conducted when LinkedIn’s main content was based on members’ professional positions and experiences. This was before LinkedIn launched *InMaps* in 2011. *InMaps* broke down members’ profile details into keywords, searchable – just like *Flickr* members use keywords to search for a photograph of interest. Further detail: see https://linkurio.us/blog/linkedin-inmaps-discontinued-visualize-network-now/ Retrieved: April 2, 2018.

purposes. One is to provide an understanding of the mechanisms and specific qualities of real-world SOs that might serve well in inviting shy people to engage in F2F interaction, and another, to form the author's perspective on how these qualities can inform the design of computer-mediated SOs in doing so.

SOs [13] differentiate themselves from other objects in real-world settings in two fundamental features: making the shared environment a collaborative space for spontaneous conversation, and reducing interactional stress (Goffman, 1967). From a socio-analytic viewpoint (Horgan, 1996), talking to people we do not know well is a potentially dangerous event we find stressful, given that the attention run back and forth in a *person-to-object-to-person* attentional model. When placed between these unacquainted communicators, an SO acts as an anxiety buffer by allowing their attention to run on a *person-to-object-to-person* model or on a *saliency map* of attention (Koch & Tsuchiya, 2007) and so facilitating a non-direct form of social engagement. It put the communicators in a *we-mode* of joint action (section 2.1.1). The SO, while embodying their relevance and eliciting the collaborative intention, also eliminates the strangeness between the individuals with a psychological bridge: a 'restricted right' to start a conversation or 'tickets' to talk (Sacks, 1992, p. 256). When this form of endorsement occurs, individuals enter a *state of talk* – a condition for which all parties declare themselves 'officially open to one another for purposes of spoken communication and as an guarantee to maintain a flow of worlds' (Goffman, 1967, p. 34). Through this way of initiating conversation, social engagement become less intimidating for people in general (Rubegni, Memarovic, & Langheinrich, 2011; Sokoler & Svensson, 2007; Svensson & Sokoler, 2008) but may not be enough for shy people. Their desire to socialise and the likelihood to develop familiarity with the others are inhibited by persistent fear (section 2.1.1) that is likely to retain their social cognition in the *i-mode* of joint action (Frith, 2012). Therefore, the sense of relatedness and 'licence' to talk, as given by general SOs

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[13] Note that, the term social object (SOs) used here is originated from sociology literature and not a synonym of the term 'social objects' used to connote social stimuli (such as negative, neutral or positive facial images) in exposure therapy literature (e.g. Blair et al., 2016). Yet, its meaning is close to that that appears in Clark-Well and Rapee-Heimberg models (section 2.1.1), specifically in the Processing of Self as a Social Object component, as purely referred to the passive form of the self of individuals and their own judgement.

may not be adequate to escalate their desire to rise above the fear, and so, foresee the positive outcome of the social interaction.

Real-world SOs exhibit four common qualities [14] that are capable to initiate rapid relationships between strangers but *relational* SOs (e.g., a seesaw, chessboard, and traditional phone[15]), unlike the others, have the ability to form an open-end relationship and influence individuals to reflect on it. These functionalities escalate the relationship. This makes *relational* SO-driven activities being associated with Karin Knorr-Cetina's 'object-centred sociality' (Knorr-Cetina, 1997, p. 1) – a form of human engagement that binds the self and the other and 'feed[s] on the supplement of their sociality'. As an artefact centre at the social activity, a *relational* SO affords the users understanding of its representation based on the intentional relations that the user and the other person have with the world through it (Engeström & Blackler, 2005, p. 308). Its materials 'exist primarily as "envelops of meaning", acquiring a social presence 'as a result of processes of [conversation] and discursive interpretation' (Engeström & Blackler, 2005) of the relations.

For the users, using a *relational* SO is in part to gaining an understanding of the other person (Kirsh & Maglio, 1994) and in part to entering a shared space for generating mutual knowledge. The object, while in use, mediates the users' shared experiences and epistemic practices. It turns the user environment into a shared action-space or *we* space (Krueger, 2011) in which 'the physical possibility of spoken interaction arises [and] functions as a means of guiding and organizing the flow of messages' (Goffman, 1967, pp. 33-34). The space taken by the object, therefore, becomes a *relational zone* that supports the 'inter-human exchange' (Bourriaud, 2002, p. 18) and enhances the individuals' sense of togetherness. It does so by sustaining their explicit cooperated attentions (Goffman, 1967, p. 24).

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[14] Observing how strangers engage in immediate conversations around displayed objects in a museum, Simon (2010) found four qualities common to real-world social objects: *personal* – drawing conversations from people's private experiences; *active* – because of their dynamic forms; *provocative* – through their capacity to prompt people's strong opinions; and *relational* – because of their physical affordances.

[15] Not multi-feature phones that support other functions than two-way communication.

In this respect, a *relational* SO has the open-ended character of Rheinberger's *epistemic things* (Engeström & Blackler, 2005; Knorr-Cetina, 1996), namely *epistemic* objects – the entities that 'lack … completeness of being and their non-identity with themselves' (Knorr-Cetina, 2005, p. 187). Using a question-generating object like this is a knowledge activity. Users unavoidably reflect on their relationships with the object itself and with the other co-users. This is a kind of knowledge that users do not have at the start and only co-develop by using the object together. This characteristic bears some similarities to Koffka's (1936) 'demand character' and Lewin's (1936) 'invitation character' of objects. When put in a multi-user environment, these objects afford social activities in which participants use it in ways towards the expectation and reaction of one another (Kaufmann & Clément, 2007). Although the relationship initiated and developed by the *relational*-SO use is only temporal, it is intimate and nuanced (Knorr-Cetina, 1996); existing knowledge and skills that the users bring to negotiate are embodied in the object and constantly revealed over the users' actions. In turn, this collaborative activity attaches new social dimensions to the object and influences the reinterpretation of its meanings. This explains how using *relational* SOs can facilitate an open-ended reflection on the shared experience, intention, and hence the newly realised social relationship.

HCI literature suggests several design attributes for facilitating user engagement and reflection on the interaction with real-world SOs, for instance, tangible manipulability (Day & Wagner, 2014), situatedness in the user community (Schellekens et al., 2015; Winter, 2013), augmentation of user's mutual interest (Falk & Björk, 1999; Jarusriboonchai, Olsson, Prabhu, & Väänänen-Vainio-Mattila, 2015), and ambiguity in user relationship (Chen & Abouzied, 2016; Schellekens et al., 2015). The latter directly serves the epistemic nature of *relational* SOs and is often found in well-adapted cognitive assisting objects (Barley, Leonardi, & Bailey, 2012), deliberately implemented with an incomplete knowledge or inexact meaning of system response. Thereby, the object requires its user to exert some degree of mental effort but not leaving them stranded without sufficient clues or paths to construct a meaningful socio-cultural condition of the user environment. The ambiguity in these object kinds promotes an intimate relationship between the user and its system through the interpretative gaps (Gaver, Beaver, & Benford, 2003), and demands the user to constitute possible meanings in relation to the condition of their own and of the social context they use it within (Kettley, 2005).

In HCI, ambiguity can be seen as a vague or powerful design resource for user interpretation. It is not favoured in traditional HCI design approaches that strive to achieve usefulness and usability (Aoki & Woodruff, 2005; Gaver et al., 2003; Sengers & Gaver, 2006); avoiding it is indeed a fundamental rule in designing such systems. Yet, this traditional concern can become obsolete when ambiguity is deliberately used and well fostered as seen in a seminal examination (Gaver et al., 2003) and critical analysis (Kettley, 2005) on its tactical uses in the design and evaluation of technological and wearable artefacts.

When the system-user relationship is set up for the user to interpret and fill in the gaps, and effectively supported by the system, ambiguity becomes a vigorous attribute that attracts user attention and constrains their engagement to the work concept and context. Examples are seen in computation-mediated SOs such as *Pop Glass* (Schellekens et al., 2015) and *Common Tie* (Chen & Abouzied, 2016) that encourage users to add supplementary knowledge about the information-minimalistic display of its single LED, embedded in local-networked drinking-party glasses and conference wristbands, respectively. Users are not lost in the interpretation path since the glowing light and colour-changing patterns vary according to the changes in user movement, location and vicinity of other users they make contact with at the event. From a user perspective, this relationship is intimate in nature (Gaver et al., 2003; Kettley, 2005) and rewarding to achieve, given that the users arrive at a possible meaning by engaging with the system and its context in a thought-provoking process and with minimal information given.

This deliberate and systematic use of ambiguity within a social setting shows the dynamic effect that incomplete disclosed information can have on initiating new relationships among strangers. As well as creating curiosity in the users, the insufficiency of information leads them to a more intimate engagement with the system and other users. Looking at *Common Tie* in particular, as Chen and Abouzied' (2016) study reveals, an information-rich display is not always the answer to facilitating F2F interaction among the unknown or newly acquainted, especially for professional matchmaking applications. On the one hand, this argument seems to oppose the clarifying character and wealth of information utilised in many sophisticated matching algorithms currently being commercialised. On the other, at the intersection between social interaction in a co-located matching context and the open-design philosophy (Sengers & Gaver, 2006), the aforementioned opacity of information can effectively leverage the user' desire to interact without having to specify the why-and-how aspects of the information. To varying degrees, users pay attention on the social activity and they can coordinate that with the accessible social information by themselves (Kettley, 2005). This is a natural mechanism of the human brain in performing knowledge inquiry (Kaufmann & Clément, 2007). In order to comprehend and uncover the non-specified meaning that social affordances offer, the brain intuits and weaves together the fragments of the existing knowledge and the newly accessible. Rather than regarding the non-specified information as incomplete, it might be seen as the withholding of information – an indirect invitation or positive challenge. According to this viewpoint, ambiguity supports the user desire to engage with the system, the other and the social situation.

A relationship between strangers becomes explicit and knowledge-driven when it is initiated through SOs that hold relational quality. A relational SO by nature promotes users' reflection on the relationship they have with it and with the other co-users. This type of SOs can inform the design for shy users in relation to their desire to socialise being in conflict with, and often being restricted, by their fears of being judged and experiencing negative outcome (section 2.1.1). They retreat into a self-focus mode while being around unfamiliar people. The literature discussed above show the benefits of the relational quality of SOs in promoting interaction among strangers. With ambiguous characteristics augmented through computational technologies, this type of SOs seems an effective means for inviting and encouraging shy users to think beyond themselves and in relation to others, drawing them into the environment where such SOs are offered as a central piece for collaboration and thinking.

2.1.3. Discussion

Cognitive-behavioural therapists have endorsed the benefits of technology by incorporating it in their research and practise within a F2F communication context – with the emphasis on technology only being a tool to support, and not replace F2F. This contrasts with the way by which socially anxious people use social technologies to bypass direct F2F contact with others. Whilst there are everyday technologies facilitating new relationships among local users, these technologies offer cognition-taxing user models that are intrusive to the social nature of the shy. In addition, they increase the likelihood of withdrawing from the constructive elements of F2F situations and remaining in a state of objective self-awareness. Social objects, particularly those with *active* and *relational* qualities show great potential to attract and encourage user interaction and hence, reflection on the relationship with the object, others and the deployed situation. Now that we are aware of shy users' limitations and the features that are lacking in social technology to address their needs without overburdening their ability, as well as, the characteristics of SOs that can contribute to positive outcomes, the challenge is to frame and adopt this information into a coherent design brief. This requires a social artefact that can persuade shy users to participate in social situations in more engaging ways despite their persistent fears and perception of own limited social abilities. Computation has gained a prominent role in conveying concepts of design artefacts while augmenting their functionalities appropriate to specific user needs. In order to form the concept and design framework for such artefacts, we will now look into theories of HCI and its related fields that offer 'natural' approaches to designing technology and how they can be applied to the technology-mediated environments (section 2.2) that affords and constrains the social interaction of shy users without impeding their social nature (section 2.3).

2.2.Natural Approaches in Human-Interaction Computer

Emerging in the 1980s, HCI is a new but broad area of research and practice (Carroll, 2003). It provides multiple scientific foundations for the design and analysis of human operating and understanding of computational technology (Carroll, 2012). HCI encompasses almost all areas of cognitive, social and behavioural science by the mid-1990s (Carroll, 2003) while adopting theories from many other disciplines (such as linguistics, anthropology, philosophy, psychology, and computer science) in which embodiment is presented as a prominent consideration (Flach, Margulies, & Soffner, 2010). The concepts of embodiment gained much interest in HCI around the time that ubiquitous computing and the rapid development of technologies became more advanced tools used by users and designers. For users, it offers a broader range of real-world sense of experiences in more ubiquitous environments (namely personal, public and social) than what desktop computers could ever offer (Farr, Price, & Jewitt, 2012). For designers, it presents opportunities to manipulate physical objects and re-examine the user's sense of presence and relationship with technology and its context (Price, Roussos, Falcão, & Sheridan, 2009). Of specific relevance to this thesis, is that it provides the foundations for understanding the nature of user knowledge derived from using computer-mediated tools, and for forming a perspective on the natural cognitive-behavioural processes of the user when interacting with the technology and others in a social context. The discussion of these two topics are drawn directly from literature grounded in embodied cognition theories (e.g. Clark, 2008; Kaptelinin & Nardi, 2012; Kirsh, 2013) and embodied interaction approach (Clark, 2003; e.g. Dourish, 2004b). This knowledge leads the researcher to form a perspective on a 'natural' approach to designing a technological aid for amplifying the social cognition of shy users and accommodating their limited abilities in social interaction, hence improving their social experience by freeing up cognitive resources towards goal-direct behaviour of more rewarding and accomplished social engagement.

2.2.1. The Nature of Tool-afforded Perception

Embodied cognition (EC) is not a single theory but a unified set of modern theories of the mind that reject the classic concept of cognitive processes originating solely from within the brain region as Andy Clark (2008) coins it as a 'brainbound' model of cognition. For this deterministic view, bodily systems outside the brain (e.g. hand gestures, conversation, facial expression or bodily movement) are excluded from the cognitive processes and deemed only as instruments (Pfeifer & Bongard, 2006, p. 137) for sensing stimuli and actualising thoughts. In contrast, EC theories (extended, distributed, situated cognition[16]) are body-centric. They share a general assertion on cognitive processes based on the body interacting with its environment (Wilson, 2002). Thinking and doing are tightly coupled; cognition thus extends beyond the brain through body parts (Clark, 1998; Clark & Chalmers, 1998), reaching the external resources and material to manipulate (Hollan, Hutchins, & Kirsh, 2000). Thoughts 'leak out' into the environment, are fed back and around in loops that crisscross the brain, body and world – the unified components for cognitive processing (Clark, 2008 p. pxxvii). One of these radical cognition approaches is based on an *enactive* view of perception that addresses cognition as constituted in the body, which actively lives and interacts with the environment (Di Paolo & Thompson, 2014). The *Enactive perception* approach (Noë, 2004; O'Regan & Noë, 2001) surmises that bodily action upon the surroundings is the only way to conceive an understanding of own ability. This view of body-environment coupling emerges in the field of ecological psychology in visual perception, namely *affordances* (Gibson, 2015), another approach in focus in this section. This approach has recently found a home in EC theories (Hinton, 2014, p. 35) as its essence aligns with those of the *extended* cognition

[16] See Arnau et al. (2013) their relations among these EC theories and their shared roles in modern cognitive science

(Clark, 1998; 2008) and *distributed* cognition (Hollan et al., 2000; Hutchins, 1996) theories, which in simplified terms, hold that cognition is extended beyond the brain and distributed across the brain-body-environment system: the unified components for cognitive processing. The concept of affordances is one of the most diverse and evolved concepts in HCI (Kaptelinin, 2014). The following discussion is not intended to capture all of its diversity in great detail, instead, focuses on how tool- and social-affordances may serve user's realisation of action possibilities as afforded by the technology and the technological-mediated social environment.

Amplification of Perceptual Abilities and Possibilities

Human perception is always an active process as it is inconceivable without bodily action upon the surroundings. The enactive approach to perception holds that what we perceive is defined by what we do and constrained by intentions to act upon any given environment. Perception in this sense is therefore not an abstract process in the brain but enaction of the skilful body with a determination to act upon what the body encounters (Noë, 2004). This kind of perception is in line with Merleau-Ponty's account of perception conceived through the *lived* body. In *Phenomenology of Perception*, he refers to the lived body as 'the vehicle of being in the world … and intervolve in a definite environment' (Merleau-Ponty, 2005, p. 98). In other words, the lived body is a living entity that exists in a physical space and with practical intention. Any consciousness that comes to it is therefore the dynamic relationship between the body itself, its action and its environment. The body is a subject of perception as he further states (Merleau-Ponty, 2004, p. 9):

> ***'[i]t is our "bodily" intentionality which brings the possibility of meaning into our experience by ensuring that its content, the things presented in experience are surrounded with references to the past, and future, to other places and other things, to human possibilities and situations'.***

Thereby, perception is an activity that procures by and through a dynamic and body-centric experience. For Merleau-Ponty, there is not much sense in thinking about an individual and his experience without referring to his body, intention and given environment.

The nature of tool use amplifies the enactive perception of one's abilities within the user environment. To explain how this change happens David Kirsh (2013) and proposes the idea of *enactive landscape* – the representational space in which we mentally construct offload our computational processes (Clark, 1999a; Di Paolo & Thompson, 2014) and perceive ourselves as active agents that can be expanded through tool use. Body schema is where the change starts to happen at the moment when we pick up a tool. Our visual neurons recalibrate the body schema to include the tool's perimeter (La'davas, 2002). Furthermore, physiological neurons seize the tool's capabilities (Maravita & Iriki, 2004) in that we perceive them as our own. Kirsh (2013) calls this phenomenon 'tool absorption'. This tool mediation triggers our *know-how* sensorimotor (Di Paolo & Thompson, 2014; Noë, 2004; O'Regan & Noë, 2001) as well as makes our bodily skill an embodiment of the tool's power, thus enables us to realise new possibilities and direct our actions in the world. This cognitive process is deeply rooted in the bodily interaction with its environment. In their book, *How the Body Shapes the Way We Think*, Pfeifer and Bongard identified embodiment as a prerequisite for high-level cognition – such as conscious thoughts, rational decision making and problem solving. The body is necessary for the cognitive process (Pfeifer & Bongard, 2006, p. 19). Many tasks become easier when cognition is shaped by body parts other than solely the brain. The intimate coupling between body and brain enables sensory activities that lead to better responses and control of physical interactions with objects and the environment.

Tools function with the same purpose the human user intends. Although tool-absorption reshapes perceptions of what one can do to the environment through the tool, the way the tool functions in the environment is constrained by the user's purpose (Clark & Chalmers, 1998). When we use tools, our thinking, bodily control and response, and the tool all act together as unified components of a cognitive system – a coupling of internal and external reality. Extended cognition theories (Clark & Chalmers, 1998; Menary, 2017) emphasise the relationship between thinking and bodily interaction with the environment, by positing that the thinking process extends beyond the skull to body parts (Kirsh, 2013) through which the mind connects in a sensorimotor experience (Price et al., 2009, p. 2). The thought system is thus affected by its components being extended or unfolded (Kirsh, 2013). This change is evident in many examples of brain-and-body coupling with tools that are designed to empower human sensorimotor skills. They range from simple tool uses (e.g. choosing a bottle cap from many others to seal a bottle; reaching out and testing a size by hand is better than trying to imagine the fit) to complex applications. An example of a complex application is *Soft Exosuits*[17] that help patients with neurological disorders to learn to walk. The cognitive accounts of these patients' walking abilities

[17] https://biodesign.seas.harvard.edu/soft-exosuits Retrieved: September 12, 2018

reflect a tenet of distributed cognition (Hutchins, 2010). In that, their sense and sense-making of walking spread beyond biological boundaries, and encompass an external computation and material with the internal. These cognitive 'organisms' act in concert as a single unit to allow the patients' brains and bodies to 'cognitively grip' or couple with tool (Kirsh, 2013, p. 3), leading them to achieve something they and many others possibly never thought to achieve. This example also echoes Merleau-Ponty's (2005, p. 167) famous example of a visually impaired person using a cane, which in turn, turns her touch into sight. The cane, when in her hand, is no longer perceived as an object but embraced as part of the body and in turn reconstructs the enactive landscape and magnifies the possibilities in the environment. Her perceived ability to navigate is extended by the cane, which becomes the 'object of intentionality' that enables her body to reach where its endpoint stretches to and her intention leads. In other words, she 'sees' the world and perceives the new abilities through, what Kirsh (Kirsh, 2013, p. 3) calls, tool-dependent affordances.

User-tool-environment Relation as Design Resource

The Merleau-Pontian object of intentionality (Merleau-Ponty, 2005) share functionalities with Gibsonian tool affordances (Gibson, 2015). Both concepts are concerned with how people 'see' an object in relation to what and how they will do with it in the given environment. A difference between the two is in their account of people's perception. For Merleau-Ponty, an object of intentionality holds a collection of sensory stimuli that, when encountered, it elicits our active perception and bodily actions onto its environment. In turn, its environment and features constrain as well as amplify our perceived ability and bodily action. This implies that an object of intention exists in relation to our goal and ability in perceiving and applying its information – here is the point of departure from tool affordances. For Gibson (2015) an object affordance is invariant to neither our needs nor capabilities to recognise it; a simple way to understanding the concept is to think of an affordance as something that is always there in the environment and to be perceived – whether we realise it or not. However, an affordance given by an object is not *value-free* information about the environment. As the object exists without bestowing its properties, prospected perceivers thus need to bring in prior experience of using another similar object and preconceived information of how to manipulate and what to expect from it.

Coined by Gibson, the affordance theory is an ecological approach to perception and action that has long been fundamental to design thinking for the HCI research community. Nonetheless, the traditional way of adopting the theory appears to be insufficient and limits perspectives in design and analysis of technological artefacts and user interfaces (Kaptelinin & Nardi, 2012; Wagman & Carello, 2003). The problem is twofold and discussed below: (a) the flawed interpretation of the term affordance in the research community and (b) the limited conceptual foundation of the theory to natural environments.

Misinterpretation of affordance can lead to a constricted view on the relationship between the user, tool and the environment. Prominent researchers (Bærentsen & Trettvik, 2002; Kaptelinin & Nardi, 2012; Wagman & Carello, 2003) criticise Donald Norman as misguided[18] when he introduced the term affordance to the HCI community in the late 1980's. In *the Design of Everyday Things*, he uses the term affordances to emphasise some aspects essential to general design artefacts. For Norman (2002, p. 9) affordances 'provide strong clues to the operation of things [… They are] the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used'. This notion implies Norman's account of affordances as *magical* attributes (Bærentsen & Trettvik, 2002; Wagman & Carello, 2003) that can make users understand meanings of the artefact and know how to operate its interfaces just by looking and bypassing the mental process. Interpreting affordances in this way preserves its abstraction and isolates the relational properties of the actor and the environment (Bærentsen & Trettvik, 2002), discounting the meaning of user interaction with the artefacts itself and its environment (Vyas, Chisalita, & van der Veer, 2006). It thus aligns the process of perceiving with classical deterministic views of cognition that assume the perception of things can be broken down into static and single contents (Stoffregen, Bardy, & Mantel, 2006). Such an interpretation overlooks the original implication that Gibson intended for affordance to be 'the complementarity of the animal and the environment' (Gibson, 2015, p. 119) and reduces the relationship between the actor and the environment into a low-level interaction, namely sensorimotor response to

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[18] despite the fact that his valuable attempt has made the affordance concept significant in HCI research and become a fundamental component for intuitive and *usable* designs that aim to minimise cognitive demands in comprehension and operation of novel user interaction models and interfaces. For further detail see Hartson's (2003) analysis on the design implications that emerge from Norman's misinterpretation of the affordances concept.

the physical stimuli of the environment (Kaptelinin & Nardi, 2012). This is where the concept of affordances becomes inappropriate for HCI (Kaptelinin & Nardi, 2012), the research field that concerns itself with advancing the means of tool use and the perception of the user's nuance and dynamic interaction within the technological embedded environment that impacts on both individuals and society as a whole.

To overcome this issue in artefact design, affordances shall not be thought of as either property of animal or environment alone. They are instead the relational properties of an animal and the various features of a situation that takes place in the environment (Chemero, 2009, p. 147). The relationships among these properties arise (are perceived) through the actor's active engagement, namely mental, physical, and sensory (Kirsh, 2010; Stoffregen et al., 2006; Stoffregen & Mantel, 2015) and the actor's abilities to perceive the affordance and act upon its hosted object and environment (Chemero, 2003). Modern advocates of the affordance theory (e.g. Bærentsen & Trettvik, 2002; Chemero, 2003; Stoffregen et al., 2006) remind us that the affordances theory emerged as an ecological approach to perception and action; it is sought to explain the human perception-action coupling capability in relation to other organisms in the given environment (namely activity, situation, place, space, etc.). Designing user interfaces that facilitate the perception-action system for technology-mediated activities is challenging since the relationships among organisms can be quite complex as well as a rich resource for design exploration. Technology, while existing as a tool-organism, allows for the interaction between the user and the environment. A well-designed interface of a tool optimises action possibilities (Gibson, 2015; Wagman & Carello, 2003). In their investigation on the two *sides* of tool interfaces: user-tool side and tool-environment side, Wagman and Carello' (2003) found that each side has its own inertial properties that allow as well as constrain the possibilities of user action to emerge. The user-tool interface in this relationship must provide appropriate information about the properties in order to maximise their opportunities to be exploited according to the demanded task and the given condition of the environment. Designers can define which affordance signifies which property and then decide on the type of interface more suitable to inform and engage the user with tool and environment properties. Recent studies involving the perception-action process has extended this approach to explore various aspects of technology-mediated interaction, such as multiple forms of engagement with technological tools (Baber, 2018; Baber, Parekh, & Cengiz, 2014), dynamic relations among the body-plus-tool system, task and environment (Mangalam & Fragaszy, 2016);

and the process of perceiving and actualising affordances of technology in collaborative platforms (Lehrig, Krancher, & Dibbern, 2017). What these works have in common is the fundamental assertion that in perceiving a tool affordance, users take an active role to be part of the interactional relationship. Their interaction encompasses selection and prioritisation of affordances (Humphreys et al., 2010), active articulation and interpretation (Vyas et al., 2006) prior to the bodily manipulation of the tool and hence the environment. This interaction-centric view emphasises the importance of the user's active role in becoming firmly involved with and be a part of the user-technology-environment system and 'seeing' action possibilities in the environment.

Social Affordances in Shared Artefacts and Collaborative Actions

Just as affordances can constitute and constrain our knowledge about possible actions in the physical and technological embedded worlds, so do they to constitute part of our social cognition (Di Paolo & Thompson, 2014). The idea of *social affordances* is an overarching extension of Gibson's original notion of the singularity in the characteristics of the environment. In that he states, the environment often hosts man-made objects but these artefacts nonetheless are (Gibson, 2015, p. 122):

> ***… manufactured from natural substances. It is [thus] a mistake to separate cultural environment from the natural environment … There is only one world, however diverse, and all animals live in it, although we human animals have altered it to suit ourselves.***

While these environment characteristics work well for a single actor/user interaction with 'natural' and less advanced tools (e.g., sticks, hammering clubs, postboxes, eyeglasses) as examples given by Gibson, it reflects a limitation in the conceptual grounds for HCI research. It is inadequate for addressing user interaction and perception in the technological-mediated and social environment – the context that is becoming an important concern to the research community. Researchers (e.g. Faraj & Azad, 2012; Hutchby, 2001; Kaptelinin & Nardi, 2012; Rizzo, 2006) have recently emphasised the need to expand the notion of the environment to include socio-technological aspects of human interaction if the concept is to be more fully exploited in HCI research. A common way of doing so is to think of affordances as functional properties of users, technological artefact and social environment with relational constraints that affect human-human interaction (Faraj & Azad, 2012).

Just as technology functions to extend the user's perception of own physical capabilities, it can also capitalise our joint perception-action systems, trigger our sensorimotor processes (Noë, 2004; O'Regan & Noë, 2001), constrain our behaviour with the technology and others (Marsh, Richardson, & Schmidt, 2009) and constitute our sense-making in participation with the others (Di Paolo & Thompson, 2014). Using technology in a social context, Hutchby (2001) demonstrates that user behaviour is governed by a network of social constraints and conventions, the relational constraints that arise through the user perceiving social affordances – the possible interpersonal actions between two or more social agents who perform with, around, and/or via the shared technological artefact. This line of thought is consistent with the use of the affordance concept in neuro-psychology literature (e.g. Marsh et al., 2009; Pacherie, 2013; Richardson, Marsh, & Baron, 2007). In this field social affordances or *joint affordances* are referred to as ecological information provided by an artefact in a social situation. They promote coordinating cues that guide individual agents to act in coherence with the others and predict their co-action outcome.

Joint affordances are one of the many factors[19] used to facilitate coordination of social cognition among individual agents and the transformation of their sense of agencies (Pacherie, 2013). This type of affordances appears in our day-to-day environment and cause individuals to switch their attention and action from a self- to *we-agency* in specific circumstances (e.g., an available public shelter that becomes crowded at the time it starts to rain). Joint affordances are an effective component for not only strengthening but also initiating the sense of connectedness and synchronicity between individuals performing separate tasks. Several studies (e.g. Marsh et al., 2009; Richardson et al., 2007) reveal that by directing the attention of individual participants who separately perform the same action (e.g., chair rocking and rhythm tapping) towards one another's action, their action pace become synchronised. Such affordance triggers the mirror neurons that allow an animal to understand the action and intention of the others (Rizzo, 2006); through the 'the ability of humans to learn through other persons and their artifacts, and to collaborate with others in collective activities' (Tomasello & Carpenter, 2007, p. 1221). Their intention to perform the activity is transformed by social motivation into a *we* intention (Tomasello & Carpenter, 2007) as well as their awareness on self-agency is directed to we-agency (Pacherie, 2013).

[19] Other factors are *entertainment, action simulation* (Pacherie, 2013), *perception-action,* and *matching* individuals (Rizzo, 2006)

Making individuals aware of the object of joint affordances is a common way to improve mutual awareness in co-agents, hence influence the sense of we-agency, and finally lead them to coordinate actions (Pacherie, 2013) and sense-making (Di Paolo & Thompson, 2014). In line with the previous discussion on the concept of social objects (section 2.1.3), some literature in coordinating cognition (Böckler, Knoblich, & Sebanz, 2012; Brennan, Chen, Dickinson, Neider, & Zelinsky, 2008; Vesper et al., 2017) provides that joint visual cues are effective stimuli for creating mutual attention. Brennan and colleagues' (2008) study, in particular, demonstrates that directing the sight of participants toward the same cue can immediately establish a shared space for visual search and increase the efficiency of their co-searching performance. This effect of joint affordances expanding individuals' perceptual abilities also appears in van der Wel and colleagues' (2012) study on the effect of coordinating bodily action. Participants had to rotate a pole along a fixed axis by coordinating their actions and gave themselves ratings exceeding a value of 100 on a scale of 0 to 100. This may be due to overstating their control over the joint action or that it indicates a mix of self- and we-agency.

This result suggests that individuals' sense of we-agency, as given by operating the same tool in a joint action, can empower an individual's sense of action scope. Pacherie (2013) explains this amplification as involving the shift from self- to we-agency in co-agents in joint actions. This shift causes the blurring of self-awareness or 'boundary loss' of self (McNeill, 1995) allowing the mutual understanding of the collective impact of participating goals, intention and action to arise (Di Paolo & Thompson, 2014).

In summary, the theories of embodied cognition discussed in this section provide two main understandings about human perception valuable to design thinking for the proposed technology for shy users. One draws on the enactive approach to understanding human perception of own abilities as derived from tool use. With tool-absorption abilities, users 'see' more action possibilities in the environment through the tool-affordance lens. Another draws on the concept of affordances, both from Gibson's original work and modern views of HCI advocates to extend the notion of the environment to include the social sphere. The original view informs that tool affordances arise through the human perception of the relational properties of user-tool-environment ecology. Like the enactive approach, the affordance concept informs that in perceiving action possibilities provided by these relationships, users need to actively engage with the system. The complexity of the relationships in such a system makes designing user interfaces challenging as well as provides a rich resource for design exploration. Designers can define several affordances just by augmenting properties of the tool itself or amplifying user active perception and bodily interaction with it.

The modern view of the affordance concept generates far greater design possibilities of tool affordances for collaborative actions. Such as joint affordance guiding users to coordinate their understanding of one another's actions as well as shifting the sense of self-agency to we-agency while performing a joint action. Socially anxious people are inclined to perceive own their social abilities to be less than what they are capable of. Designing a socially assistive tool with interfaces that afford simultaneously the sense-making of individual interaction with the technology and the collaborative actions with others may extend their socialising possibilities, and subsequently lead to positive changes in their engagement with others in a social environment. In addition, optimising the role of social affordances in the tool may be a way to shift their focus from the self to the shared aspects in the social environment and thus facilitate meaningful action towards the improvement of their social interaction.

2.2.2. 'Natural' Interaction in Computation-mediated Environment

In such ways that the embodied views of human cognition (section 2.2.1) provide HCI research with opposing-Cartesian perspectives on human-world relationships, the embodied views of human interaction provide perspectives on the meanings of lived body actions, as arisen through its interaction with the physical and social environment. The embodied view of interaction has been popularised in the HCI community since Dourish introduced it in his 2001 book, *Where the Action Is?* In that, he proposed *embodied interaction* as a foundation for design and analysis of meaningful physical and social experiences with interactive systems that are built on ubiquitous computing platforms. Rather than denoting an interaction style or a model as its term might suggest, embodied interaction refers to an approach for analysing and designing interactive technology, which concerns itself with 'the creation, manipulation and sharing of meaning through engaged interaction with artefacts' (Dourish, 2004b, p. 126).

Embodied interaction approach emerged at the two interactions of *tangible computing* and *social computing* research fields. While tangible computing focuses on augmenting physical objects and making them the interface for interacting with the computational world; social computing is concerned with the social understanding of interactions that are enhanced by computation. The first intersection between tangible and social computing is in their use of the embodiment concept which is not simply referred to as physical realities. Rather it is the presence of a participative status in the everyday world; the occurrence of physical objects that people use as well as embodied interpersonal actions and conversations (Dourish, 2001, p. 235) This implies that not only is interaction with technology in a physical context important, but the social context too. Even more important is exploiting the ways in which people interact by using long-term skills and existing knowledge being applied naturally (Dourish, 2004b, p. 17). This makes embodied interaction a rich design and analytic perspective that attempts to exploit familiar and natural forms of interaction and expression with digital technology embedded in people's every day social realities (Dourish, 2004b, p. 190). Taking embodied interaction as a design foundation, therefore, means adopting a natural approach to designing user interaction models and interfaces (Dourish, 2001, p. 239).

The second intersection is in their employment of ubiquitous computing as the prevailing platform. Ubiquitous computing enables unobtrusive physical and mental engagement with other people through the interaction with technology, and distribute computation-embedded interaction in the world beyond the desktop (Dourish, 2001, p. 229). Through the innovation of artefacts and interaction techniques, ubiquitous computing also moves HCI away from the virtual world into the real world and the mixed-reality world. The notion of the real world is explored beyond its simple physicality, namely to include the social and personal worlds. Recently, mixed-reality research has blurred the conventional boundaries between real and virtual worlds (Price et al., 2009). It does so by enabling social interaction with embodied autonomous agents, such as seen in a study of social judgment in human-robot interactions (Wiltshire, Snow, Lobato, & Fiore, 2014) and psychotherapy practice in *Second Life* (Brahnam, 2014; Brahnam & Brooks, 2014). This led Price and colleagues (2009, p. 2) to redefine embodied interaction as 'a mix of the virtual and physical, intangible and tangible, reality and fantasy, where new theories of embodied interaction pair the physical, digital and social interface with the human sensory system'. This definition suggests that embodied-interaction technology is less concerned with the innovation of its artefacts and manipulation techniques; it focuses instead on the communication within human practice, their meaningful engagement with one another through technology.

What persists in the new notion of this approach is its original conception of *embodiment* as, Dourish (2004b, p. 125) pointed out, meaning not just the physical existence of user interaction with technological artefacts, but also the user 'being' grounded in everyday, mundane practices. This concept, being at the heart of the embodied interaction approach, holds that one's active bodily experience in the world is the medium for feeling, thinking and perceiving (Marshall & Hornecker, 2013, p. 1). In other words, the body is the real-world source of sense-making, while its action is the *tool* that renders the meaning. The real world, Dourish (2004b, p. 190) asserts, is the place 'suffused with social meaning'. From a user perspective, embodied interaction in the real world, therefore means making our interaction meaningful by coupling our body and understanding of social meanings offered by the technology.

Social interaction, the central aspect of this thesis, is a common human practice that can be challenging at times, but even more so for shy people on a regular basis. For these reasons the embodied interaction approach seems suitable as a design foundation for technology aimed at strengthening meaningful social interaction for shy users and their interpretation thereof. Following on from this, the next discussion will look at one of the design principles offered by this approach, namely how interaction with an interactive system can be turned into meaning, and what characteristics are required from the technology to facilitate this. This is to gain a more detailed and broader understanding of what natural aspects of technology, inspired by this approach, can offer by way of finding a suitable HCI framework that benefits the nature of socially anxious users.

Meaningful Actions as Enabled by Coupling with Effective Tools

Embodied interaction is a phenomenologically inspired approach, as Dourish (2001) explains. To understand how Phenomenology[20] inspires this approach when applied to the design of interactive systems, two aspects of embodiment featured in Phenomenology are important considerations. Firstly, *embodiment is about establishing meanings* of one's action upon an artefact, including the understanding of one's own and others' actions involved in the same activity. The meaningful engagement with the world in this sense, therefore, encompasses both the familiar physical and social skills and the active participation with others through using the artefact. From this aspect Dourish draws a natural model of interactive-system interfaces (Dourish, 2001, p. 239). Such an interface

[20] Heidegger's standpoint (Heidegger, 2001), as rejecting those of Husserl's, on meanings as already exist in the world; they are only revealed to us through our actions in the world.

allows users to search, discover, and develop the meaning of its use through their everyday practice and familiar metaphors. Users' interpretation of a system metaphor depends on their prior knowledge and experience. Intuitable user interfaces, as commonly constituted from metaphorical elements to facilitate tangible interaction models, for social interaction are examples of technologies that convey meaning in ways that can be naturally understood. They are designed to allow ordinary skills to shape the meanings of user interactions with the interface, and with other people through it.

The second aspect, *meaning arises in the course of action* we perform with the world. In turn, it reveals the meanings to us depending on how we act upon it and react to its response. In other words, our understanding of the world proceeds from our engagement with and action within it. In the same vein, the meaning of interaction within a technology-embedded environment can only emerge while the user is actively engaging with it. This is because meanings are not an inherent property of a system or interface but are embodied in the ways it is used by individual users (Dourish, 2004b, p. 126) and their encounter through it (Dourish, 2001, p. 239; Verbeek, 2005). Meanings in this sense can arise through three design aspects; *ontology*, *intersubjectivity* and *intentionality* (Dourish, 2004b, p. 126); each plays a different role in user understanding. Intentionality stands out in terms of the direct pathway it offers to users and pertinent to the aims of this study. This pathway makes salient the system element on which the user has to focus in order to correctly interpret the meaning.

Intentionality also maintains the relationship between action and meaning in a robust and versatile fashion – known as *variable coupling* (Dourish, 2004b, pp. 138-144). Coupling with an interactive system results in a continually changing relationship between the user, the interface and the meaning of its representation. This way, user attention becomes fluid while the person renegotiates with the system and controls its interface and representation (Dourish, 2004b, p. 202). Robustness and versatility are main characteristics of interactive systems; they allow users to seamlessly renegotiate and discard responses according to their purpose. This kind of relationship characterises the variability in coupling and reflects the phenomenological concept of tool use. When in use, the tool takes on the ready-to-hand state and becomes almost 'invisible' – in the sense that focused user attention is withdrawn from its operation. Its physicality is perceivably concealed in the extension of hand and object of manipulation, incorporated into a single unit of activity. When not needed, its appearance becomes apparent – immediately shifts back to a present-at-hand state, an object that is perceptually separate from the activity itself. The user would then need to adapt and re-orientate the relationship with the tool. With this kind of flexibility, variable coupling cannot be achieved through predefined system rules or the manifestation of technology alone. The technology must be in use and is subject to the user's intention to manipulate it.

Incorporating variable coupling in system interfaces and functionalities is fundamental to the embodied interaction approach. Doing so turns an interactive system into an embodiment of the fluidity of the user physical action and purpose (Dourish, 2004b, p. 126). Designing technology to facilitate variable coupling is therefore not simply a direct mapping of user needs onto interface features but recognising many possible ways and levels of coupling. To provide such coupling, designs must be available for *effective* use (Dourish, 2004b, p. 142). This type of usage occurs when only the features relevant to the user's current focus and action become immediately available, to avoid congestion of less relevant information at that time. Through variable coupling the user can revise and reconfigure their relationship with the task at hand and the environment in a transparent way.

Benefits and Design Challenges of Transparent Technology

Transparent technology reflects Weiser's vision of an *invisible computer* or also known as *calm technology*. It holds a metaphorical notion of 'drawing computers out of their electronic shells' (Weiser, 1991, p. 80). The idea has become a focal point of ubiquitous computing research by seamlessly integrating computation in mundane working and living environments. Norman (1998) elaborated this vision in *The Invisible Computer* in which he referred to it as a sort of human-centred technology integrated into the user's life and biological capacities. As such, the user 'sees' it as a task-specific tool, not an artefact embedded with thousands (if not millions) of electronics and computation. The 'average' user is not required to understand the low-level operational language but acquire functional knowledge (Norman, 1998, p. 176) through a clear conceptual model of the system. As a result, it allows for a novel, pleasurable and creative interaction for the user to fulfil their need without worrying about the hindrance of its complexity. This transparency is commonly achieved by facilitating an extreme or 'tight' coupling between the system and its user. Such coupling places the information processing and the computer itself completely in the background of the users' attentional field so that the user can interact *through* the system, not *with* it. This makes the technology cognitively transparent to operate, similar to the way a cognitively gripping tool (section 2.2.1) works. Users can focus on the object of interest and the activity for which the technology is designed to support, and can control as well as comprehend its interfaces without investing significant mental work.

Designing transparent technology encompasses system automacy emphasised by context-aware computing and wearable computing. Both follow a human-centred development path to create tools that subtly fit into the user's environment and adapt to change. However, they differ in the way coupling occurs with the user and the utilisation of user context. The context-aware attempts to achieve a system that autonomously and constantly bypass the user's apparent mental and physical efforts. Its system (namely designer's original intention) manages the coupling by regarding almost everything in the user environment as its context, continually harvesting, processing and offering information at all times (Erickson, 2002). All system activities are transparent to the user's general awareness and become 'invisible' when in use. This kind of transparency is therefore traded off with the user's sense of control. Wearable computing strives for a similar autonomous operation but only on the task at hand and within the wearer's personal context. Following this design principle of wearable computing allows for the wearer to manage the coupling and not the designer (Dourish, 2004b, p. 142). It does so by taking the wearer as a mobile locus (Clark, 2003, p. 47) – where a stream of personal information is stored, retrieved, processed and distributed according to changes in the wearer's personal conditions and needs. Operating on this need-to-use and need-to-know basis, a wearable computer becomes a 'truly personal' (Falk & Björk, 2003) and transparent tool that integrates itself in the user context in a way unobtrusive to her or his demands.

Completely and constantly transparent systems such as those enabled by context-aware computing, on one hand, seems beneficial to users who are prone to interaction anxiety. It minimises the challenges and psychological burdens commonly encountered in desktop computer environment with computational facilities that match their common skills and existing knowledge (Falk & Björk, 2003). On the other, it discourages improvement in physical- and cognitive skills such as reflection on interaction and deployed context (Hornecker, 2012, p. 181), techniques for new communication (Clark, 2003, p. 48) and problem-solving (Shaer & Hornecker, 2010, p. 68). With tasks completely and constantly embodied in user actions native to the user environment, there is a risk that transparency can cause the user to overlook how important and meaningful the required actions and interactional context are. Central to these challenges seems to be the term ‘invisible’ being taken ‘too’ literally. Both Weiser’s and Norman’s invisible technology are no more than creating what Clark (2003, p. 28) refers to as an ‘invisible-in-use’ technology. On specific occasions, it performs system activities without stretching the user’s cognitive processes rather than completely disappearing into the background, either in a literal or perceptual sense (Weiser, 1991, p. 80). Instead, it adapts to the user’s condition and not vice versa (Norman, 1998) and prioritises the tasks which the user is trying to accomplish.

Designing a transparent technology that tends to disappear in the users’ background, it is also important for the technology to promptly reappear in their focal attention when needed, to become an empowering tool not a distraction. This back-and-forth shifting capability reflects the ‘effective use’ (Dourish, 2004b, p. 139) of technologies conceptualised in the embodied interaction approach. In particular, it allows for the coupling to be managed by user demand at will unlike constant tight coupling that can hinder system effectiveness because it subverts the nature of human thinking processes. Human thoughts are highly changeable and for a tool to be effective in this regard, a tightly coupled system needs be endorsed with some temporal absence of its coupling state, hence allowing for a flow of engagement, separation, and re-engagement with the user thoughts and actions (Clark, 2003; Dourish, 2004b). Coupling with its user in this way, a transparent technology is known to have ‘flippability’ (Clark, 2003, p. 49). It is highly flexible in terms of engaging user peripheral and central attention. Flippability is a defining characteristic of an effective transparent tool that can tightly couple as well as temporally disengages itself from the user’s periphery effectively. In other words, it varies its own states naturally to the user cognition and interaction. Appropriately, it shifts from invisible-in-use while being operated and becomes readily available for thought and inspection when needed (Clark, 2003, p. 48). These characteristics originating from the embodied interaction approach, support a more natural way of user interaction with physical surroundings and social environments. Through this approach, we next will be looking at what natural computation-mediated technology means and can offer as a design perspective.

Criticisms on the Naturalness of Technology

There has been some criticism from HCI and related research communities (Hornecker, 2012) on the term ‘natural’ as used for ‘natural user interfaces’ (NUIs) in commercial sectors. The term NUI, in particular, has become a catchword for promoting newly developed touchless, gestural and body-movement recognition features offered by innovative-game user interfaces that go by many names such as Leap Motion, Microsoft Kinect and Nintendo Wii. With support from interaction designers (e.g. Greenfield, 2006; Saffer, 2008), it is said that these products provide innovative experiences with a ‘natural, intuitive and realistic feel’ due to not requiring specialist techniques for operation. Further claims are made that interaction with this kind of technology comes naturally because system behaviour is mapped onto the user’s pre-existing and ordinary set of actions in everyday communication. The user controls that these interfaces facilitate are not new and has been recognised by the research community as post-WIMP (Beaudouin-Lafon, 2004; van Dam, 1997), direct manipulation (Fitzmaurice et al., 1995; Hutchins et al., 1985), and reality-based (Jacob et al., 2007; 2008) interaction models, employing gesture-based inputs (e.g., whole-body, hand and eye movements).

By not limiting user control to the traditional desktop operation but exploiting naïve physics and everyday skills to manipulate computational contents, these models offer more natural feel to the interaction than traditional desktop computer. Nonetheless, these gesture-recognition interfaces are far from ‘natural’ (Hornecker, 2012, p. 175) if not facilitating ‘users’ well-entrenched skills and expectations of the real world’ (Shaer & Jacob, 2009, p. 2), and hence the real-world sense of spatial movement and orientation with technology. Obvious examples that ignore these characteristics are evident in research too, such as those requiring newly invented hands gestures unfamiliar to the way technologies are commonly used (e.g. Chen et al., 2018; Dangeti, Chen, & Zheng, 2016; Grandhi, Joue, & Mittelberg, 2011). Although having capabilities to recognise patterns of finger, hand and wrist movements, it still ‘imposes a layer of cognitive processing between the user and the computer’s execution of the user’s intent’ (van Dam, 1997, p. 64). This is opposed to the emphases of NUI research that aim to reduce mental effort and accelerate learning. Following some negative comments from the HCI research community, some scholars believe that *Natural User Interfaces Aren’t Natural* (Norman, 2010) and naturalness in interaction with technology is an HCI unattainable goal (Hornecker, 2012) and if it were feasible to achieve, NUIs should not at all require interfaces (Krishna, 2015; Lim, 2012). Interestingly, despite such critical views from leading HCI advocates, the number of NUI literature is growing.

In the below discussion, we first look into how HCI and its related fields (interaction design and ubiquitous computing in particular) define the meaning of naturalness in ‘natural’ interaction and interfaces of computation-embedded artefacts. This is followed by a review of design frameworks that support the conceptualisation and analysis of naturalness of technology.

Defining Naturalness through the Embodied Interaction Approach

From an interaction perspective, the above issues seem inherent in the non-reality-based interaction model of technology. However, when looking further into their gesture recognition techniques, these interfaces are vision-based (Kinect and Motion Leap are particular examples) as formed within the *representational* lens of technological context (O'Hara et al., 2013). Although this lens promotes non-desktop user experience with computer systems, sets out new challenges for engineering and natural language processing, it reduces the notion of naturalness to the representation of technological interfaces and loosely equates naturalness with ‘intuitive’ and ‘easy-to-use’ (Norman, 2010) without careful examination of interaction contexts (Dourish, 2004a). Recent studies show that user expectation of a natural experience with technology depends on more than engaging with the interface alone. Examples include the degree of difficulty in interaction in relation to past experiences (Asikhia, Setchi, Hicks, & Walter, 2015), consequences of intuitive actions upon interfaces (Blackler, Popovic, & Mahar, 2006; P. Turner, 2008), ease of embodied metaphor decoding processes (Celentano & Dubois, 2014), concerns of low-cognitive skills appropriate to sensorimotor habits and specific needs in different contextual actions (Ghosh, Shruthi, Bansal, & Sethia, 2017). Such evidence suggests that focusing the naturalness of technology only on the representation of its interface can lead to a narrow design discourse and thinking of user interaction context.

Embodied interaction approach highlights the role of meaningful actions with technology, others and context. This makes it a rich conceptual tool to decentralise naturalness of computation-mediated artefacts from a *representational lens*, to a wider context in which the focal point on the complex relationship between body, mind, and the environment is central. It has been applied to many subclasses of ubiquitous computing systems (Antle, Corness, & Droumeva, 2009a) because of its appreciation of the relationship between a computational system and the context of use (Dourish, 2004a, p. 20). However, ‘context’ in ubiquitous computing is variably interpreted, depending on theoretical grounds.

Various concerns for system design therefore arise. Two main concerns, reflected in the literature, are explored here through the *representational lens* and *interactional lens*. Both offer a unique understanding of the notion of naturalness, whereas the representational places limit view on designing user interactions, experiences, and contexts for technology while the interactional poses many design challenges.

The representational lens is influenced by positivistic theories that seek to reduce details of social phenomena to abstraction. Context, interpreted through this concern, often focuses on the technical notation. Such notation is useful for system developers to specify step-by-step procedures, to realistically model human action onto a computational system (Dourish, 2004a, p. 20; 2004b, p. 4). Context is thus seen as a set of constant features of human activity and settings – such as location, identities, time and other quantified conditions of the physical environment (Brown, Bovey, & Chen, 1997; Ryan, Pascoe, & Morse, 1997). The environment of an activity is predefined, captured, encoded and modelled. This makes it purely available for observation and representation. An example is Jacob and colleagues' work (Jacob et al., 2008, p. 201) demonstrating a successful leveraging capacity of natural interfaces from well-established knowledge of the non-digital world into reality-based interaction with technology. Abowd and Maynatt's (2000, pp. 30-32) meta-review is another evidence addressing the importance of the representational approach. In that they conclude, without a predefined representation of context, design applications are left with only ad hoc possibilities and lacking the capacity to coupling the context with natural interaction provided by ubiquitous computing systems. Central to these applications of the term naturalness are pre-existing forms of interaction that are definite, definable and material. However, viewing the context of computational systems through the representational lens under-emphasises the character and everyday role of human practice, as Dourish (2004a, p. 19) demonstrated. In this respect, he proposed an alternative view of contextual notation of naturalness in relation to human interaction and how the interaction is mutually understood and maintained among co-users of the computational system.

In contrast, context interpreted through the interactional lens is not a predefined, static or discrete unit; it relies on dynamic features of social mechanisms. This is because the interactional lens is grounded in the embodied interaction approach and phenomenology, which concentrate on examining the relational properties of social settings to understand human action. Hence, interactional context is a set of relational properties that link objects of interaction and social activities together. Context in this sense adapts along mutual understandings and interests, as well as physical and psychological changes within the joint action of people who make the activity happen. A challenge in interpreting context as an *interactional lens* is to make the system responsive not only to the physical properties of the user and technology, but also to their social settings. In addressing this challenge, it is important to remain attuned to mutual human interests, attention and shared activities. By their nature, these things change constantly.

The notion of naturalness, seen through the interactional lens is opposed to the idea of building naturalness of technology on the materiality and definable physical features of user interfaces (O'Hara, Harper, Mentis, Sellen, & Taylor, 2013, pp. 2–3). Instead, naturalness is reflected in the rapport between the co-users' physical and social contexts, such as the circumstance and experience to be enhanced by the use of an interactive system. In other words, naturalness is not something seen in the artefact one uses, which is rather the embodiment of interaction mechanisms of technologies designed for multi-users. Naturalness of technology, in this sense, brings people together to coordinate their experiences (O'Hara et al., 2013, pp. 2–3) and in turn, to mutually constitute the meaning of 'natural use' of the technology.

Design Frameworks for 'Natural Use' of Technologies in Social Contexts

Much literature on naturalness in technology involves research on *tangibles* enabled by ubiquitous computing. The use of embodied interaction to facilitate a hybrid between physical, digital and social aspects of computation-embedded artefacts is widely discussed. For this mix of elements to work well as an interactional system to support the naturalness of human-human technology-based interactions (Dourish, 2004b, p. 142), is to draw on a combination of views from many disciplines (Hornecker & Buur, 2006, p. 9). These fields include computer science, HCI, industrial design and so on. They share characteristics of the physical embodiment of data and interaction embedded in 'real space'. Such disciplines come together under the umbrella term 'tangible interaction'. Tangible Interaction originated from tangible user interface research fields (Ishii & Ullmer, 1997) that focus on representational aspects of user actions. Unlike tangibles in the original concept , tangible interaction focuses on human interaction in design thinking (Dourish, 2004a; O'Hara et al., 2013). It moves away from a representational to interactional model of human action and context. Based on these characteristics, this part of the literature review expands Hornecker's (2005) original quest: *why tangibles work* *well to support user experiences*. Rather than providing the detailed characteristics and functionalities of technologies in general as the original literature already does, the discussion below presents three specific conceptual frameworks that support the conceptualisation of technology, design and analysis of user interaction and experience in social settings.

The *Reality-based Interaction* framework (Jacob et al., 2008) provides four reality themes: *naïve physics, body awareness and skills, environment awareness and skills,* and *social awareness and skills*. Only the fourth group prioritises pre-existing social awareness and skills, such as verbal and non-verbal communication, the exchange of abstract and physical objects, and collaboration in collaborative tasks. However, combined with other themes they become an interaction style with rich characteristics to support physical and social realities. Examples include bridging a sense of community in physical, virtual and social worlds through an exchange of objects (Kalanithi & Bove, 2008), augmenting non-verbal communication in groups (Dickie, Vertegaal, Sohn, & Cheng, 2005), and regulating communication in crowded social settings (J. D. Smith, Vertegaal, & Sohn, 2005) with eye contact.

The *Tangible Interaction* framework (Hornecker & Buur, 2006) provides a platform for conceptualisation and analysis on the relationship between embodied and social interactions. Its four interrelated themes are *tangible manipulation, spatial interaction, embodied facilitation* and *expressive representation*. In non-equal degrees and different ways, these themes support tangible experience of social context, depending on their complementary design components, which are useful to the design and development of tangible interaction models, interfaces and spaces for social interaction. The embodied facilitation and spatial interaction themes in unison are useful for subtle or implicit direct user behaviour in a social environment. The remaining themes contribute to social interaction in indirect ways, by addressing the importance of social experience through enabling *direct manipulation* (Hutchins et al., 1985) of shared objects. They render the mutual interaction expressive and the system representation legible.

The *'Ideal Shifts'* framework (Fernaeus, Tholander, & Jonsson, 2008) was formed in response to the 'practice turn' in contemporary theory of sociality putting human activity as central to social context (Schatzki, Knorr-Cetina, & Thermann, 2005, p. 11). Addressing design challenges in HCI, ubiquitous computing, and tangible interaction research, it provides four conceptual shifts: *from information-centric to action-centric,* *from properties-of-system to interaction-in-context, from individual to shareable,* and *from objective to subjective-interpretation.* The themes promote the user's perspective on interacting with technology, focusing on user experience and contextually embedded interactions. The way these themes shifts conceptual design perspectives are by 'moving' the characteristics of tangible interactions towards more action-centred ventures in everyday and shared environments. They do not merely address the importance of seamlessly integrating artefacts with the user's physical action and environment, but also with the ongoing and shared activities that are natural to the situations in which the artefact is used. The usability of user interfaces is central to traditional interactive system designs. By contrast, these shifts highlight meaningful user interaction with an artefact, and the understanding of how users intentionally interact to orientate themselves towards interaction with other people. The shift *from individual to shareable*, especially, supports the use of shared artefacts for collaborative action and goals in a robust and flexible manner. An interface can thus adapt to the dynamic nature of social activities.

In summary, meaningful actions can be enabled by coupling with effective tools that seem invisible to operate and act as prompts for thinking. This way the tool fits naturally in with the meanings of interaction embodied in the action itself and relationships between users and their surroundings. The naturalness of technology, as offered by the representational lens, refers only to user interfaces and their materiality. Nonetheless, through the Ideal Shift framework, context can be applied more naturally by emphasising the social interaction context and through the relational properties between the user, technology and the social environment. This is useful to the investigation and analysis of the change in the behaviour of socially anxious users while using the proposed technology (discussed in the chapters 5 and 6). In as much, the Reality-based Interaction and Tangible Interaction frameworks are useful to conceptualise and develop the user inputs and representation of the system response as discussed in chapters 5 and 6. The Tangible Interaction, in particular, is useful to the evaluation of the system behaviour including the ways the technology facilitates the direct manipulation of technology and attach social dimensions to the materiality and manifestation of its user interfaces.

2.2.3. Discussion

Returning to the focus of this research, socially anxious people have a tendency to underrate their own social abilities. Applying the embodied views of human cognition for the design of technology with variable-coupling features to connect with user's already existing desire to engage with greater success in the social environment, we might predict that the user can perceive their 'true' social-ability and engage with others from a more active viewpoint. In addition, adopting the embodied interaction approach for the system design and its interfaces – so that it seems to be invisible when in use but always give prompts for thinking with – we might further expect the user to realise meaningful social interaction, as afforded by the social cues in the system display and behaviour. In this way, the interaction model of the technology fits naturally to the user's social cognitive abilities and becomes an empowering tool to co-manage the demands of the social situation, and in ways closely related to how people usually perform in social situations. Cognitive and behavioural performances of shy people are often stretched when encountering unfamiliar environments with high-attentional demands. To design a novel tool that does not impose itself on the user cognition and action, the tool should not interfere with the user interaction. By that, it should, in no time, become natural to use: accelerates learning, reduces mental load, and unobtrusive to the user's cognitive state as well as their physical and social environment. The next section (2.3) presents concepts and characteristics of interaction styles and user interfaces that support this natural design approach adopted in this thesis.

2.3. Unobtrusive Interaction Styles and User Interfaces

The embodied views of cognition (section 2.2.1) and interaction (section 2.2.2) explain how much our thinking is influenced by prior bodily actions traced within the mental resemblances of past events (Zwaan & Madden, 2017, p. 224), which in turn, guide our actions and constitute our knowledge to be accurately applied on something similar encountered at a later stage (Hurtienne, 2009a, p. 15). A technology that facilitates this kind of knowledge is intuitable; not requiring significant mental effort to operate and comprehend its representation. Similarly, when the technology resides in our environment in ways that only engage our peripheral attention but can shift into focal awareness mode when needed, it can facilitate peripheral interaction. These characteristics make interaction with system interfaces unobtrusive to user cognition and physical action. However, to introduce a new technology into the social environment of shy users, it is important that the appearance and interaction model of technology do not draw the attention of others directly onto the user. The discussion in this section is concerned with these three characteristics of technology: intuitable operation, peripheral engagement and low social weight. The aim is to understand which design factors are important to forming a low-cognitive-demand and low-key interaction model and computer-mediated artefacts for users whose cognitive capacities are put under stress when engaging with unfamiliar people and situations.

2.3.1. Intuitive Use of Technology

'Intuition' is a Latin word referring to a mental state in which an object is apparent in one's vision (Carus, 1916, p. 132). As a cognitive-affective element of human information processing, intuition enables *direct knowing* (Sinclair & Ashkanasy, 2005) – a non-sequential form of processing that bypasses conscious reasoning to previously stored knowledge in the memory. Although direct knowing requires a certain amount of cognitive effort for scanning and identifying the relevance of existing knowledge, the required cognitive process operates at a subconscious level. Hence, knowing something intuitively means to understand it without the need for time-consuming mental effort and prior training; the knowing comes 'naturally' (Raskin, 1994, p. 17). Intuition is an important HCI concept for designing interaction and user interfaces (Blackler et al., 2010; Britton et al., 2013; Hurtienne & Blessing, 2007a). It is constructed on the linguistic theory of image schemas (Lakoff & Johnson, 1980) and their metaphorical extensions (Johnson, 1987) which, when applied to the user's cognitive dimensions, provide significant value to the extent that it convey meaning in user interfaces (Rogers, 2012).

Design for Familiarity and *Effortlessness* in Intuitive Interaction

As a cognitive process, intuition denotes recognition and understanding of a current sensorimotor experience based on perceived information from the past (Bastick, 1982). This information is encoded and stored in the memory in a form of image schema or abstract representation (Johnson, 1987) – a mental process humans use to overcome the burden of infinite detail in our surroundings (Mandler & Cánovas, 2014, p. 19). What makes a schema powerful is not the schema itself but its metaphorical extensions (embodied metaphors or metaphors) that exist in a human's ability to transfer an abstract concept from a source domain to give meanings to other concepts in numerous target domains (Johnson, 1987). One of the target domains in which metaphors have been widely integrated is user interface design for various purposes. Examples include helping users to understand the complex operation of a computer system (Blackwell, 2006; Svanæs, 2001); reducing reaction time and errors (Hurtienne, Weber, & Blessing, 2008a); improving the intuitive use of screen-based applications (Fischer, Itoh, & Inagaki, 2015;

Hurtienne, Langdon, & Clarkson, 2009); and increasing the efficiency of post-WIMP interactions (Hurtienne & Blessing, 2007b; Hurtienne, Israel, & Weber, 2008b). A common aspect shared among these works is the sense of familiarity they offer to the user, as enabled by the robustness (Hurtienne et al., 2008a; Hurtienne, 2009a) and universality (Blackler & Popovic, 2015, p. 204) of metaphors. Among many categories of metaphors (Hurtienne, Klockner, Diefenbach, Nass, & Maier, 2015, p. 238), the *space* category (e.g., *up, down*, *low, high*) is the most familiar to us and ubiquitous across different cultures (Kovecses, 2005). This is because they are partly formed early in life and retrieved frequently in physical manipulation of tools and in everyday *visuospatial* thinking (Hegarty & Stull, 2012) – the understanding of space dimensions and non-spatial entities representing larger space dimensions from small scale symbols as found in map reading.

Familiarity when using interactive systems for the first time is a primary characteristic of intuitive interaction – a common interaction model of low-cognitive-demand systems. Intuiting such system equates ‘familiar use’, meaning that user skills are readily transferred (Raskin, 1994, p. 18) from prior knowledge and experience with similar systems. This removes the need for operational and functional instructions of the current system that in turn reduces mental demands on the user. Familiarity as a design element provides benefits to both the system designers and users (Blackler et al., 2006; Blackler & Popovic, 2015; Blackler, Popovic, & Mahar, 2003). It eliminates the need to demonstrate system functionality and allows for engaging with the system without learning or prior training. The main benefit of familiarity in design is in the subconscious applications of user experience and knowledge while using a novel system. Users can complete tasks quickly to arrive at results they anticipated (Blackler et al., 2003). In order to assist users in this way, the system must provide sufficient and effective information that leads to accurate performance (Hurtienne & Blessing, 2007b; Naumann et al., 2007). System and interface designs that comply with this rule require minimal or no cognitive effort towards goal achievement. This is an important element for using interactive systems when users are already restricted by new technical challenges and task rules (Streitz, Röcker, Prante, Stenzel, & van Alphen, 2009). Intuiting its interfaces, therefore, does not demand apparent effort; users can free up their cognitive resources (Hurtienne & Blessing, 2007a; Naumann et al., 2007) for managing other challenges (e.g., in the system and user environment).

Effortlessness is another characteristic of interaction with intuitable systems. It is enabled by the two prerequisites for intuitive interaction with its interfaces: prior knowledge and unconscious application of the knowledge (Hurtienne, 2009b). These two conditions determine whether the interface requires mental resources for learning to operate and understanding system response, without the explicit need to acquire new knowledge. It has been used as a design and evaluation criterion for interfaces that facilitate intuitive interaction (Diefenbach & Ullrich, 2015; Fischer et al., 2015; Ullrich & Diefenbach, 2010b; 2010a). *Effortlessness,* as an evaluation criterion, is used for the evaluation of intuitive interaction and usability testing of traditional user interfaces. Although they both address the importance of user effort in applying unconscious knowledge (Diefenbach & Ullrich, 2015), the usability test focuses on the use of newly gained information about the system, whereas the intuitive evaluation focuses on the subconscious application of previously acquired knowledge.

***Compatible* Mapping and Metaphors as Conceptual Tools**

Compatible mapping (Blackler et al., 2006) is a method used to create a sense of easy-to-use by 'matching' the user input to the system response. When compatibility between the two exists, the system can facilitate greater effectiveness (e.g. fewer errors and higher accuracy), efficiency (fast response and low cognitive effort), and user satisfaction. A compatible mapping commonly requires embodied metaphors [21] for creating and sustaining the consistency between the system's internal elements (e.g., concepts, features, aesthetics and so on) and any others outside it (e.g., metaphors from other domains). These elements have been widely investigated (Antle, Corness, & Droumeva, 2009b; 2009a; Macaranas, Antle, & Riecke, 2012; 2015) based on Fishkin's (2004) *metaphor as verb* conceptual framework. Many studies have explored the benefits of embodied metaphors in a mapping of natural inputs (mundane and bodily actions) onto computation-embedded interfaces (Antle, 2007; Koleva, Benford, Ng, & Rodden, 2003; Svanæs & Verplank, 2000).

Antle and colleagues' studies (2009a; 2009b; 2009c) focus specifically on whether an emphasis on embodied metaphor can make a system more intuitive to use. In that, they compare user experience from participating in two whole-body responsive environments;

[21] 'Embodied metaphor' is another term for a metaphorical extension of image schemas. The term reflects the way past experiences are encoded in an abstract form and embodied in metaphors. The term is commonly used in research on intuitive interaction through body-action built on ubiquitous computing platform.

one implemented with an *intuitive-interaction* model (with *more-less* metaphorically mapped interfaces) and another with *non-intuitive-interaction* model (with descriptive-information mapped interfaces). The results show that embodied metaphors facilitated intuitive interaction, as reflected in the participant reports for easier use.

Central to the ease of use in the *intuitive-interaction* model is the saliency of the compatibility between the physicality of user action and the tangibility of the system response. Making this compatibility explicit is to match the structure of human physical experience (Svanæs, 2001, p. 390) with familiar metaphors in the system interface. Mapping the physical, in this sense, is not limited to the 1-to-1 matching of user action and system feedback (Antle, Corness, & Droumeva, 2009a, p. 240) which is reported as being efficient for directing user focus towards required tasks (Macaranas et al., 2012; 2015). Beyond this isomorphic mapping the question arises as to how users' prior knowledge of the physical input leads them to several kinds of direct knowing (Antle, Corness, & Droumeva, 2009a, p. 240), namely to operate properly, anticipate the system feedback and perceive the meaning of embodied interaction. This is evident in the original work (Antle, Corness, & Droumeva, 2009a; 2009b; Antle, Corness, Bakker, Droumeva, Van Den Hoven, & Bevans, 2009c) and more recent studies (Macaranas et al., 2012; 2015) have expanded this approach to improve intuitive use of natural user interfaces. They found that the matching of users' everyday actions and common encountered metaphors (presented in the system output) leads to the acceleration of subconscious interaction with the system and perception of its meaning.

In summary, the intuitive use of technology occurs when the user can apply prior knowledge unconsciously and without much thought. It feels effortless to operate its interfaces and perceive meanings of its response; hence the user feels familiar with the system using it for the first time. Metaphors are a commonly used tool to create such characteristics of intuitive interaction. A metaphorical mapping between user physical input and system tangible output, when made explicitly discoverable, can make the system even more intuitive for use. It occurs when the physical input is a type of action that users perform in their day-to-day activities and the tangible output is comparable to what they encounter in other systems

2.3.2. Low Attention-demand Technologies

A social situation consists of many sub-phenomena requiring different degrees of attention. Most social technologies demand full attention to operate. They divert the user's focus away from the situation and are likely to conflict with social norms and disrupt the user's social performance. When the user is prone to social anxiety, the technology can become a burden adding cognitive load and physical challenges. To develop a social technology to improve their social cognition and interaction, the technology should not compete with other elements in the ongoing situation in terms of attentional demands. The literature review in this discussion is influenced by a shift in human attention research around the mid-1960s'. Traditional attention theories argue that cognitive attention can only be fixated on one thing while it is withdrawn from the others. In contrast, modern attention theories hold that human attention can be dispersed onto several objects and simultaneous tasks (Juola, 2016, p. 2) and can switch back and forth depending on the changes in the peripheral events to which the focal attention is diverted. In the following, we first look into modern attention theories to understand how peripheral attention operates when performing multiple tasks and perceiving information from many sources. The discussion will then review peripheral user interfaces, in particular, information displays that are appropriate to facilitate non-focus-demand interaction in the social environment.

Related Theories to Peripheral Attention

Modern attention theories play a crucial role in designing technology for an information-rich environment such as found in social situations. *Filter Attention Theory* is an example explaining that some types of information can be perceived even when not attended to (Moray, 2018; Norman, 1968; Schneider & Shiffrin, 1977; Treisman, 1964). A recent study (Moray, 2018; Norman, 1968; Schneider & Shiffrin, 1977; Treisman, 1964) found that information from the periphery can leak through to focal attention, if relevant to the person's context and focal task. This cognitive ability applies to both the visual and auditory stimuli, including the actions and responses of other people. The way people act is affected by the degree of attention paid to parallel tasks. *Resource Theory of Attention* is useful for designing multiple tasks (e.g., one primary and many peripheral) that are intended to be maintained without apparent attentional effort (Wickens, 1981). Focal tasks are generally more complex and demand greater attention resources than peripheral tasks (Lavie, 2001). Nonetheless, the primary can be automated if it involves pre-existing knowledge and well-practised sensorimotor skills (Juola, 2016), saving attentional resources for peripheral actions and having an awareness on what is happening in the background environment.

Not everything within the visual scene is equally important to a person's perceptual system at any one time. *Feature-integration theory* (Treisman, 1985) explains how a person decides to attend to certain visual properties and ignore others. Central to this theory is the low-level visual-reception mechanisms that humans possess. It is known as the *pre-attentive processing* (Treisman & Gelade, 1980) that perceives multiple visual properties at a rapid[22] pace. Primitive visual features (Table 1) register before focused attention occurs (Chavira et al., 2002; Healey & Enns, 2012; Huber & Healey, 2005; Ware, 2012).

Table 1: Pre-attentive features arranged in four categories of visual primitives, namely form, colour, motion, and spatial position (Ware, 2012)

Categories	Features
Form	line (orientation, length, and width), size, curvature, spatial grouping, blur, added marks, numerosity (one, two, or three objects), and convex/concave shape from shading
Colour	hue, intensity, and convex/concave shape from shading
Motion	flicker, direction of motion
Spatial position	two-dimensional position, stereoscopic depth

Pre-attentive features 'pop out' among others in the observer's visual field, but these features do not hold the same degree of salience (Ware, 2012). To compensate for those less obvious features, rapid eye movement takes place between fixations. Eye movement is part of the natural visual search; it allows low-frequency visual changes to be recognised even though they are part of information residing only in the peripheral attention sphere (Findlay & Gilchrist, 1998). This implies that information presented to the periphery will benefit the observer more if it is intended to form an overview of knowledge, not detail.

Our surroundings impose visual objects with infinite detail beyond the limits of our low-level information processing. This 'deficit' is partly caused by the lack of attentional resources (Alvarez, 2011) to retain precise information at a glance (Ariely, 2001).

[22] Within less than 250 milliseconds (ms) without requiring the observer to serially scan the entire visual field, whereas the human's eye moving and focusing operation takes about 200 ms or less (Healey & Enns, 2012; Ware, 2012).

However, our high-level visual processing can compensate for these limitations, as the *Ensemble Coding Theory* explains. This ability is known as *ensemble coding*, a rapid and automatic operation that summarises visual information (Healey & Enns, 2012) without the need for focal attention (Alvarez, 2011; Alvarez & Oliva, 2009). It enables us to perform cognitive computation on a group of visual objects that exhibit similar low-frequency features (Neumann, Ng, Rhodes, & Palermo, 2017), such as overall brightness (Bauer, 2009), mean location (Alvarez & Oliva, 2008), average change of features across time (Albrecht & Scholl, 2010), and counting of items in sets (Burr & Ross, 2008; Feigenson, Dehaene, & Spelke, 2004; Whalen, Gallistel, & Gelman, 1999).

In summary, peripheral attention theories provide an understanding of how peripheral attention operates to allow humans to perform multiple tasks and perceive diversified information without the need for focal attention or can be of use before focus is required. The growing literature in pre-attentive processing and ensemble coding, in particular, challenges a common assumption that visual objects perceived without focused attention do not yield useful information to the observer. They demonstrate that the human visual system can seize a precise summary of grouped visual objects from the averaging (statistical summary) of imprecise information, as gained from peripheral awareness of visual objects. Below we look further into available interaction and information-display modalities suitable to facilitating peripheral attention in shy people.

Peripheral Interactions

Peripheral interaction with a computation-embedded object does not demand user focal attention. When such an object is designed to assist users in a social activity, its use can conserve cognitive capacity and advance their social interaction and experience. Presented below are three interrelated interaction styles capable of enabling peripheral action upon technology. These models build on one another, presented in the consecutive subsections: *Peripheral-tangible* interaction, *Peripheral-subtle* interaction, and *Implicit* interaction. A brief exploration on their similarities and differences below is aimed at putting together a collective of computer-mediated interaction characteristics that may benefit users who are prone to cognitive overload (such as the shy) when performing multiple tasks in a social interaction.

Peripheral-tangible Interaction

Peripheral-tangible is an interaction model that can automate as well as disengage user actions upon physical artefacts. It does so synchronously with the natural process of the user engaging with the artefact. Proposed by Edge and Blackwell (Edge, 2008; Edge & Blackwell, 2009) through their research on tangible user interfaces for peripheral interaction, peripheral-tangible interaction reflects the effective use of computation-mediated systems designed with flippability characteristics (section 2.2.2). In their own words, (Edge & Blackwell, 2016, p. 20) peripheral-tangible interaction is about:

> ***Episodic engagement with tangibles, in which users perform fast, frequent interactions with physical objects on the periphery of their workspace to create, inspect and update digital information which otherwise resides on the periphery of their attention.***

It implies that peripheral-tangible interaction allows for information to remain at the periphery, retrieved only for quick updating without occupying the main focus for long or adding to the cognitive load by overcrowding the centre of attention. Furthermore, this type of interaction enables perception and action to take place without giving it much thought; it happens almost unconsciously. This advantage is made explicit in the way it diminishes *gulfs of execution and evaluation* (Norman, 1998). It does so by indicating possible actions on the digital information and tightly coupling the physical state with the digital state (Edge & Blackwell, 2016). Accordingly, this physical-digital hybrid holds two main characteristics for peripheral-tangible interaction: peripheral engagement and the augmented tangibility. Together they exploit features of long-established tools and well-practised skills of users to minimise the demand for task-attention.

In designing such a hybrid, Edge and Blackwell (2016) introduced a framework comprising several components, including the *objective demands of the task*. This design component is also useful in determining to which extent the tangibility of system interface and its interaction modality put demands on user cognition. The objective demand, through its three factors – temporal, mental and physical – can indicate whether the mental load required for interacting with tangibles exceeds the peripheral threshold of user attention. Many studies (Bakker, Van Den Hoven, Eggen, & Overbeeke, 2012; Edge & Blackwell, 2009; Hausen, Boring, & Greenberg, 2013; Hausen, Boring, Lueling, Rodestock, & Butz, 2012) employ this approach to investigate the impact of the peripheral-tangible model and the benefits of tangible interfaces used in the social domain. Their results demonstrate the capability of this model to minimise cognitive demand when using new techniques for operating novel user interfaces, and improve the user social presence, manage social routines and enable effective ways for social learning and interaction.

Peripheral-subtle Interaction

Peripheral-subtle interaction, or *subtle* interaction, is an interaction model that supports background activities and engages with user communication channels in an unobtrusive fashion. Like peripheral-tangible interaction, subtle interaction projects information immediately onto the performer's periphery without demanding apparent physical effort (Hausen, 2012). It also exploits the tangible affordances of digital artefacts to engage user background experiences as seen in recent works (Edge & Blackwell, 2016; Olivera, García-Herranz, & Haya, 2011). However, subtle interaction goes further in two aspects: making it low-key to perform and running concurrently with other tasks. The first aspect is in the way it makes use of a non-engaged or underused communication channel already employed by other ongoing tasks. An example is seen in Olivera and colleagues' (Olivera et al., 2011) *Do Not Disturb*, where an augmented coffee table linked to a wireless social-networking system, takes the performer's hand lifting a coffee cup (embedded with a QR code) as a user input for managing her/his social presence. Their study results demonstrate that this hand gesture, while conforming to local social conventions of being at a coffee table, also reduces information load imposed on the sight and auditory channels when compared to the user's management of social presence on a traditional graphical-user-interface system.

The second aspect is in its emphasis on succinct information belonging to the deployed context. This is similar to the use of information in peripheral-tangible interaction. Both types of interaction are initiated and completed quickly but for different design purposes. The information delivered through peripheral-tangible interaction is brief because user focus is on the foreground task rather than the background (Edge & Blackwell, 2016). In contrast, subtle interaction is brief because the nature of the information it delivers is concise (Olivera et al., 2011, p. 280) and the meaning and outcome of the action it triggers are richer. This aspect also makes subtle bodily gestures more than mere interaction with technology on a subconscious level. The task commands, as enabled by the underused communication channel, are often unrecognisable, given that they are naturally integrated into the context and the already performed action. Examples are the hand gesture in the context of the augmented coffee table (previously mentioned); the sitting up/down on smart chairs (Probst, 2016); and the foot tapping action on the wireless-Tweeting shoes (O'Nascimento & Martins, 2010 [23]). These interaction commands are already available in mundane activities, making use of them minimises physical effort and at the same time maximises social acceptability.

Recent literature shows an alternative use of the term 'subtle interaction', describing covert user control of computational systems to achieve subtlety in social performance. This covert-subtle interaction is employed in many applications (Anderson, Grossman, & Wigdor, 2015) investigating low-bandwidth interaction commands for deceiving bystanders into thinking that a performer is carrying out mundane tasks other than the one he/she is actually performing through a hidden system interface. Systems that facilitate covert-subtle interaction are often manifested in small wearable items, such as spectacles (Costanza, Inverso, Pavlov, Allen, & Maes, 2006), bracelets (Hansson & Ljungstrand, 2000) and rings (Matthies, Perrault, Lecolinet, & Zhao, 2014). These devices, while allowing for conventional gestures native to activities within the employed environment, serve the secret operation of the performer. It requires full attention to operate and practice to reach a degree of concealed interaction with the technology in front of other people. Seen from this viewpoint, it is unsuitable as an interaction model because it fails to reduce cognitive load which is an essential requirement for the intended use in this study.

Implicit Interaction

Implicit interaction is a form of peripheral interaction that holds an assumption that the system understands the user's behaviour within given situations (A. Schmidt, 2000). It prioritises the user foreground tasks through the use of computer systems running in the background. As a result, it has the potential to significantly reduce cognitive demand for system manipulation – a quality it shares with peripheral-tangible and peripheral-subtle interactions. However, unlike the aforementioned, the system that facilitates implicit interaction requires no or very little user attention to operate (Ju, 2015; Ju & Leifer, 2008; A. Schmidt, 2000). Users may or may not be aware of the system because their actions are 'not primarily aimed to interact with a computerized system but which such […] system understands as input[s]' (A. Schmidt, 2000, p. 192). An example of implicit interaction is of visitors approaching a building entrance where a doorman is stationed and prompted in opening the door. From task initiation to completion, the entire

[23] Retrieved March 31, 2017, from https://gizmodo.com/5457277/rambler-sneakers-tweet-every-single-step

interaction process of the visitor is completely embedded and seamlessly automated in the doorman's 'system'. An explicit command by the visitor is not needed. In order to support users in this way, a computer system should accurately perceive and interpret the user actions, circumstances and changes in the context (A. Schmidt, 2000, p. 192). This implies that the system's behaviour, purpose and capability need to resemble those of the user while behaving in ways not obvious to the user's awareness.

The concept of Implicit Interaction is inspired by Weiser's (1991) vision of 'more-seamless integration and less-obtrusive operation' of a system and Nielsen's (1993) idea of non-command user interfaces. They emphasise the disguised physicality of the computer, in both sensing (Shibata et al., 2014) and displaying (A. Schmidt, 2000) parts, which is a characteristic of implicit interaction. This enables the interface to demand no explicit interaction while anticipating ways for the user to physically, cognitively and socially engage with other matters in the environment deemed to be of more importance (Ju & Leifer, 2008). In turn, this gives fresh challenges to task design, similar to those of context-aware systems requiring constant tight coupling behaviour (section 2.2.2). One of the crucial challenges is to find a balance between two interaction factors: system awareness and user attention (Poslad, 2009). Achieving the correct balance depends on the extent to which the user feels comfortable with the system taking control of their environment, actions and experience. The intended interaction is to happen outside the attentional field, on a subconscious level (Bakker & Niemantsverdriet, 2016). In order to succeed in finding the right balance (e.g. Atterer, Wnuk, & Schmidt, 2006; Sawhney & Schmandt, 1999; Shibata et al., 2014; Witt & Kenn, 2006), the system automation needs to be implemented in ways knowing about the user's 'every move' (Atterer et al., 2006; A. Schmidt, 2000), behaving as if it resembles the user behaviour (A. Schmidt, 2000) and deliberately suppressing user attention (Poslad, 2009). For system behaviour to appear on a subconscious level, Poslad points out (Poslad, 2009), is no more than giving the system non-intrusive, invisible, tangible, natural, and anticipatory characteristics – aligned with the outcome of the natural design approach to designing computer-mediated interaction models and interfaces (section 2.2.2).

These characteristics often leverage everyday bodily actions to achieve implicit human-machine interaction. However, apart from emphasising the subtlety of interaction with computer systems, implicit interaction is also concerned with whether it is acceptable and suitable for social settings (Ju & Leifer, 2008). To this end, finding ways for the interaction model to be socially appropriate and its computer system easily adopted in social environments. Proposed design principles, that cater to the social aspects of implicit interaction, emphasise the structure and pattern of social transactions (Ju & Leifer, 2008) and the interchange of contextual information within social settings (A. Schmidt, 2000). Among many bodily actions that facilitate such exchanges, a handshake has become a primary design component for user input, establishing two parallel forms of communication, between two people (Bennington, 2008) and the exchange of information between computational devices (Ateniese, Kirsch, & Blanton, 2007; Balfanz et al., 2003; Hou, Lai, & Liu, 2016). Systems that incorporate both human and machine handshakes are often built on wearable computing embedded devices, such as wristbands (Abouzied & Chen, 2014; Augimeri, Fortino, Rege, Handziski, & Wolisz, 2010) and gloves (Cranor et al., 2011) whereby the system has access to a variety of social situations of the users. Among these examples, Abouzied and Chen's (2014) work is central to the use of contextual information. They employ human and machine handshakes as a cooperative action to enable the implicit exchanges of social information between systems, and of social transactions between users in the context of a match-making situation. Their study reveals that new social connections are less meaningful to users if the information has little social context attached.

In summary, the primary benefit of the peripheral interaction model is its low attentional demands on users that allows for interaction with the computer system to move outside the sphere of focal attention. Interaction with the system, hence, occurs subconsciously; thereby preserving attention resources for other ongoing tasks. The three peripheral models of interaction presented above highlight different interactional aspects and differ in the degree of appropriateness for facilitating social interaction. The *peripheral-tangible* focuses on brief, mundane and well-practised actions that can retrieve information from the periphery by the physical affordances offered by digital systems. The nature of these information updates, moving instantly between peripheral and focused states, cause only minimal disruptions to focal attention and has a low impact on social interaction goals. The minimal-cognitive-demand principle is also taken up by the *peripheral-subtle* and *implicit* interaction models. However, these two do not exploit all of the existing well-practised actions. The *peripheral-subtle* only utilises the already executed actions which are native to the ongoing situation. Operating its system does not require additional physical or mental effort other than those used for managing social routines; this gives the model an extra characteristic: social suitability. The *implicit* interaction works on the assumption that the computer system resembles the social intention, behaviour and anticipation of the users. Operating its system does not require any attention at all. Hence, while interacting with one another the users may or may not be aware of their interactions being supported by the system. This can also be counterproductive if it prevents users from noticing any changes in the social context and it for this reason important to have a design principal that makes these specific changes explicit to the users.

We next look into the type of information display that presents information specific to the user's peripheral attention.

Peripheral Displays

Peripheral display is a type of information display that resides in the user's subconscious awareness and, when prompted, can shift into focal attention when required. In HCI literature, the term appears interchangeable with 'ambient display' and 'notification display' given that they share the design objective to deliver information of an event running parallel to another. McCrickard, Czerwinski, and Bartram (2003c), for instance, refer to notification display as an umbrella term for ambient and peripheral displays. Both provide information while not demanding substantial attention from users to be noticed but the notification display presents highly critical information as opposed to ambient. Mankoff and Dey (2003) regard peripheral display as the umbrella term of the other two that differ in their information displaying behaviour. Ambient displays present information continuously in a non-disruptive manner, without trying to move information into the user's focal attention. Notification displays do the opposite, at certain times. Pousman and Stako (2006) define ambient displays as systems that present non-critical but important information, which can move between central and peripheral attention. They further characterise ambient displays as a tangible form, embedded appropriately and aesthetically in the user environment while constantly and subtly updating their information content. All of these notions are useful in understanding the many characteristics of peripheral displays. However, the notion taken by this thesis aligns with that proposed by Matthews, Rattenbury, and Carter (2007), given that they set the condition for a peripheral display as – a tool operated by the user who also manages other activities running in concurrently. Hence, its operation commonly demands minimal mental and physical effort to execute. This informs the unobtrusive design intention of the current thesis: to present social information that is useful to the users without distracting them from other ongoing social activities.

Related Concepts – Calm but not Slow

Although aesthetics is not central to this thesis, this characteristic is useful to understand the concept of peripheral displays. Given that the behaviour of peripheral displays and the nature of the abstract information they represent, peripheral displays can be aesthetically pleasing to look at. This characteristic makes peripheral displays appear to be similar to experience-based artefacts (Dalsgård, 2008; e.g. Sas & Dix, 2009; Thieme et al., 2011) from *slow* technology designs that promote reflection (Hallnäs & Redström, 2001). Such artefacts are manifested with a temporal slowness, revealing system responses in a serene, non-disruptive and elegant manner. However, as Hallnäs and Redstörm (2001) stated, *slow* technology serves more than mere temporal aesthetics in design; its appearance might be perceived as low speed but this temporal sense is not exclusively tied to the speed of interaction with technology. Using slow technology, the time spent with it is metaphorically stretched out, allowing for conscious thoughts on its operation, functioning behaviour and manifestation to occur. In this regard, the aim of *slow* technology vision is not to make technology invisible in use nor facilitate low-cognitive demand like those emphasised by *calm* vision (section 2.2.2) – the concept where peripheral displays draw from. This aspect is also reflected in the associated interaction models (previously discussed) where the duration of peripheral displays is brief so as not to interfere with other forms of interaction in the user environment.

Social Construction of Peripheral Displays

The fast-paced development of ubiquitous computing and electronics have advanced computer-embedded displays to the point that it is possible to provide information almost in every context of the user, namely intimate, private, public and social. The design foundation of peripheral displays for social context builds directly on the *calm* vision; while updating information in the background and facilitating a lightweight form of information monitoring (Dey & de Guzman, 2006), peripheral displays enrich the foreground interaction (McCarthy, 2002) by affording mutual understanding of co-observers as well as their interpersonal actions (section 2.2.2). Since the late 1990's, this approach has been taken by the ubiquitous computing and coordinated information display research communities to promote social awareness and relationships among people who are co-present. Examples are seen in a variety of studies using a public display to provide social cues and initiate social interaction between passers-by, such as

Borovoy et al' (1998), Falk and Björk' (1999), McCarthy et al' (2002; 2001), Williams et al' (2006), Landstorfer et al' (2007), and Jarusriboonchai et al' (2015).

Among the influential studies, McCarthy and colleagues' (2002) revealed an interesting aspect of peripheral displays when used to facilitate informal interaction (namely spontaneous and serendipitous conversation) between people who were unfamiliar to one another but had coordinated social profiles. Placed in a workplace area these people routinely visited, the display drew their mutual attention by customising the display information shared by their profiles. An interesting outcome was that even when the display content did not match their interests, they still conversed about the changes it made to the environment and its manifestation. This implies that information is not the only factor promoting social interaction but also the social setting. Based on the *interactional* viewpoint (section 2.2.2) that regards elements within an interaction context dynamic and relational, peripheral display can be seen as socially constructed by people (Crabtree, Hemmings, & Rodden, 2003) because its changes occur in a space where people's routine actions take place. In addition, this space can be seen as an active *site* (Grudin, 1990) that directs and articulates people's actions and conversations. A peripheral display in a social setting where people come to perform a joint activity can therefore constitute a mutual understanding of its use.

Challenges in Development

A peripheral display by nature serves the user from a 'position' in the background and subconscious level where at least two activities (namely a primary and secondary) run in parallel. It presents information to the subconscious awareness so that the user can perceive the information without focusing on it. Peripheral displays inherit this *transparent* nature from the *calm technology* vision to enrich the primary activities of 'casual' interaction and user experience (McCarthy, 2002). Therefore, the design intention for peripheral displays does not only assist the primary activity but also support the user to pursue the motive for such an activity and improve their experience of doing so (Matthews et al., 2007). Engaging with such an experience-based technology, the user focus is not on the secondary activity where the technology operates within, nor is the user as an interactor directly or actively part of its operation. This makes it difficult to implement traditional HCI design frameworks (Matthews, Hsieh, & Mankoff, 2009), that mostly emphasise direct manipulation of technology, task concentration and completion. In contrast, Matthews and colleagues (2007) proposed a design framework specific to peripheral displays. It highlights the three design dimensions (namely *scope of use*, *class of support activities* and *criticality*) that, when applied, help to define which user activity and motive the display must support; how it should exist and behave in the user environment; and which interaction model fits best by being appropriate to the user environment.

Challenges in Evaluation

The lack of peripheral design frameworks leads to challenges in evaluation techniques (Carter, Mankoff, Klemmer, & Matthews, 2008; Mankoff et al., 2003). Like the aforementioned design frameworks, early research in peripheral displays adopted traditional HCI evaluation techniques for the usability of graphical user interfaces. These techniques, such as heuristic evaluation (Baker, Greenberg, & Gutwin, 2002; Nielsen & Molich, 1990), informal expert reviews (Vredenburg, Mao, Smith, & Carey, 2002), and end-user thinking-aloud protocol (Yen & Bakken, 2009), are practical for defining the impact of user interfaces. They require the user to directly act upon and control the system representation precisely and at a specific time or within a given duration. Their assessment criteria are task-central, such as *effectiveness*, *efficiency*, *learnability*, *memorability*, *errors*, *usefulness*, and *user satisfaction errors* (see details in Matthews et al., 2009). These criteria are primarily based on the usability of technology, not the user experience for which peripheral displays are intended to support.

As the concept of peripheral display becomes increasingly popular in HCI community, researchers have started to develop specific evaluation frameworks to assess user experience while carrying out a primary task. Some are mainly developed from traditional usability so that they remain within the *learnability*, *usefulness* and *user satisfaction* criteria but also include new criteria such as *awareness* (Mankoff et al., 2003; McCrickard, Chewar, & Somervell, 2003b; Shami, Leshed, & Klein, 2005), *interruption*, *reaction*, *comprehension* (Mankoff et al., 2003; McCrickard, Catrambone, Chewar, & Stasko, 2003a), and *unobtrusiveness* (Mankoff et al., 2003; McCrickard et al., 2003a). Some others, such as the Peripheral-Display Toolkit (Matthews, Rattenbury, & Carter, 2003), are constructed on traditional criteria but also adopts experience-based HCI theory. This toolkit was later elaborated by the same research group (Matthews et al., 2007) to include five evaluation criteria specific for peripheral displays: *appeal*, *learnability, awareness, effects of breakdown* and *distraction. Learnability* and *distraction* are closely related criteria that complicate the assessment of peripheral displays. For instance, to assess how much learning effort is required at first-time use, researchers often ask the user midway to assess whether they interpreted the information correctly without looking at the display (Stasko, McColgin, Miller, Plaue, & Pousman, 2005). The challenge still remains on how to assess these criteria without disruption of use or interfering with user experience.

Time, location and quality of prototypes pose further challenges for the evaluation of peripheral displays. Evaluations are commonly conducted as long-term field studies (Bakker et al., 2012; Bakker, Van Den Hoven, & Eggen, 2015; Edge & Blackwell, 2009; Hausen et al., 2012) because of the need for technology to integrate with routine activities of users. This integration needs to be as ‘seamless’ as possible or up to the point that the display lies outside the user attentional field while their focus is on something else. However, recent studies have demonstrated the potential for successful evaluations of certain elements in a one-off laboratory setting. One evaluation (Olivera, Rivas, & Iturriaga, 2014) was conducted on the condition that the user interaction model of the display was ‘highly’ subtle, imposing information on the user environment without being the focus of attention. Another favourable outcome is evident in a study (Hausen, Tabard, Thermann, Holzner, & Butz, 2014) validating user experience by using the same peripheral display in a one-off laboratory-based and an eight-week in-situ setting. The results showed no substantial superiority of one setting over the other except for the mental load measured in the in-situ setting being higher than in the lab-controlled environment. Although the laboratory-based evaluation lacked long-term integration of technology into the user environment and the same mental demands, it offers various possibilities for investigating some usability issues more thoroughly. The user behaviour, in particular, could be more closely observed without possible interferences presented by in-situ settings.

Further on the nature of peripheral display research that is often limited by rapid prototyping processes, researchers pointed out that the early stages of implementing the design concept, technological and computational aspects often have an unpolished appearance and unrefined system behaviour. It is common for these low fidelities to draw some attention from users, contradicting the peripheral use of technology that should be performed outside attentional focus. As a result, it is difficult for users to appreciate what the system offers, especially, when using it in-the-wild study where other distractions in the natural environment already exist. This implied that although the laboratory-based evaluation is not ideal, it can be practical for certain stages of prototype and its required conditions of use.

In summary, any peripheral display presents contextual information to the user's periphery of attention. It continuously provides this without distracting from the demands of other concurrent running activities. This makes it suitable for providing contextual cues in an environment where people come to perform a joint activity to exchange knowledge towards a mutual understanding of the changes in the context and the unfolding of their interrelated actions and experiences. With a display that can provide social cues without the need for focal attention, the user can interact with it in an indirect way while managing other tasks of the social routine. Using it, therefore, means to strengthen the motive for ongoing social activities and improve the social experience; it eliminates any difficulty in operating its system and perceiving information. These benefits to the user, in turn, pose a challenge to the measurement of usability and efficiency of a display that mostly remains in the background and on a subconscious level. Nonetheless, fundamental to developing a new technology is the need for it to be proven as useful. Some traditional usability-based criteria (namely *user awareness* and *satisfaction*) remain helpful in terms of fundamental concern, while some new criteria (namely *learnability* and *distraction*) are helpful to assess whether the use of technology and its manifestation are unobtrusive to the user's mental, physical and social experience. Assessing *distraction* seems the most challenging if conducted with the provision of not interfering with the user experience, especially in the real-world social environment where many other distractions already exist. Furthermore, almost all development phases of peripheral technology result in low-fidelity prototypes, making it unavoidable, to a certain degree, to draw user attention to the technology. In this respect, as the literature suggests, an evaluation of peripheral displays can be done practically in lab-based settings but the display needs to be subtle in terms of appearance, functioning behaviour and the changes it makes in the user environment. This approach is evidently suitable for short-term evaluation and provides researchers with more possibilities to understand user behaviour and give more control over confounding effects on user attention.

2.3.3. Low Social-weight of Wearable Display

Social weight (SW) of technology has its foundation in Mullaney's (1999) Theory of Markedness. According to the theory, 'markedness' refers to an action unnatural or atypical to the social norm causing the action to become an object of attention. The more it deviates from the norm, the more weight it carries (Lois, 2003, p. 191) and more attention it draws to the person performing it. SW of technology, as a research topic, is gaining attention in the *wearables* branch of HCI and ubiquitous computing, given that wearable technology is broadening the frontier of human-computer integration into everyday activities. The use of wearables, therefore, creates more opportunities of technology attaching SW to the user in a social context. Most wearable computing literature defines *physical presence* and *social convention* of technology (Dunne et al., 2014; Profita et al., 2013; Toney, Mulley, Thomas, & Piekarski, 2002) as the main attributes contributing to SW. *Cognitive load* is another attribute emphasised by Toney and colleagues (2002) in their definition of SW as the deterioration in social interaction through technological artefacts. However, cognitive load in computer-mediated social interaction can be influenced by many factors other than interaction with the technology itself, such as the personality traits of the interactor, the interaction partners and the dynamic nature of the social situation. This argument is also discussed in more detail in this chapter, particularly in sections 2.1.1, 2.3.1 and 2.3.2 given that it is important to understand how SW of technology can draw undesired attention from an interaction partner, as triggered by the appearance of the users and their use of technology that are inappropriate to the social context (Dunne et al., 2014). Accordingly, the discussion below draws primarily on wearable computing literature. It seeks to understand how such SW occurs and what approaches are available to reduce wearable SW of information displays. The review then moves on to a specific display modality: *vibrotactile* regarding its covert potential as an information display.

Approaches to Minimising Wearable Social Weight

One of the reasons for the emergence of wearable computing has been to reduce the overt nature of ubiquitous technology. Nonetheless, such technology can still attach SW to the user for several reasons. One such lies at the heart of design thinking that shows little concern for the intimate relationships between the wearer and the technology and between the wearer and other entities in the social context. This happens when the user is placed in a static end-user role, as Kettley (2007) demonstrated. When this occurs, the co-existence between the user and the technology separates the user from its local context and community. Other reasons are more obvious in the manifestation of the technology, as caused by, for instance, the novelty of new user interfaces, novel interaction techniques, and traditional HCI approaches that tend to prioritise system functionality over appearance. Subsequently, it can turn the wearer into an object of undesirable attention. For example, by incorporating overt technologies into wearable items, the user can be associated with a ‘cyborg’ culture and/or labelled a show-off. As evidenced in Sheridan and colleagues’ (2000, p. 195) survey, the public perception of the wearer identifies with negative stereotypes, namely ‘geek show’ and ‘walking freak’. Such perceptions conflict with the expectations of users who prefer low-key public attention.

Negative attention caused by the SW of a wearable display can be avoided by reducing its visibility (Møller & Kettley, 2017); making its *physical presence* more synchronous with the *social convention* of the user context (Dunne et al., 2014; Profita et al., 2013). Based on the utilisation of these two attributes, the literature suggests two main approaches to reducing wearable SW. One is to combine both and another is to manage the physical presence alone on the redundancy of social convention.

The approach that combines physical presence with social convention is useful when a wearable display and its interaction technique need to be partly invisible. Common design techniques of this approach are to integrate the required hardware into a garment or worn accessory, as well as have its interaction model disguised in bodily actions or gestures native to the social situation. Therefore, the display can be partly visible but not alien to the user context. Such partial-invisible characteristics often allow for providing the user with subtle and public cues with low-bandwidth information. It requires only minimal attention from the user to perceive and comprehend. This way, the display becomes an ambient feature, presenting information to the user’s periphery without requiring conscious effort (section 2.3.2). An example of partial-invisible social displays is a group of wireless networked *Speckled Brooches* and *Pendant* (Kettley, 2007). The changing behaviour of their LED lights is mapped by the greeting activity and the proximity of the wearers, so that these ornaments can augment social awareness and bonding amongst the wearers. Another example is *CommonTies* (Chen & Abouzied, 2016), a series of wireless-networked wristbands embedded with an RGB LED. It changes the colour pattern according to contextual changes (namely current and previous locations of nearby wearers) in a social networking to facilitate new connections among attendants who have common interests. A similar concept to this example but slightly different in method, is the *SocialButton* bracelet (Landstorfer et al., 2007). It is embedded with several LEDs to exhibit short messages among group members within the same proximity. These examples have one thing in common; they map a social pattern of the user activity onto the social presence of technology. Such mappings augment social cues in ways not interfering with the social formalities. The appearance of these wearables and their changing behaviour can attract unwelcome social attention from other people present. However, the wearables convey and update information synchronously with changes in the context of co-users. It is socially acceptable within the particular user context because co-users have a mutual understanding of the purpose and effects of the technology.

Social convention becomes less of a concern when wearable displays are totally covert. This is the approach by which the physical presence of technology is utilised alone. Its design challenges are thus focused on dealing with other social factors that involve the user's perception and understanding of the displayed information, and the embedding of display devices in the available and appropriate features of the hosted platform (e.g., clothing and wearable accessories). The bandwidth of information is one of the main concerns to this approach. High-bandwidth displays are often traded-off against the availability features of the embedded platform. A popular trade-off is seen in the mixed-reality display of 'smart' eyewear (e.g. Intel Vaunt glasses[24] illustrated in the right-handed frame of Figure 3) The display projects information on holographic reflector material of the lens and then into the user's retina. Its system leaves no trace of the atypical physical presence of regular eyewear in Vaunt. However, its display provides only 400-by-150-pixel images, notably less than the 640-by-360 display of Google glasses[25]. Despite the design aesthetics that add a 'utopian-minimalism' style to its appearance, the physical presence of Google glasses (see the left-handed frame of Figure 3) fails to minimise social weight because of the bulky electronic parts on one side of the glasses. Nonetheless, due to the technical complexity and high cost of production and material, this type of visual displays is not as popular in wearable research as some other display modalities, such as vibrotactile, even though its effective usage mostly applies to relatively low-bandwidth information and its technical complexity and user perception of the information are common challenges to research and development.

[24] Retrieved February 8, 2018, from https://www.theverge.com/2018/2/5/16966530/intel-vaunt-smart-glasses-announced-ar-video

[25] Retrieved September 27, 2018, from https://www.inverse.com/article/40998-google-glass-vs-intel-vaunt

Figure 3: Comparing the physical presence of Google glasses (left) and Intel Vaunt glasses (right)

Advantages and Challenges of Vibrotactile Displays

The tactile sense allows for humans to perceive information through skin contact. This vibrotactile modality have advantages over other communication modes in situations where the communicators prefer some privacy and their sight and hearing channels are otherwise engaged. When used to provide social cues in face-to-face situations, it allows for the appearance of a vibrotactile display and its required interaction to be completely covert (Pohl, Medrek, & Rohs, 2016; Toney et al., 2002; Toney, Mulley, Thomas, & Piekarski, 2003). While not adding visible SW to its users, it also preserves the privacy of their information and releases the user’s eyes and hands for other ongoing tasks. The latter benefit is especially valuable in social situations where diverting the eyes from interaction partners is deemed to be socially inappropriate. As a means for conveying social cues, vibrotactile displays can strengthen social ties (García-Herranz, Olivera, Haya, & Alaman, 2012; Werner, Wettach, & Hornecker, 2008), maintain social relationships (Rabby, through, & Rodden, 2002), influence social inclusion (Knudsen, Morrison, & Andersen, 2011), improve social awareness in discreet and socially acceptable ways (Oakley, Kim, Lee, & Ryu, 2006; Pohl et al., 2016; Toney et al., 2002; 2003), and enhance the sense of social agency (Giannopoulos et al., 2008, p. 307) and sense of ‘self’ (Gemperle et al., 2003, p. 4). So far, only Giannopoulos and colleagues’ (Giannopoulos et al., 2008) demonstrated the successful use of vibrotactile feedback to improve the social behaviour of socially anxious users in a virtual environment.

Touch is the first and immediate sense that a human develops and masters from an early age (Fulkerson, 2014 p. xxi). A recent study on the perception of vibrotactile cues (Pielot & Oliveira, 2013) reported that 95% of participants who were using a vibrotactile display for 10 minutes while participating in a social-networking event could perceive the tactile information without focused attention being required or being annoyed by it. Other literature (Brewster & Brown, 2004; Horgan, 1996) also refer to the use of vibrotactile interfaces to facilitate low-mental demands of technology in situations where visual signals are rich and might cause cognitive overload. Wearable displays for light-weight cueing in social situations that follow this approach, typically have an array of miniature vibration motors embedded in body-worn accessories, such as in armbands (Gemperle et al., 2003; Lee & Starner, 2009; 2010; Pohl et al., 2016), shoulder pads of a jacket (Toney et al., 2002; 2003), and trunk harnesses (Sarfraz, Constantinescu, Zuzej, & Stiefelhagen, 2017). However, the successful use of vibrotactile displays involves more than the embedding of technology. User perception of vibrational stimuli is as much of a challenge as the technical configuration of the message. To overcome these challenges, it requires the understanding of intricate neuro-physiology, the complex mechanisms of vibratory stimuli and techniques used to manipulate stimuli parameters. These factors are all interrelated to vibrotactile perception.

The ability to perceive vibrotactile stimuli is affected by many skin-sensitivity parameters, such as *body site* and its *two-point discrimination threshold*[26]. Literature shows that the sensitivity levels of popular body sites employed in wearable display research such as the forearm and upper arms are relatively equal, but differ in their two-point discrimination thresholds (Myles & Binseel, 2007). The upper arm registers a greater threshold, namely between 44 mm (Gemperle et al., 2003; Weinstein, 1968) and 50 mm (Cholewiak & Collins, 2003). The reasons for this, as studies showed, are that skin sensitivity increases in the body parts that are less hairy (Mahns, Perkins, Sahai, Robinson, & Rowe, 2006; Sofia & Jones, 2013) and further away from the bone (Oakley et al., 2006). The ability to perceive vibrotactile stimuli can be improved by manipulating several parameters of the vibratory motors (or *tactors*), their spatial orientation and spatiotemporal techniques. There are numerous tactor parameters (e.g., *vibration intensity*, *pulse frequency*, *pulse duration*, *pulse interval, and type of tactons*[27]) requiring complex configuration for control purposes. Modifications of these single and combined parameters (particularly the first three[28]) not only produce substantial differences in

[26] The distance between two pressure points that are perceived as two distinct points (Gemperle et al., 2003). When vibrotactile stimuli are applied on two points located apart by less than this distance, the stimulated points are perceived as one.
[27] Type of tactons used by reviewed literature are DC eccentric rotating mass actuators such as seen in http://sensorwiki.org/doku.php/actuators/eccentric_rotating_mass_erm_motor; retrieved May 31, 2016
[28] Further details of these tacton parameters and manipulation methods are provided in Appendix A.1

vibrotactile perception but can also result in various types of spatiotemporal modes (e.g., static and dynamic) and tactogram (e.g., deictic and alphanumeric)[29].

In summary, the use of wearable displays can increase social weight when it elicits negative attention from others. This happens when the display and its required interaction are designed in ways that separate the human-technology mediated role from the local context; the physical presence of the wearer and the technology deviate from the social convention in the environment it is being used. Minimising the visibility of wearable displays is a common approach to reduce social weight. It can be done either by making the technology and its manifestation partially visible or entirely covert. The success of a partially visible display relies on how well the social pattern of the wearer is mapped onto the technology's functioning and displaying behaviour. This kind of human-technology integration often complies with a low-bandwidth characteristic of the displayed information to minimise undesired attention while perceiving the information. The vibrotactile modality of information displays serves this purpose well, given that it allows for both the display to be disguised in wearables and the interaction to be concealed. However, the vibrotactile display is a challenging research area that requires the understanding of human perception of vibrotactile stimuli and the techniques for manipulating hardware and parameters to achieve specific vibrational information and tactograms. Nonetheless, the literature shows several promising techniques useful for creating low-bandwidth information displays while preserving user privacy of information and interaction. This makes vibrotactile a promising modality for providing information in a social context to people who prefer a higher level of privacy during social interaction.

2.3.4. Discussion

Following on from the previous literature review of the natural approach for designing technology (section 2.2) to serve the specific needs of people prone to social interaction anxiety (section 2.1), this section explores design concepts of interaction styles and user interfaces applicable to the natural approach. As a result, the overall discussion in this chapter compiles information in response to the first central research question outlined in section 1.4:

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[29] Further details of commonly used techniques for forming tactograms are provided in Appendix A.1

RQ1: How can a social object be used to aid the social interaction of shy users?

By gathering such knowledge, we see the possibilities of using computer-mediated artefacts to encourage users in subtle ways towards improving their engagement with others in a social context.

The interaction models and user interfaces referred to in this section (2.3) are threaded under the unobtrusive theme of technology. The intuitive use of technology is unobtrusive to the cognitive process by providing a metaphor-implemented interface that maps the user action to system response; where prior knowledge can be applied at the subconscious level. The attention required by peripheral models of interaction and user interface, remains on the periphery; acting upon the system as well as making sense of its displayed information then occur predominantly outside the field of focal attention. Nonetheless, attention can shift in and out from the focal point for specific design purposes, particularly for emphasising meaningful action and information. Low-social-weight displays facilitate low-key engagement with technology. This is achieved by assimilating its manifestation and supply of information into the social convention of the user context. Applying these concepts might come close to reaching an ideal set of characteristics that lays out the design principle, guidelines and specific requirements for developing a new social technology in response to the second central research question:

RQ2: What are the key advantages of facilitating social interaction with subtle technology?

These questions will be readdressed in the next chapter to uncover and justify the research assumptions through methods and frameworks appropriate to designing such technology. And that might aid the user without conflicting with their cognitive and behavioural traits commonly exhibited in the social environment.

Chapter Three

3. Methodology

At the heart of this research lies the intention to explore and identify new characteristics of social technology unobtrusive to the cognitive-behavioural nature of shy users. Implemented in a computer-mediated artefact, such characteristics were expected to facilitate the user's social interaction in a more subtle and beneficial way than commonly available social technologies do. This intent led the researcher to formulate two consecutive central research questions (RQs) (elaborated in sections 1.4 and 2.3.4) that shaped the sequential integration of qualitative and quantitative approaches to forming the research activities. The current chapter begins with a rationale behind the framing of the research design driven by the RQs. In that, a unified description of the research (i.e., research phases constructed with an exploratory sequential mixed methods approach, and case studies) is given along multiple points at which the qualitative-quantitative data integration occurred (section 3.1). Next, it describes the components required in conducting the studies; this part covers the types of data to be investigated, the methods for sampling, study participants (sections 3.2), and conceptual model – driven by the design perspective of *Applied user psychology* (Moran, 1981) and a design principle of subtle technology – commencing from *quality of experience* (Alben, 1996) and natural user-behaviour (Oviatt, 2006). An overview of customised technical instruments comes after (section 3.3). Finally, it presents the researcher's awareness of the research limitations and challenges as well as the ethical concerns in working with socially anxious test participants (section 3.4).

3.1.Designs of Research and Case Studies

Mixed-method approaches bring together quantitative and qualitative data collection and analysis to 'draw out new insights beyond the information gained from the separate quantitative and qualitative results' (Fetters, Curry, & Creswell, 2013). This approach is applicable 'even when a fusion of the two sets of findings was not envisioned at the outset' (Bryman, 2007, p. 9). Such a prospect is known to be effective when, for example, assessing different levels of a phenomenon by triangulating, complementing (Greene, Caracelli, & Graham, 1989; Sale, Lohfeld, & Brazil, 2002) or enriching the depth of one type of data with another (Martin 1987 cited in Greene et al., 1989). The common benefit of this approach to research, is the improvement in interpretability of findings from multiple viewpoints needed to be explored and/or confirmed (Creswell & Plano Clark, 2017). Among the available implementation models for mixed methods approach, the exploratory sequential model with three phases (Creswell, 2014; Creswell & Plano Clark, 2017; Plano Clark & Ivankova, 2016) was chosen for three main reasons. Firstly, it provides a research space for the research problem and relationship between RQs to unfold (Creswell & Plano Clark, 2017; Onwuegbuzie, Bustamante, & Nelson, 2009; Teddlie & Tashakkori, 2009). Secondly, it allows for the research theme and design approaches of non-existing instruments to be customised and applied specifically to the conditions of a selected population, rather than bending the research needs to 'off-the-shelf' standards (Creswell & Plano Clark, 2017, p. 96). This is why this research design is also known as 'instrument development design' (Creswell, Fetters, & Ivankova, 2004). Finally, it fits the ultimate goal to generalise and complement the quantitative findings with the preliminary foundation of qualitative information required for understanding the psychological needs of the prospective users of the proposed technology.

3.1.1. Three-phase Research Model

An exploratory sequential mixed methods model is a three-phase research design. It starts with the qualitative collection and analysis of information. Then follows the translation of qualitative findings into research approaches and tools to be assessed quantitatively in the final phase (Creswell & Plano Clark, 2017, p. 96). This model fits in well with the *exploration* and *development* phases of this research designed in response to RQ1 – to obtain collective knowledge about the characteristics of novel computer-mediated tools appropriate to aiding shy users' social interaction, and the *generalisation* phase in response to RQ2 – to identify the advantages of the proposed technology over non-subtle characteristics of social technology.

Phase I

The first phase, *exploration*, started with the qualitative method. Its preliminary activities set out to explore the nature of shy people and their anxious dispositions which can escalate due to the interaction demands of regular social technologies, but may benefit from the implementation of unobtrusive features of computer-mediated artefacts. This exploratory phase was conducted solely through reviewing literature in social psychology and sociology (section 2.1) and Human-computer Interaction (HCI) and ubiquitous computing (sections 2.2 and 2.3). The synthesis of these bodies of knowledge informed the development of many research components in the following-up phases.

Phase II

The second phase, *development*, was dedicated to the knowledge transfer and investigation of technical plausibility. The acquired qualitative results were applied to develop conceptual models of the computation-mediated social objects; outline the set of features, characteristics and parameters to be implemented in the early prototypes; identify important and assessable variables; and design of activities for user evaluation. Two feasibility studies were conducted in this phase. Qualitative and quantitative data collection and analysis from these pilot studies informed one another and suggested the need to change the design approaches of the technology. Strategies and detailed integration of qualitative-quantitative approaches in these studies are described in the following subsection (3.1.2).

Phase III

The third phase, *generalisation*, marked the final exploration of this research. It was designed to generate quantitative research components to gather a deeper understanding of the effects of subtle characteristics of technology, iterate design of the prototype, and to compare the merits of using a subtle social aiding tool as opposed to non-subtle, namely obtrusive, high-cognitive demand or 'in-your-face' technology (Clark, 2003, p. 35). These components allowed for the sampling of quantitative results from an empirical study (the Final study). Finally, the quantitative findings were generalised with inference of the qualitative research results derived from research Phases I and II.

All three phases are presented in Table 2 that explains the overall research activities organised in phasing blocks showing the points where qualitative and quantitative methods integrate. The integrations were applied to both the overview and activity levels. On the overview, the qualitative data was first collected and analysed to form the research foundation and unobtrusive-technology theme that drove the research development towards the final quantitative-based generalisation. On the activity level, both approaches were combined to support one another in the data collection, analysis and interpretation of results under the *complementarity* purpose (Greene et al., 1989; Lee & Smith, 2012; Sale et al., 2002)

The use of a notation system, particularly applied on the shorthand, describes features and characteristics of the methods. On general usages, the uppercase and lowercase indicate method roles: priority and supplement (J. M. Morse, 1991) while the underlines denote key activities that affected RQs. On the topmost level: QUAL → [QUAL →← quan] → [QUAN → qual = generalise findings], the single arrows (J. M. Morse, 1991) indicate how methods occur in a sequence while the double arrows (Nastasi et al., 2007) indicate recursive processes of both methods; the parentheses (Plano Clark, 2005) indicate the intersected methods within a bigger perspective of intervention designs (i.e., instrumentation, user interaction modelling, and systematic assumption of technical characteristics); and the equal sign (Morse & Niehaus, 2009) indicates that the quantitative method was the core and firstly applied to explore phenomena (i.e., user behaviour and self-graded social experience). It played a bigger role in determining the Final study's purpose and assessment of the advantages of the technology. The qualitative method followed to enrich the interpretation of the study's findings, expand the generalisation to socially anxious user population, and form the design principle of the technology. Lastly, the asterisks indicate a major change in the technological design approach, described in the next subsection.

Table 2: Exploratory mixed-methods table, including research activities organised in a three-phase sequence

QUAL → [QUAL →← quan] → [QUAN → qual = generalise findings]						
	Phase I: exploration		**Phase II: development**		**Phase III: generalisation**	
Model	**Qual data collection, analysis**	**results built into**	**QUAL + quan measures, instrumentation**	**results built into**	**QUAN + qual data collection, analysis**	**Interpretation.**
Research activities and points of methods integration	• State *qual* RQ1 and determine *qual* approach • Identify the *qual* samples • Collect opened-end data with lit review protocol to fit the *qual* samples	• Analyse info RE tech, and develop theme and characteristics (charcs) • Analyse info RE social anxiety, and develop charcs of user needs, common behaviour and capacities • Map tech charcs onto those of user • Synthesise mapping info to set assumption for RQ1 • Identify the info needed to inform Phase II's activities (e.g., build conceptual model of tech, conceptualise features and charcs of interaction styles and user interfaces) and Phase III's primary research components (e.g., *quan* RQ2, *quan* features of tech and of comparative tool)	Pilot I study: vibrotactile display		Final study: subtle-peripheral visual display	
			• Set plans for *quan* and *qual** feasibility testing procedures • Design and build instrument for *quan* measures • Recruit expert evaluators • Collect closed-end data	• Analyse results (descriptive) • Examine pro/con results • Draw conclusion from *quan* findings • Interpret conclusion and synthesise with Phase I's *qual* data to interpret con results • Dispose *qual* testing plan*	• Set plan for experimental *quan* procedure • Design and build instruments for *quan* measures and tool for comparative test • Mapping tech's and comparative tool' charcs onto those of user behaviour and experience • Recruit social-anxious participants and pre-collect *quan* and *qual* data • Collect closed-end data with voluntarily opened-end data	• Analyse results (descriptive + inferential) • Examine pro/con results • Draw conclusion from *quan* findings – complemented with available *qual* findings • Interpret conclusion and synthesise with Phases I's and II's *qual* data to answer RQ2 • Reflect on what extent and in what ways *quan* findings validate and complement the assumption for RQ2 • Generalise the charcs of tech that are superior to comparative tool • Refine key charcs to build design principle of tech for social-anxious users • Reflect on the research limitation and potential improvement
			Pilot II study: peripheral visual display			
			• Recentralise tech design approach and revise tech concept and charcs • Set plan for experimental *qual* testing procedure • Design and build user interaction model and instruments for *qual* measures • Determine charcs of participants and apply for ethical approval • Recruit shy participants and pre-collect *qual* and *quan* data • Collect opened-end data	• Analyse results (descriptive) • Examine pro/con results • Draw conclusion from *qual* findings – complemented with *quan* findings • Interpret conclusion and synthesise with Phase I's *qual* data to answer RQ1 • Refine RQ2 and set assumption for key charcs of tech based on the *qual* and *quan* findings and Phase I's *qual* data • Identify the info needed to inform Phase III's activities (e.g., iterate tech design, refine tech behaviour and manifestation, build conceptual model for comparative tool, acquire statistical knowledge and skills) and components (e.g., variables of user behaviour and experience, refined *quan* features of tech and comparative tool, sampling instrument)		

3.1.2. Case Studies

Seen in the research-design model (Table 2), the literature review advanced an unobtrusive theme of technology to assist the natural behaviour of shy users. This theme was rendered into different modalities of wearable *social objects* (section 2.1.3) that facilitate a peripheral interaction with peripheral and low-social-weight user interfaces (section 2.3.2). Each modality was inspired by the nature of social technology for users who are prone to interaction anxiety (section 2.1.2). These differences in interaction models and user interfaces led the researcher to conduct three empirical studies outlined as follows.

Pilot I Study

This study was designed with regards to prospective users' social preferences for privacy and low-key appearance. The vibrotactile concept informed the development of Vibrosign armband for giving social cues to the wearer in a discreet manner. Owing to potential issues users can experience in correctly perceiving vibrotactile messages, this study was initially planned for two purposes: one to assess its capacity to enable the natural model and characteristics of human and computer interaction (section 2.2), and another to facilitate social interaction among users. The first purpose was to define quantitative parameters of the armband and its possibility to convey a number of detailed messages. Its quantitative findings indicated potentially negative impacts of the vibrotactile modality on the user's cognitive experience and the limited capability of the technology to perform the role of a social object (chapter 4). This addressed the research needs to abandon the second purpose of this study and change the technological design direction to explore the possibilities of a more general form of information representation: visual modality in the follow-on study.

Pilot II Study

This was designed as a platform to improve the capacity of a peripheral social object in reducing cognitive demand (than the approach in the Pilot I study) and facilitate social interaction between users. The concept of peripheral displays was the rationale for the development of the first visual-based display prototype, namely Icebreaker T-shirt, to provide mutual social cues to multiple users. A peripheral display was inlaid in the frontal area of the prototype to encourage interaction among shy people who met for the first time. This testing instrument and procedure were set up with the primary goal to validate a pre-constructed Icebreaker model (section 3.3.1) and a primary assumption of key features and characteristics of the technology (section 3.3.2) to facilitate low cognitive demands and a feeling of naturalness when used (section 2.2). Further objectives were to assess the practicalities and limitations of hardware and computation configuration and to compare user social behaviour and experience when they did not use any assistive social technology. The qualitative findings of this study were examined and complemented with a quantitative description of the user performances. Together they addressed the suitability of the public-visual displays as an approach to improving the social interaction of the prospected user. Furthermore, the outcome repeated some positive findings consistent with those referred to in literature (section 2.3.2), such as (McCarthy, 2002) and (Chen & Abouzied, 2016). This was, in particular, research projects that investigated the ambiguity concept in creating social objects (section 2.1.2) and the unexpected capacity of a peripheral display in encouraging conversation between people who were unfamiliar to each other (section 2.3.2). These findings (chapter 5) showed the appropriate potential of this approach and highlighted the importance of increasing the technology’s state of being subtle. In addition to this outcome, it was successful in the technical configuration resulting in a novel user interface (namely soft-circuit display) and wearable social application. Although the quality of the low-fidelity prototype caused some disruption to the user experience, and this being a common issue with rapid prototypes, this approach was retained for refinement in the further research stage.

Final Study

This study was designed as an iterative platform for refining the look and feel of a higher fidelity prototype (than the t-shirt prototype) and analysing quantitative data collected from an experiment on the degree of subtlety of socially assistive tools. The concept of the subtle-peripheral display was applied in the 2nd visual-based prototype, namely Icebreaker Jacket with a snapped-on Social Badge. It was used to manipulate the condition of subtlety in comparison with a handheld Social Card – both providing the same social cues (used in the Pilot I study). This allowed for assessing user behaviour and the extent to which both social tools differed in improving user social experience. This testing instrument and procedure were set up with the primary goal to validate the assumption for keys characteristics of subtle technology that made it superior to non-subtle characteristics. Its further aim was to generalise the quantitative findings into a design principle for a subtle social object for socially anxious users. Further details of this study's procedure and outcome are presented in chapter 6 and a more conclusive discussion in chapter 7.

All three studies are illustrated in a flowchart (Figure 4) that shows the knowledge building path encompassing both RQs towards the generalisation of research outcome and refinement of a design principle for subtle social objects for socially anxious users (section 3.3.2).

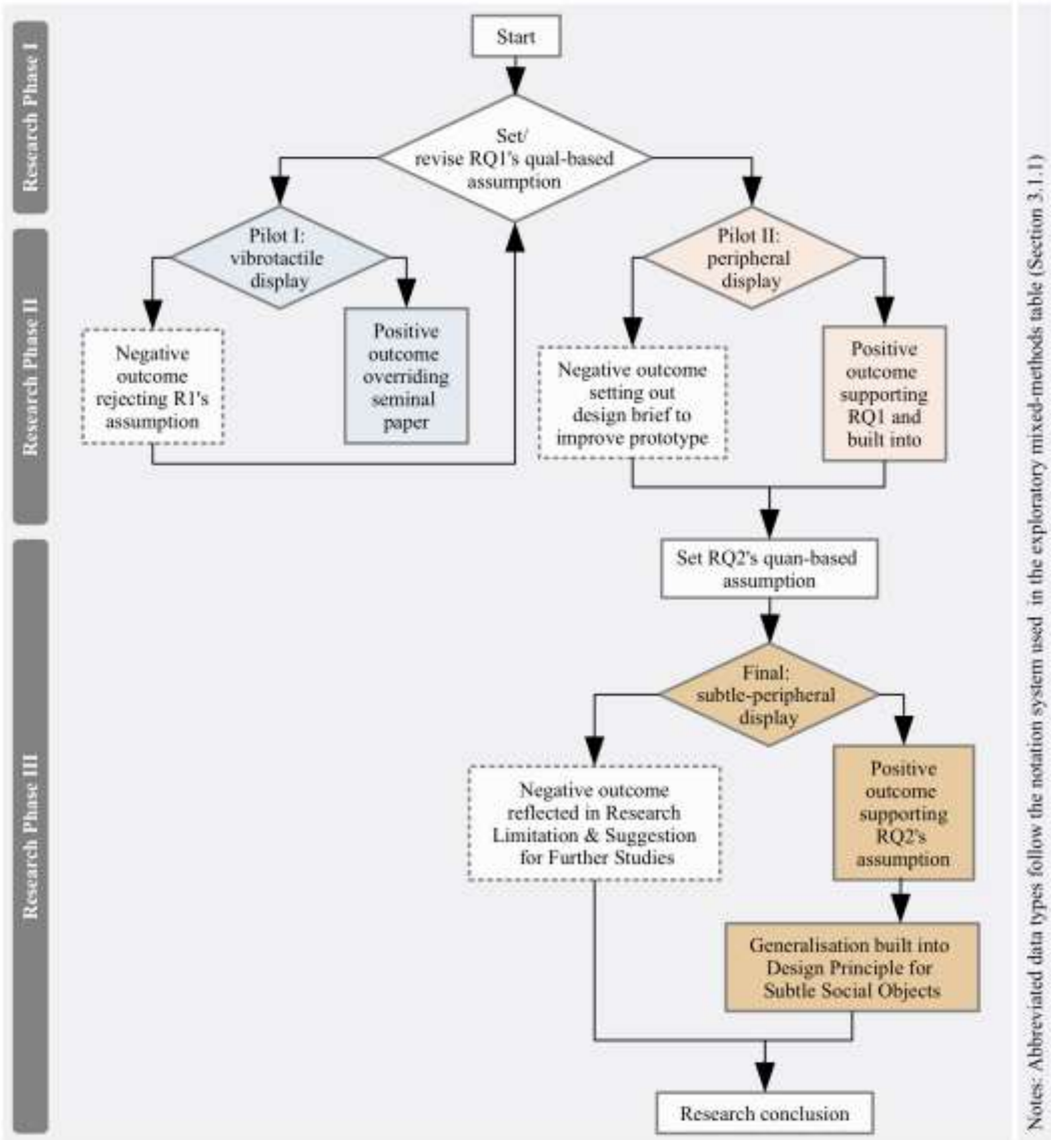

Figure 4: Flow-chart of three consecutive studies (namely Pilot I, Pilot II, and Final) with knowledge built and transferred from the setting and revising both central research questions to the generalisation of research outcome towards the building a design principle for subtle technology

3.2.Samples, Sampling Methods and Instruments

In response to the RQs and processing the studies' goals, this research required a combination of qualitative and quantitative data to define what makes a computation-mediated social object subtle when in use, and how might that lead socially anxious users to more effective social behaviour and rewarding experiences as opposed to using a non-subtle social technology. In order to build such knowledge, it requires an investigation into the impact subtle technology may have to change the social behaviour and experience of the user. These samples are posited to acknowledge the diversity of the selected population because social anxiety is perceived differently in different cultures (section 1.1.1). Accordingly, all of the samples fed into the case studies were drawn from members (e.g., researchers, academic staff and students (main population) of University of London institutions. The convenience of this site is that the members are diverse in cultural backgrounds and, particularly in the Final study, imitate the characteristics of samples used in the seminal investigation on social anxiety conducted by Carducci and Klaphaak (1999). The representation of multiculturalism in society is an important factor for successful research regardless of quantitative and qualitative driven approaches (Allmark, 2004). These samples were gathered in three different stages associated with the stand-alone case studies (Table 3). Below we look into the principles behind these samples and selection methods, each building on the modalities of wearable information displays used in each study.

3.2.1. Parameters Affecting Vibrotactile Perception (Pilot I Study)

The Pilot I study assessed the users' ability to sense, recognise and interpret vibrotactile information. Such perceptual abilities, according to vibrotactile-display literature (section 2.3.3), could be manipulated by various parameters of the vibrational stimuli (tactors) and techniques for forming tactograms (section 4.1.2). The vibrotactile armband prototype was used as the computer-mediated instrument for this purpose. This generated the user's information perceiving ability for sampling. These included several numerical parameters (section 4.1.2) assessed through a closed-end questionnaire during the study. Since developing vibrotactile displays is subject to many technical challenges, the assessment of samples was conducted using six expert reviewers recruited from members whose research or practice were based in fields of electronic engineering or computer science and who were familiar with vibrotactile technology.

3.2.2. Attention to Peripheral-visual Social Cues (Pilot II Study)

The Pilot II study assessed whether and how a peripheral visual display can present social cues to the peripheral attention of shy users. Literature on low attention-demand technology (section 2.3.2) imparts many techniques to facilitate interaction models and displays without interfering with the ongoing social activity. Shy people are known to lack conversation content and the courage to start a conversation (section 2.1.1). The peripheral display on the shirt front was to provide social cues 'useful' to generate conversation between a pair of wearers while its operation technique initialises the physical and social connection between strangers. Hence their social behaviour and meeting experience could be observed. The collection methods for these samples were made through an ambient video-audio recording placed some distance in the background, and a post-test open-ended questionnaire. These methods were chosen with regards to two research emphases. One is the social nature of participants who are concerned with anonymity and prone to interaction anxiety (section 2.1.1). Another is the interaction model of peripheral displays that does not compete for user attention but allows the ongoing primary activity to continue uninterrupted while assisting the user to pursuit the motif and enhance the experience of performing the main task (section 2.3.2). Since this study was the first to validate the Icebreaker model for shy people (section 3.3.1), 11 shy participants were recruited through London Universities' emailing lists. Embedded in the recruiting email inviting shy people to participate was a pre-test questionnaire to assess the degree of social anxiety in the respondents. The open and closed-end questions gathered the respondents' demographic and social profiles, and interests – necessary for constructing the social cues used in the testing procedure.

3.2.3. Advantages of Subtle Social Cues (Final Study)

The Final study was set to measure the extent to which the subtle social cues were better at facilitating social interaction and improving social experience between users who are socially anxious and unfamiliar to one another. To proceed this aim, samples were specified around a number of common social behavioural traits of socially anxious users and their grading of social experience while using the subtle (Social Badge) and non-subtle (Social Card) socialising tools. Such quantitative and qualitative data can be analysed and interpreted in comparison under key criteria, such as the differences in the extents of awareness, usefulness and satisfaction while using each tool. Additional to this design thinking is the challenge of peripheral-display evaluation in general, given that the technology is designed to reside in the user periphery. However, samples relating to user awareness are subtle and nuanced; prior evaluation administrators often have to interrupt their participants midway in order to assess and collect such samples. This, in turn, directs the focal attention to the technology itself. To overcome this challenge, these samples were collected in a less intrusive way. This was enabled by the design of the test event simulating a speed-dating situation, where meetings are set in rounds. The interval periods between these rounds provided the researcher with opportunities to collect these samples in ways acceptable to the already performed task (section 2.3.2) and social convention (section 2.3.3) of the event. Hence, these samples were collected during the testing period. Other samples relating to user usefulness and satisfaction were less challenging to collect because they are secondary user experience, which can be graded and summarised at the end of the meeting event.

The collection of data during and after the test was made by using questionnaires, although video-audio recording of user behaviour was a debatable choice to be used. The recording could potentially eliminate the need of the during-test questionnaires but Pilot II study showed that people prone to social anxiety, seemed to find this intrusive and in conflict with their preference for anonymity (section 2.1.2). Another consideration was the quality of records that can be influenced by the Hawthorne Effect (Oswald, Sherratt, & Smith, 2014). This has been recognised as interpretation bias in behavioural social sciences research (Bramel & Friend, 1981; Chiesa & Hobbs, 2008; McCambridge, Witton, & Elbourne, 2014) due to participants' awareness of the fact that they are being monitored.

Shyness itself is also a factor in compromising the number of samples collected in Pilot II study as there were some no-show participants at the test event. This was posited to be affected partly by scoping the sample selection within the shy population and by labelling the prospective recruits 'shy' in the email invitation (section 5.1.2). Respectively, the selected population in the Final study was targeted by an email inviting people who sometimes experienced interaction anxiety when encountering strangers in social situations. The email was embedded with a pre-test questionnaire containing demographics, social profile and preferences, and Social Interaction Anxiety Scale (SIAS) questions (Mattick & Clarke, 1998). This method allowed for *purposive sampling* (Bloomberg & Volpe, 2012); once the respondents met the SIAS criteria, they were examined (based on demographics and social profiles) whether they were familiar with the others. Finally, nine socially anxious participants, 'strangers' to the others, were selected. Their social profiles and preferences were used to configure the social cues used in the test procedure.

Table 3: Sample types and data collection methods including required population in three separated studies

Study	Data Type	Sampling Methods	Sampling Time/ Purpose of Use	Population/ Selection
Pilot I	Quan	Closed-end questionnaire (QA)	During test/ Tech configuration (for QA completion) and quan analysis for further tech development	Researchers and practitioners in electronic engineering and computer science departments/ Experts in vibrotactile displays
Pilot II	QUAL + quan	Closed-end and opened-end QA consisting: a) closed-end questions (with additional comment fields*) about social profiles and preferences b) 5-point Likert ShyQ** questions	Pre test/ Qual and quan configuration for test procedure	Universities of London members/ Shy members
	QUAL + quan	Video-audio records of actions and body language	During test/ Qual and quan analysis and interpretation for further tech improvement	
	Qual	Closed-end QA (with additional comment fields*)	Post test/ Qual analysis and interpretation	
Final	QUAL + quan	Closed-end and opened-end QA consisting: a) closed-end questions (with additional comment fields*) about social profiles and preferences b) 5-point Likert SIAS*** questions	Pre test/ Qual and quan configuration for test procedure, qual analysis and interpretation	Queen Mary University of London members/ Socially anxious members
	Quan	Closed-end QA	During test/ Quan analysis and interpretation	
	QUAN + qual	Closed-end QA (with additional comment fields*)	Post test/ Quan analysis and interpretation to be integrated with qual data and refined for generalisation of design principle	

Notes: All abbreviated data types follow the notation system used in the exploratory mixed-methods table (Section 3.1.1); * To allow respondents to provide deeper information (e.g., feelings, attitudes, and/or their understanding of the subject); ** Shyness Questionnaire (Bortnik, Henderson, & Zimbardo, 2002); and *** Social Interaction Anxiety Scale (Mattick & Clarke, 1998).

3.3. Conceptual Instruments

Apart from the computation-embedded instruments (namely Vibrosign armband, Icebreaker T-shirt and Icebreaker Jacket) used to elicit the phenomena to be sampled, the research also required foundational tools to conceptualise behaviour and characteristics of the instruments. These tools informed the design of the systems, interaction models and user interfaces and the investigation of user's needs and natural ways of interacting with technology and other users in an instinctive manner. Such system qualities are important in this thesis specifically to address the limitations of shy people's social skills, which derives mainly from their cognitive-behavioural capacity being (over)stretched when dealing with the demands of social interaction (section 2.1.1). Respectively, this led the researcher to adopt an HCI natural approach to designing social technology for the prospective user (section 2.2.3).

An HCI perspective, *Applied User Psychology* or known as *User Psychology* (Moran, 1981), was fundamental for implementing the natural approach to solving the issue. This perspective is a branch of applied sciences that serves computer system design. In general, applied science perspectives are concerned with 'bending' user behaviour to fit the designer needs and hence system tasks. These systems are thus designed with technology-driven assumptions, such as a belief that 'users can adapt' to whatever the system is built to do (Oviatt, 2006). In contrast, User Psychology prioritise on adjusting system behaviour to the nature of user behaviour, as Moran (1981) demonstrated. The cognitive aspects of the user as obligatory design factors, with a system performance standardised to reliably assure user satisfaction during and after use.

In this research, a User Psychology perspective is applied throughout the system design processes to accommodate the needs and behaviour of socially anxious users. It provided a logical structure for a systematic enquiry – from witnessing the complicated interaction between the expressions of social anxiety and social technology through the user's cognitive behavioural views, to approaching the problem with an unobtrusive theme of computer-mediated artefacts and user-centred designs of technology and other research components and activities. Results of this application are seen the founding of two conceptual tools.

One is in the Icebreaker Cognitive-Behavioural model for designing social assistive systems for shy people. Its four components partly play a role in promoting a more constructive kind of social behaviour concerning the limited cognitive resource and cognitive-behavioural nature of the user. Together these components form a sequence of design building blocks for how the system features and responses should be constructed to divert user attention from unconstructive social elements towards the useful resource that might lead the user to a more rewarding social outcome than what they normally experience.

Another is in the Design Principle for a Subtle Social Object for shy users (section 3.3.2). The 'social object' features as the key component of the aforementioned model (section 3.3.1) – meaning that the User Psychology perspective is primarily applied in composing the design principle. At this point, the perspective already provided that cognitive burden forms the basis of the unconstructive social behaviour of the user. In this regard, Alben's (1996) criteria for designing 'qualities of experience' is partly applied in the foundational criterion of the design principle. Oviatt's (2006) model of natural user behaviour of user interfaces is partly applied to its other criteria that work together to minimise the cognitive demands of the technology. As such, the system 'can be designed more intuitive, easier to learn, and … effectively free up [users'] mental resources for performing better while also remain more attuned to the world around them' (Oviatt, 2006, p. 871).

Described in the following subsections are detailed components of the icebreaking model (section 3.3.1) and the social object design principle (section 3.3.2).

3.3.1. Icebreaker Cognitive-Behavioural Model

For shy people participating in a social situation, initiating and maintaining conversation are the most common barriers to overcome (section 2.1.1). Fear of negative responses from conversation partners is an underlying cause of these difficulties. The fear triggers a *vicious cycle* that causes individuals to process their 'self' as the social object (Clark-Wells and Rapee-Heimberg models). This 'self-processing' predisposes the individuals to excessive self-awareness and threat-hypervigilance. Subsequently, these unconstructive cognitive behaviours deflect their attention away from the social situation and distort their perception of social encounters as difficult to manage. The longer this negative loop repeats itself, the greater the tendency is for the individual to appear quiet and timid when meeting an unfamiliar person. This appearance, in turn, can cause the social atmosphere to become 'frozen' and uninviting space.

In order to break the ice with a computation-embedded artefact, this research took the Clark-Wells and Rapee-Heimberg social anxiety models as references to form the Icebreaker Cognitive-Behavioural model of social technology. Processing the self is addressed in both references as the psychological key that feeds and maintains other social anxiety components. Respectively, the Icebreaker model was constructed to seize this unconstructive behaviour by amplifying constructive elements within the social context. Its central component: 'Processing of "Multi-self" as a Social Object', was designed to attract the user attention while providing useful cognitive and conversational resources. Taking the role of an augmented social cue, this key component feeds back and forth to the other components and is expected to trigger the targeted component: 'Initiating and Maintaining Conversation with the Other'. The simple logic of the model is to appropriate the user focus for improving social behaviour and experience. Presented in the following diagram (Figure 5) are the relationships amongst its four components illustrated with arrows, while dotted lines indicate possible scenarios where some components can be bypassed. Next, we look into the design thinking of each component and how its role can have a psychological impact on users' social performance in a situation implemented with the Icebreaking model.

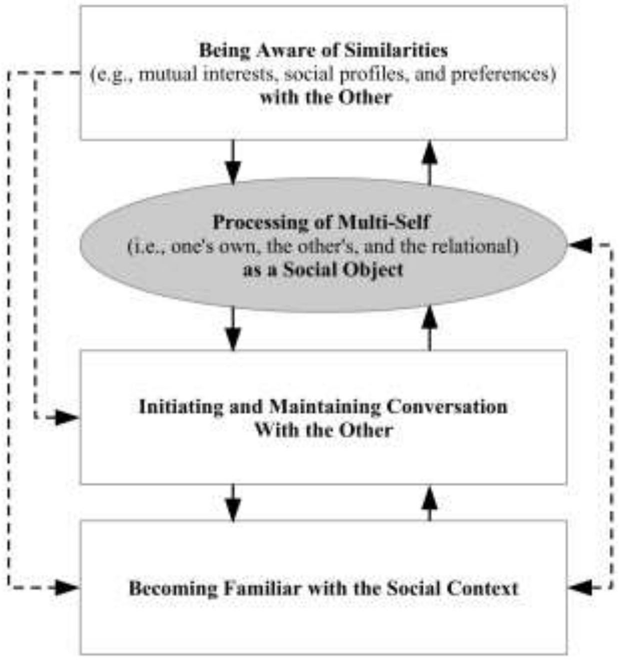

Figure 5: Icebreaker Cognitive-Behavioural model for facilitating face-to-face interaction in a computer-mediated environment in which an augmented social cue is presented

Being Aware of Similarities

This component addresses the importance of knowledge relating to the common information users share. On entering the social situation, users have to be informed of having social profiles and preferences in common, to some extent, with the others. This information can be on mutual interests or compatibilities that suit the user's case scenario given that unfamiliarity with other people and situations contributes to social fear. Hence, similarity of personal preferences is a potential source of empathy among strangers (Batson, Lishner, & Cook, 2005) and can promote engagement in real-time social contact (Kytö & McGookin, 2017a). When the similarity reflects mutual interests, it can generate appreciation between strangers by promoting the belief that 'the other is similar to oneself, which makes it easier to imagine liking the other' (Reis, Maniaci, Caprariello, Eastwick, & Finkel, 2011, p. 557). Under these circumstances, conversing with another person becomes easier; attraction reportedly increases satisfaction during a personal interaction. Although some researchers do not agree with these views (Finkel et al., 2015), some others (Mayer, Hiltz, & Jones, 2015, p. 547) have shown that similarity is an important criterion and is widely used in successful social-initiatory applications to introduce a stranger to another.

This model is designed as suitable for research taking randomised-controlled trials (RCTs); there exist the possibility of users lacking commonalities with the others. If that happens – no similarities appear across the users' existing profiles – this model needs taking into account how people orientate themselves towards relevant aspects to sustain and manipulate everyday social situations (Svensson & Sokoler, 2008). Hence, the shared location and intention that users bring to engage in the situation already constitute similarities or shared goals among participants.

Regardless of other components of the model, making individuals aware of their similarities primarily set out a positive atmosphere. This in turn assists in diverting the user's attention away from self-processing in indirect ways, as shown in dotted and solid lines of the diagram (Figure 5).

Processing of 'Multi-Self' as a *Social Object*

This component is crucial to shifting the user attention away from the self- and threat-monitoring towards the central elements of the social context, namely the other person and their immediate relationship. The shift can be strengthened by augmenting the aforementioned similarities in an incomplete form of social cues. So that it creates an interpretative gap leading to an intimate relationship to unfold between the user and the Icebreaker computer system (section 2.1.2). Processing ambiguous social cues may not entirely eliminate users' self-awareness, but certainly promotes their construction of relational knowledge, such as the current condition of the user herself, the other person and how these conditions are related. This is the point where processing of multi-self takes place.

Illustrated as dotted lines in the diagrammatic model (Figure 5), there exist exceptional cases for which the social cues may be bypassed. These depend on the degree of social anxiety the users have. One case is concerned with users like the shy, who can enter a social situation as 'forced extroverts' (Carducci & Klaphaak, 1999). These users have an existing desire to engage in a conversation and they may do so by bypassing the processing of augmented social cues. The other cases pertain to users with a more severe form of social anxiety. For them, knowing that they have something in common with another may not lead them to think about what constitutes the similarity. In other words, they may maintain being excessively self-aware and/or searching for threatening cues in the environment. What these exceptions suggest is that augmenting social cues does not guarantee an immediate conversation among the users. However, they are unquestionably becoming more familiar with the social context and are psychologically invited to initiate a conversation. This, in a way, subtly increases their chance of talking or leads them to consider processing the social cues.

Regardless of these cases, the augmentation of social cues already caters for the user's psychological needs. Whether the cue can become a tool for breaking the ice can be influenced by how its information display is implemented with certain qualities and characteristics of social objects (section 2.1.2). So that it is suitable to attract the users' attention; provides them with restricted 'rights' to begin a conversation (Sacks, 1992, p. 256); and eases the fear and cognitive-behavioural prevalence that maintain the *vicious cycle*. Although this topic will be further discussed as part of the design principle for subtle social objects (section 3.3.2), it is important to note that, because of the user's psychological nature, cognitive overload is a prevalent feature for these users during social interaction. Providing social cues in an abstract form are likely to facilitate the *pre-attentive* processing of information and to accelerate *ensemble coding* in the information perceptual process (section 2.3.2).

Initiating and Maintaining Conversations

Users initiating and maintaining a conversation with the other are the expected outcome of mediating the Icebreaker model and its computational artefact in a social environment.

This conversation, in one way, can happen as a direct result of either the users 'Processing of Multi-self as a Social Object' or 'Becoming Familiar with the Social Context'. In another, it can be prompted by the users 'Being Aware of the Similarities with the Other'.

Such variety of pathways entails different degrees of immediacy in the conversation making, which lies in the user ability and intention to socialise. Those with sufficient intention, as mentioned above, may immediately force themselves to do so. Others who are more reluctant, may need time to familiarise themselves with the social context, while those whose attention has been diverted to processing the relational self may start talking out of curiosity, sparked by the abstract information conveyed in the augmented social cues. Together with the given cues, their thoughts become the material for co-founding conversation topics. This reflects the model's character, exploiting the user's existing needs and strengthening their cognitive-behavioural ability to utilise such conversation resources but not encouraging dependency on technology use.

Owing to the nature of their cognitive behaviour (section 2.1.1), socially anxious people tend to interpret unclear or ambiguous signals negatively (Clark & Beck, 2010a; MacLeod & Rutherford, 2004; Miers et al., 2014). This derived a concern on using abstract and incomplete information encapsulated in the social cue. Although HCI, interaction design and contemporary art literature demonstrate various tactics to craft and utilise ambiguity as a design resource for generating user engagement with computer-mediated artefacts and environment (section 2.1.2), there is a lack of literature directly informing the benefits of ambiguity in engaging users with social anxiety. Nonetheless, Carducci's (2000) survey revealed the compensation techniques used by shy people to overcome social barriers. In that, 91% of respondents tried, at least once, acting more socially confident than they actually felt. This suggests that the shy and those with mild social anxiety are likely to make further effort when given an interpretative cue to initiate a conversation. This assumption was validated in the Pilot II study (the key research activity set to verify this Icebreaker model) and confirmed with richer results in the Final study of this research.

Becoming Familiar with Social Context

Familiarity is an important factor in creating a promising environment for social interaction. This component is the bottom line of the Icebreaker model, drawn on the concept of a *familiar* stranger – an individual who associates with another through the regular sharing of a common physical space (Milgram, 1977). Although their relationship may never rise to direct interaction, having knowledge of their routine association can produce a sense of comfort and reduce anxiety among strangers (Paulos & Goodman, 2004). In addition, personality and social psychology literature showed that similarities between these people contribute to the sense of physical ease, security and inclusion in face-to-face interaction (Reis et al., 2011).

Along these lines, socially anxious people are likely to feel less threatened while sharing a social space implemented with the Icebreaker model. Its available social cues provide mutual knowledge that leads the users to share an intention and negotiate their needs during the progression of their relationship. In this sense, the social relationship is rapidly established as a feeling of being included, hence familiarity is built up through both the conversation and other social routines. With this sense of familiarity, either the person converses more or thinks more about the relational self, whichever direction dissimilates their focal attention away from the self and towards the useful elements required for maintaining social routines. As a result, the social situation is perceived as attainable and manageable.

3.3.2. Subtle-Social Objects Design Principle

The aforementioned augmented social cue operates on multiple roles to improve the social interaction of socially anxious users. As a psychological assistant, it decentralises the user's attention away from the self-awareness and threat-vigilance. As a cognitive aid, it offloads the users' internal computational processes (Card, Mackinlay, & Ben Shneiderman, 1999a; Larkin & Simon, 1987); externalising information about social cues to support rational thinking (Bertin, 1983). As a socialising tool, it provides a resource for conversational topics and helps to break the ice. These roles of technology were designed as a direct response to the social need and nature of the user. In various ways, they make obvious the immediate relationship between the users, without demanding apparent mental load or time to comprehend the meanings of social interaction, and improve the social experience. In this respect, the augmented social cue becomes a subtle *social object* – hypothesised (RQ2) to offer greater advantages to social behaviour and experiences than regular models of social technology.

The three components in this design principle was used to formed a guideline for implementing characteristics of the system and user interfaces. These criteria were synthesised from qualitative data collected in the research Phase I that provided the theoretical background (chapter 2) for designing the computation-mediated prototypes used in the Pilot II and Final studies.

Aimed to improving the users' social behaviour and quality of their social experience, the design principle begins with the *User Insights* categorised as *needs, cognitive-behavioural predispositions,* and *preferences* (top row on Table 4). These insights become a set of required system characteristics, categorised by *benefits, features,* and *appearance and functioning behaviour* (left column on Table 4). Each mapping (grey-annotated cells on Table 4) was a result of background-knowledge synthesised with the outcome of Pilot II study; and transferred (noted with key literature excerpted from chapter 2) to set the assumption for RQ2.

Bringing these characteristics together in the user interfaces of the augmented social cue, it put the display on the role of a subtle display for facilitating social interaction for socially anxious users. At this point in the research, it was hypothesised to be superior to a non-subtle display in terms of:

- giving a 'ticket to talk' and influencing an anticipation of positive socialising outcome;
- diverting attention from negative internal (self-assessment) and external (negative response) social cues to itself;
- creating an interpretive gap or ambiguity to elicit conversation
- augmenting an instant social relationship between users.

Subsequently, it was expected to turn the user environment into an inviting collaborative space for exchanging social knowledge and meaningful interaction.

This design principle was fully implemented in the Icebreaker Jacket prototype iteratively designed with the Social Badge used in the Final study (chapter 6). The study outcome is presented in chapter 6 and reflected on as part of the research conclusion in chapter 7.

Table 4: Design Principle for Subtle Social Objects for Shy Users, organised in a 3-by-3 table mapping user insights (left column) onto system characteristics (top row). The mapping was based on theoretical background key literature excerpted from chapter 2 (grey-annotated cells).

System Characteristics \ User Insights	**Needs:** • a gentle but • highly persuasive invitation to talk • assurance for positive outcome	**Cognitive-Behavioural Predispositions:** • self-mornitoring • threat-vigilance • info overloading	**Preferences:** • low-key and low-cog actions • certain degree of anonymity • low-cog sense-making • privacy of own info
Benefits (be given): • an instant right to talk • pre-knowledge about conv partner • extended conv resource • amplified social abilities	• *Social objects* (Engeström, 2005; Knorr-Centinal, 1996, 1997, 2007; Simon, 2005) • ticket-to-talk (Goffman, 1967; Sack, 1992) • Embodied cognition (Clark, 2008; Clark & Chalmers, 1998; Kirsh, 2013)		
Features: • seize attn to itself • trigger processing of relational self • trigger joint action and social-agent role • question user-user and user-tech relationships with an interpretative gap • offload mental work		• Cognitive behaviour (Clark & Wells, 1995; Rapee & Heimberg, 1997) • Ambituity (Gaver et al., 2003; Kettley, 2005) • Relational artefacts (Engeström & Blackler, 2005; Knor-Centinal, 1996) • *we-mode* cognition (Frith, 2012) • *we space* for F2F interaction (Krueger, 2011) • Joint affordances (Gibson, 2015; Pacherie, 2013) • Shared action-space (Krueger, 2011)	
Appearance & Behaviour: • tangible and peripheral to interact with • abstract and comprehencible at subsconscious level • prompt to be thought with • socially situated and acceptable			• Transparent tech (Dourish, 2004; Clark, 2003; Norman, 1998; Weiser, 1991) • Tangible and flippable user interfaces (Clark, 2003; Dourish, 2004b; Homecker & Burr, 2006) • Natural approach to designing ubiComp tech (Dourish, 2001, 2004a) • Design frameworks for social context (Fernaeus et al., 2008; Jacob et al., 2008; Homecker & Buur, 2006) • Intuitive interaction (Blackler et al., 2006; Blackler & Popovic, 2015; Hurtienne, 2007; 2009) • *Interactional* lens and context (Dourish, 2004b; O'Hara et al., 2013) • Embodied interaction (Dourish, 1999, 2004a) • Peripheral display (Matthews et al., 2007; McCarthy et al. 2002) • Peripheral, Subtle interaction (Edge & Blackwell, 2016; Olivera et al., 2011) • Low-social weight (Toney et al., 2002)

3.4.Research Considerations

Evaluating technologies for behavioural change is challenging, particularly for technologies intended to improve the cognitive-behavioural traits of people with social anxiety. Shyness is a complex and persistent condition, with no instant remedy or quick solutions (S. Scott, 2007). As follows, three issues concerning the short-term design of experiments (DOE) were discussed along with user evaluation and data analysis (section 3.4.1). Given that the Pilot II and the Final studies entailed socially anxious participants from which the main findings of this research emerged, these studies are of special focus.

This focus also applies to the ethical concerns (section 3.4.2) of the Pilot II and Final studies involving the character traits of test participants.

3.4.1. Design-of-Experiment Concerns

Short-term Studies

The first DOE issue is concerned with the short-termed event designed for the data collection process. Had the research token a long-term field study (Rogers, 2011), its outcome could have led to a more detailed development in social behaviour in some routine use of the technology. These alternatives could also achieve a greater number of repetitive data-collection events that are commonly employed in psychotherapeutics. However, this research was not intended to *cure* shyness as outlined in the researcher intention (sections 1.2 and 2.1.1). The evaluation processes were created as instant scenarios to observe user experience and improvement in behaviour while managing the challenge of social interaction with a computerised aiding tool. Despite literature showing long-term cognitive treatments (Beidel & Turner, 2007a; Haug et al., 2000) do not guarantee an improvement in social behaviour (Clark, 2001), the technology used in the research studies was designed not require significant learning effort or long-term practice from the test participants.

Accordingly, each experiment designed for the last two studies was simulated as a non-romantic (professional) speed-dating situation where socially anxious users were encouraged to anticipate a positive socialising result, perceive their extended social capacity, and engage in an instant social experience. This design might not directly contribute to current practices in social anxiety therapy. However, following a post-positivist view, all research contributes to understanding a generally known issue (Wildemuth, 1993) – in this case, the problem that shy people have with initiating conversation with strangers.

Speed-dating was chosen as a testing event because of its many benefits to the shy user's social behaviour and the design structure of studies, particularly useful for studying the behaviour of people looking to form new relationships (Turowetz & Hollander, 2012). Other events, such as social networking, can be more complex and challenging for shy people, who hold somewhat reserved personalities. Speed-dating is rule-driven; strangers come to perform solicitation in a collaborative and orderly manner. In turn, it provides attendees with the opportunity to start interpersonal relationships at the simplest level.

For these reasons, speed-dating can serve the user's psychological needs to be invited and given 'rights' to converse with the others. Speed-dating also provides researchers with a social activity that can be used to simulate naturalistic social contexts and investigate social interaction behaviour and experience (Finkel, Eastwick, & Matthews, 2007; Turowetz & Hollander, 2012).

Data Analysis

The second issue was concerned with the post-positivist view of obtaining knowledge through a rigorous scientific method, which support the view that possibilities in obtaining biased results might occur in any study regardless of the theories they draw on (Floden, 2009). Being aware of this pitfall, 'transparent' statistics was employed in the data analysis of the Final study. This approach was also followed because of criticism regarding traditional null-hypothesis significance testing (NHST) and reporting in the HCI and psychology research communities. The purpose of 'transparent' statistics is to advance scientific knowledge through 'clear and complete knowledge' given in the research report. Hence, the representation of the Final study results is based on both NHST and practical significance statistical (PST) methods. Whereas PST often seems 'disappointingly complex, […] in transparent statistics the quest for scientific truth prevails' (Kay, Haroz, Guha, & Dragicevic, 2016, p. 2) over the 'aesthetic criteria of novelty' (Giner-Sorolla, 2012, p. 567). The generalisation of test results is mainly based on PST. Nonetheless, the required NHST processes and results are reported and discussed as thoroughly as possible. Regarding the value of *direct replication* in psychological experiments (Simons, 2014), other researchers who wish to repeat the studies or validate the analysis can refer to the details of the employed statistical methods, particularly of the Final study (chapter 6).

The outcome of NHSTs often yielded large *p*-values owing to the small-sized samples (Coe, 2002; Ferguson, 2009; Sullivan & Feinn, 2012), indicating non-significant results. This reflects a long-standing statistical debate on interpreting *p*-values in research. Like other scholars who criticised the approach of arbitrarily standardising of .05 significance level (95% confidence interval), Cohen (1994), like Tukey (1991, p. 100) who demonstrated that 'the effects of A and B [...] are always different – for some decimal place'. His view was consistent with that of Rosnow and (1989, p. 1277), who stated that 'surely, God loves the .06 nearly as much as the .05'. Therefore, effect-size estimations (through PST) should be considered as they are not affected by the size of samples as *p*-

values are (Coe, 2002; Nakagawa & Cuthill, 2007; Sullivan & Feinn, 2012). Another benefit of effect size estimation is that it results in the direction of effects (i.e. magnitudes of difference or association). The estimation of effect sizes increases the practicality in the interpretation and comparison of test results within each analysis series, especially when aligned with Cohen's effect size benchmark (Becker, 2000; Ferguson, 2009). Accordingly, a graphical aid, forest plot, for easy comparison and interpretation of test results was generated at the completion of each analysis series in section 6.4. Substituting the traditional NHST with PST (using effect sizes with associated CIs) is a common approach to rigorous design and data analysis for small-scale experiments (Bacchetti, 2013; Bacchetti, Deeks, & McCune, 2011; Nakagawa & Cuthill, 2007)– the approach adopted in the Final study.

In all studies (chapters 4, 5, and 6), a set of empirical-studied questions was defined as an explicit guideline for assessing the relationships between independent and dependent variables of interest. What differentiates the Pilot and Final studies in this thesis is the structure of data analysis. Pilot studies, as platforms for feasibility assessment, only require descriptive data analyses. The Final study, as a platform for systematic evaluation of user feedback, required both the descriptive and inferential data analyses. The inferential statistics (in section 6.4) is structured with a set of tests of difference and tests of association (where the characteristics of datasets allow). All of the methods used in the inferential statistics are non-parametric statistical methods regarding the size and distribution of the available samples.

User Evaluation

The last DOE concern was orientated toward evaluation methods that combined usability and user-behaviour and -experience criteria in assessing the user interfaces of the Icebreaker T-shirt and Icebreaker Jacket prototypes. These technologies were intended to facilitate subtle peripheral interaction. Peripheral user interfaces are a new research field that has fewer criteria for conformity in user evaluation than traditional HCI interfaces. Many studies have employed usability tests even though they are not fully applicable (Kaye, Boehner, Laaksolahti, & Ståhl, 2007; Vermeeren et al., 2010) because they are central to accomplishing tasks that belong to the user's focal attention. Peripheral use of technology, by its definition, occurs when the user's central focus is not at its interface or operation but elsewhere – that is, engaged in the primary tasks of the ongoing activity. The interfaces are not compulsory tools to enable primary task efficiency. They simply advance the user's understanding, intention and experience of their ongoing activities (Matthews et al., 2009). From this perspective, many usability criteria (e.g. *time-efficiency* or *error rate*) were not suitable for assessing the developed technology. When introducing an additional artefact into an environment that users already find challenging, it is important that they feel it is worthwhile to expend additional effort to cope with the situation. This addresses the need to apply certain usability criteria to the user-experience evaluation. Possible criteria include *usefulness*, *learnability* and *user satisfaction*, which were therefore significant aspects for the user evaluation of this research, particularly in the Final study.

Another widely adopted usability assessment is the heuristic evaluation by experts (Lewis, Polson, Wharton, & Rieman, 1990; Nielsen, 1992). This approach is known to be one of the most effective methods for uncovering many design problems (Novick & Hollingsed, 2007). It can be used when other resources – such as time, budget, participants and prototypes – are limited. However, this method does not provide samples from 'real' users (as seen in the samples collected in the Pilot I study). One might argue that results from other widely used methods, such as RCTs, also yield a possibility of not deriving from real users due to the nature of randomisation.

Here it is arguable that expert evaluation methods are highly suitable for assessing ambient-peripheral displays, especially for subtle user interfaces (Olivera et al., 2014). However, this reasoning is not always valid. Exceptions occur when dealing with restrictions inherited from design goals, such as improving user experience and assisting people with cognitive (Li, Lu, & McDonald-Maier, 2015) or visual (Blasco, Marco, Casas, Cirujano, & Picking, 2014) impairments. Another exception is specific to special study treatments for user behaviour and personality, namely the shy trait. These unique characteristics are not always apparent to experts in the field. Assessments of user experience by real users also pose disadvantages, particularly when the design goals are heavily focused on the novelty of technology. This emphasis often results in users showing excessive interest in the appearance and operation of the display, rather than focusing on how it fulfils their needs, its impact on their perceptions (Mankoff et al., 2003), or their experiences while using it (Vermeeren et al., 2010).

It is questionable that this research while investigating behaviour change, it should entail user experience studies. It is important to stress that user experience in this research is not simply limited to user feeling or impression on engaging with a socio-technological embedded context. Instead, by ‘experience’, it means the quality of experience (Alben, 1996, p. 11):

> ***all the aspects of how people use [the technology]: the way it feels in their hands, how well they understand how it works, how they feel about it while they’re using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it. If these experiences are engaging and productive, then people value them.***

This definition is consistent with Nigel Bevan’s (2009) argument that experience-based evaluation criteria (e.g., *user preferences*, *psychological impact*, *satisfaction*) were unavoidable components to be investigated – they allowed for examining how the system affected user behaviour while interacting with the display system and after use.

3.4.2. Ethical Concerns

Social anxiety in some cultures put the person in a socially vulnerable role (section 1.1). The evaluation processes in the 2nd Pilot and Final studies involved direct interactions between the researcher and socially anxious participants. Two main questions emerged during the evaluation process regarding the following concerns.

Behavioural change

Is it politically correct to attempt improving someone's behaviour? Social anxiety is known to pose several negative effects to the social experience of shy people and others who encounter people who suffer from this form of anxiety. Therefore, the recruits who had experienced social anxiety (required in Pilot II and Final studies) were advised on the nature of the study and had to express their intention to participate in the experiment. In addition, all recruits were informed to be given opportunities to try out a new artefact aimed at improving social interaction.

Stressful Situation

Is it morally correct to expose socially anxious people to strangers? This can be unethical on face value but becomes less of a concern when considering that the recruits accepted invitations to the event on condition that they were to be given multiple chances to meet new people who had similar social profiles and interests. It follows that the event might have increased negative feelings and it was therefore important to explain the event beforehand to all recruits and that they had to express their willingness to participate in consent forms. Furthermore, the test environment and procedure were arranged in a well organised manner and the recruits were treated with commonly understood boundaries, such as privacy, anonymity and time. They were also given the unconditional option to withdraw from the test event at any time should they so wish. Regardless of the Queen Mary Research Ethics Committee approval, this consideration is based on the fundamental principle for the UK code of ethical practice[30] and researcher's personal experience of social interaction.

3.5. Summary of Research Methodology

This research adopted an exploratory sequential mixed-methods approach to designing research strategies and conducting activities throughout. Its three distinct phases allow an investigation into the impact of a non-existing tool on a prevailing problem, namely subtle technology for shy users, to be speculated, implemented and reported in an informative way. Its emphasis on the qualitative at the beginning was useful to the *exploration* phase (I); making it possible to identify a research gap in the HCI natural approach relevant to the needs and limitations of the marginalised user of current social technology. It also equipped the researcher with knowledge of how the possibilities of computer-mediated tools can be applied in the *development* phase (II). This middle phase generated qualitative and quantitative outcome crucial to forming the research assumption for a subtle technology. Such knowledge enabled the researcher to iterate the design of the technology and collect richer quantitative-based data in the *generalisation* phase (III). Within this last phase, several hypotheses were tested on the advantages of subtle technology over non-subtle. This led to a refinement of the design principle for novel social technology to encourage socially anxious users to improve social interaction in non-intrusive ways. Several research challenges occurred mostly in phases II and III involving the development, evaluation and improvement of novel instruments. These activities required extended time and effort to expand skills in technical development and data analysis in particular; careful ethical dealing with the limited number and sensitive character of the test participants. Details of these challenges and techniques used to overcome such difficulties are described in chapters 4, 5, and 6. It is then reflected on in the closing discussion of this thesis (chapter 7).

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[30] Refer to the National Counselling Society's approach to ethical issues: https://www.nationalcounsellingsociety.org/about-us/code-of-ethics/ Retrieved: October 9, 2018.

Phase II

Chapter Four

4. Possibilities of Vibrotactile Display for Implicit Cueing (Pilot I Study)

The covert nature of vibrotactile modality makes it a favourable candidate for presenting secret social cues to shy users (section 2.3.3). This study, as stated in the Methodology chapter (section 3.1.2), was initially set up to examine two research purposes: one to assess the quantitative parameters important for a wearable vibrotactile display conveying private information, and another to facilitate social interaction of the prospective users, namely to implement the Icebreaker model. Vibrosign armband was configured as a computation-embedded instrument to serve the first purpose. A Quantitative-based questionnaire was used for the usability assessment conducted with six experts in the field of vibrotactile user interfaces. The results showed some possibilities of the technology to deliver various tactograms. However, some restrictions appeared to outweigh the potential benefits due to placing greater demands on the cognitive resources of shy users during social situations (section 2.1.1). Hence, it was deemed not worthwhile to investigate the second purpose. Nonetheless, findings from this small-scale feasibility test yielded new knowledge about vibrational parameters for improving user perception of tactograms and skin sensitivity of the upper arm, broadening vibrotactile interface literature. This chapter is organised in three main parts. It begins with the required tools and methods for the study including the design of the experiment. Next, it presents the results of data collection and analysis before concluding with a justification of the study outcome.

4.1. Study Tools and Methods

4.1.1. Development of Vibrosign Armband

Design Rationale

The tactile sense is one of the richest human communication channels (Choi & Kuchenbecker, 2012, p. 2093) but less exploited in interface design (Hoggan, 2013; van Erp, 2002) for social interaction, given that the skin is the private property of the communicator. About 70% of information we perceive in an interpersonal environment is made up of visual and auditory; sight and hearing are thus overused compared to the tactile sense that provides only 21% of social information (Riener & Ferscha, 2008). In addition to the low-key interaction model (section 2.2.3), there has been evidence showing that vibrotactile displays can be computerised to convey information in ways to reduce cognitive load (Choi & Kuchenbecker, 2012, p. 2093). Drawing on the embodied views of cognition (section 2.2.1), the sense of touch is the earliest form of perception, action and reasoning for constructing an *enactive* experience (Gillespie & O'Modhrain, 2011). Vibrotactile interfaces are hence natural and intuitive to use (Choi & Kuchenbecker, 2012, p. 2093) while supporting subtle and private forms of information (Costanza, Inverso, Allen, & Maes, 2007) in situations in which high-demand cognitive or visual signals might cause overload (Brewster & Brown, 2004; Hoggan, 2013). For these reasons, a vibrotactile display was posited to benefit shy people who seek privacy and avoid disclosing their information. Thus, this display modality was implemented in the design of Vibrosign armband, a wearable computer-mediated display for providing information to aid shy users in social situations.

Design Goals

Vibrosign armband was initially planned to be used as an augmented social notification in a face-to-face social networking event implemented with an indoor wireless body-area network (WBAN) system. The system was intended to steer a shy user to a friendly zone in the test event. It was intended to be a technical aid to ease shy users into a social situation when meeting with strangers, and to be implemented according to the Icebreaker model (section 3.3.1).

Based on the design principle for subtle social objects (section 3.3.2), the armband would have given implicit and private social cues unobtrusively. Its main functionalities were conceptualised to covertly:

- locate and steer users to a friendly zone consisting of people with the same interests and compatible social preferences. The user was presented with letter (alphabetical) and graphic styles of tactograms, namely left, right, forward and backwards.
- inform the social compatibility level (1 to 5) between the user and the closest person, using 1-dimensional force feedback of vibration.
- inform the user of detailed compatibility (namely categories of mutual interest) using five tactograms: F for film genre, H for hobbies, M for music genre, N for novel genre, and S for sports.

Given that this study was designed as a feasibility testing of the technical aspects – that is, the robustness of wireless communication and the effectiveness of tactor's (miniature vibratory motor) parameters used to generate tactograms. The overall goal of this study was therefore to verify usability of the technology and users' ability to recognise and interpret the vibrotactile messaging stimuli.

Development and Outcome

In order to serve the aforementioned design intention, Vibrosign armband (Figure 6) was configured as a covert notification tool worn on the right upper-arm – a relatively popular body site employed in wearable tactile research (section 2.3.3) and away from the user's sightline and the onlookers' observation. The development of its user interface and system logistics were informed by the reviewed vibrotactile literature (section 2.3.3) and synthesised towards the outcome of the development process, discussed in more detail in the next section.

Figure 6: Vibrosign armband prototype and controlled application were tested by visitors in a demonstration session at the Tangible, Embedded and Embodied Interactions conference in 2013 (left and top-right); vibrotactile interface of Vibrosign, showing nine tactors arranged in a 3-by-3 grid display.

User Interface and System Operation

Vibrosign was capable of providing navigational cues, degree of users' social compatibility, and conversational topics. Its display interface was embedded with an array of nine tactors organised in a 3-by-3 spatial arrangement. All tactors were 8-mm pancake-style shaftless DC actuators (3.7V. rating), commonly used in wearable vibrotactile applications (Van Der Linden, Schoonderwaldt, & Bird, 2009). Each was driven by a pulse width modulation (PWM) channel of a ATmega328 IC in an Arduino Pro Mini, a compact and versatile 32-kilobyte microcontroller with adequate output channels for the intended use of this research. Although its PWM frequency and amplitude cannot be directly modified, it was possible to generate specific amounts of supply voltage using a duty cycle adjustment technique. This allowed for generating various levels of activation intensities.

A wide selection of tactors was available in the market at the time when the Vibrosign prototype was developed (see Choi & Kuchenbecker, 2012 for further details), the 8-mm actuators were chosen for two reasons. The first was to keep the display dimension as small as possible while retaining a high-performance level of vibrotactile stimuli. Although no prior studies had explored 2-dimensional vibrotactile displays for the upper arm, the literature suggested that a small contact area for stimuli could cause more vibratory strain on the skin receptor than a larger area (Phillips & Johnson, 1981). The minimum area of display achieved in the final prototype was 94-by-94 mm. The second reason was to improve vibrotactile acuity of the upper arm, aiming to minimise the known two-point discrimination thresholds reported in prior studies. Weinstein (1968) reported ~45 mm as an average two-point discrimination distance for static stimuli tested on the underside of the upper arm (Weinstein, 1968). Cholewiak and Collins (2003) suggested 50 mm for vibratory stimuli tested on the same body area.

Figure 7: Material and configuration of Vibrotactile armband prototype. Tactors (8-by-4.3 mm) mounted on 1-by-100-by-100 mm acrylic supports, with Velcro sheets, to optimise the resonating force on the skin contact area (top left); Vibrosign system circuit (bottom left); an early prototype of armband base with Velcro stripes for experimenting with two-point discrimination threshold (middle); and tactors positioned 35 mm apart from the centre-point of each other (right).

Following these design considerations, an early version of the Vibrosign prototype (Figure 7) was designed with all tactors positioned along Velcro strips sewn onto the internal side of the armband. With the advance of hardware and a fixed 500 Hertz frequency, this system can discriminate a 35-mm distant threshold – a much shorter distant achieved by Weinstein (1968). Its intensity and pulse duration can be customised through a system controller application to provide tactile sensations according to each user's preference.

System Controller

As it was intended for use in a local WBAN social networking system, the armband (Figure 8) was implemented with a low-power RN-42 Bluetooth module, ready to communicate with a smartphone or local computer. The Vibrosign controller application was developed using the Armarino API for Android platform. It allowed the armband to be controlled by an android phone application over a serial communication protocol. The controller was able to operate two modes of stimuli: tracing mode and static mode, by sending a series of 10-string characters: mode, duty cycle rate, pulse duration and ON-OFF state for all nine tactors.

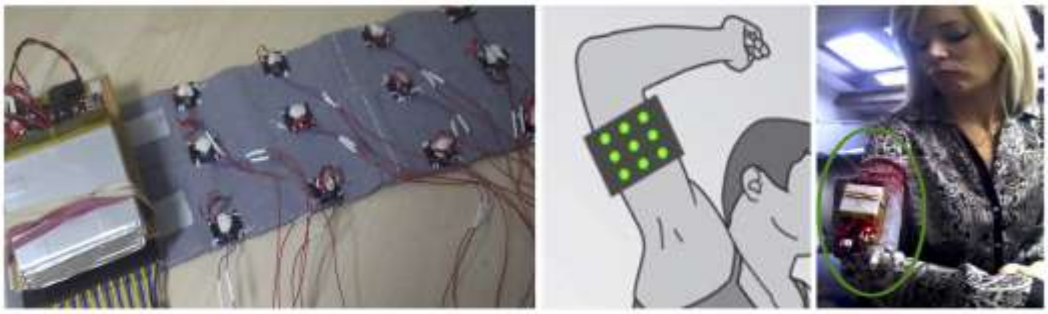

Figure 8: Internal side of Vibrosign armband prototype with 3-by-3 tactor array embedded (left); diagram of all tactors positioned on the underside of upper arm (centre); and a test participant wearing the armband with main circuit fastened on the outer side (right).

Summary of Development Outcome

Through this development, the final version of the Vibrosign armband was able to generate two modes of deictic and alphanumeric tactograms. These had a customisable activating intensity and pulse duration at 500 Hertz and a ~35 mm two-point discrimination threshold.

4.1.2. Experimental Design

Participants

Six right-handed researchers and practitioners in vibrotactile displays participated in this pilot study. Five people were computer science researchers from Queen Mary University of London and one was an R&D staff from the research laboratory at Lean Mean Fighting Machine, the co-funder of this part of the project. These test participants were aged between 22 and 45 years, two of which were women and four were men.

A question regarding the ‘small’ number of test participant arose, given that this was a quantitative-based study. However, these participants had reasonable knowledge and skills in vibrotactile interfaces with two having had experience with complex-vibrotactile applications. The others had varying levels of vibrotactile experience, ranging from the development of gamification controllers to end-user experience in haptic notification features.

Samples and Methods

To assess the capacity of the armband in the delivery of intended social cues (section 4.1.1) and to observe user experience, the assessment focused mainly on the two parameters shown in Table 5 included in a during-test questionnaire.

Table 5: List of variables, test and analysis methods for Pilot I study

Variables	Test methods	Analysis methods
User preference on vibrotactile activating intensity and duration of a single tactor	Thinking-aloud protocol (Dumas & Fox, 2012)	Quantitative
Accuracy of user perception of each tactogram	Comparisons between user response and a research facilitator's record	Quantitative

Testing Tools

Three main testing tools were used in the experiment: a Vibrosign armband, a wireless controller software installed in an Android phone, and a quantitative-based questionnaire.

Setup

The testing environment varied according to what was practical for the participants. Most locations were in a busy office environment with between 6 and 24 staff moving around according to their office routines. The testing area was situated mostly in a corner of each office. This uncontrolled condition gave some benefits to the test because at a real social networking event, visual and sound signals are difficult to control.

Test Procedure

Participants were informed that the purpose of the experiment was to assess how accurately they could recognise vibrotactile cues, with limited experience of using the Vibrosign armband. Each participant was required to wear an armband on the right upper arm, with the vibrotactile display area facing the inside of the arm. Vibrotactile literature suggested (section 2.3.3) the inside arm to be less hairy and therefor more sensitive to vibrotactile stimuli than the outer arm (Cholewiak & Collins, 2003; Cholewiak, Brill, & Schwab, 2004; Mahns et al., 2006; Sofia & Jones, 2013). Next, the participant was presented with visual representations of 11 tactograms: two deictic symbols (namely left arrow and right arrow) in tracing mode; two letters (L and R) in static mode[31]; and seven letters (F, H, L, M, N, R and S) in tracing mode. Regarding the differences in modes of stimuli and numbers of required tactors and inter-pulses, the creation of these tactograms were varied in durations (Table 6), ranging from 500 ms (e.g., static L and R) to ~5300 ms (e.g., tracing H and S).

Table 6: Duration of stimuli for each of 11 tactograms under the default configuration parameters, namely pulse duration of 500 ms and inter-pulses length of 100 ms

Tactograms	Modes of Stimuli	Durations (~ms)
Left arrow	Tracing	1700
Right arrow	Tracing	1700
Letter L	Static	500
Letter R	Static	500
Letter F	Tracing	4700
Letter H	Tracing	5300
Letter L	Tracing	2900
Letter M	Tracing	4100
Letter N	Tracing	4100
Letter R	Tracing	4100
Letter S	Tracing	5300

Visual representations of these tactograms (Figure 9, Figure 10) were used as training material and also eased the participant's memory of tactograms. They helped the participant to understand how the letter tactograms were orientated along the upper arm and mapped on the 3-by-3 grid-like display area of the armband.

[31] Other letters (e.g., F, H, M, N and S) were not rendered in static mode. Several pre-test results obtained during the development stage (prior to the evaluation) suggested poor recognition rates for static letter tactograms. Hence, static letters L and R were anticipated to draw low recognition rates. Nonetheless, they were selected for this evaluation process only by reason for comparing the advantages (if there were any) of deictic (left arrow and right arrow) over letter tactograms for navigation cueing.

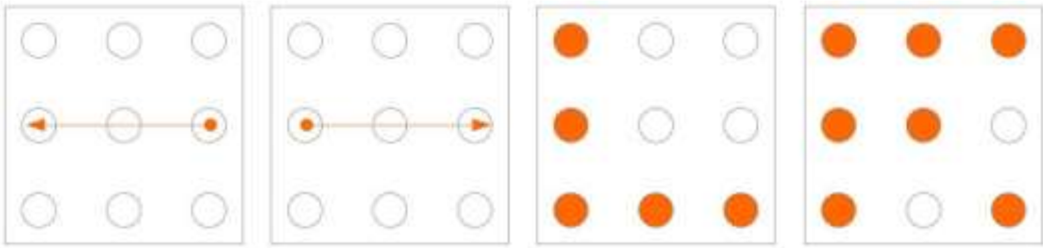

Figure 9: Visual representation of two deictic tactograms. Left and right arrows operated in tracing mode, and two letter tactograms (L and R) operated in static mode.

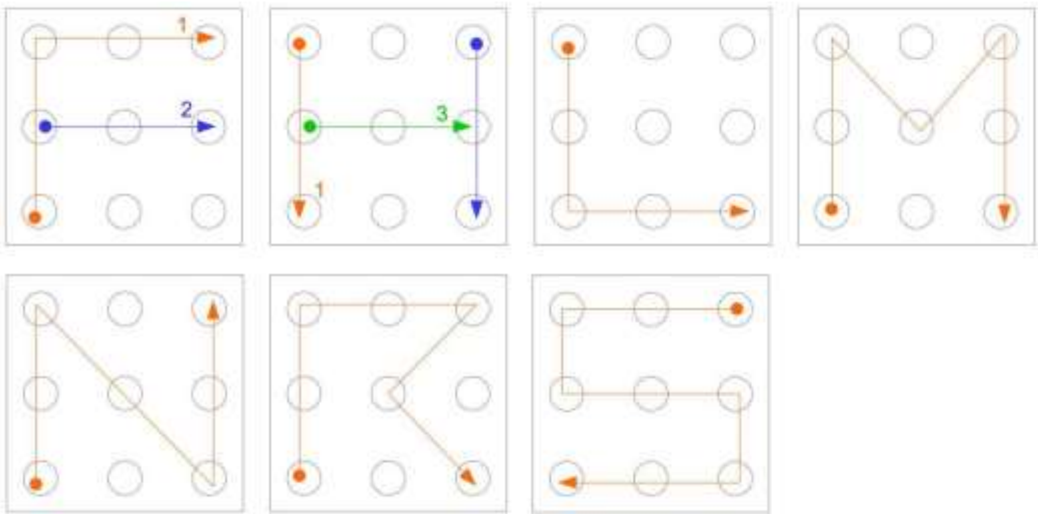

Figure 10: Visual representation of seven letter tactograms operated in tracing mode (F, H, L, M, N, R, S). The first two tactograms were traced with a pen-writing style in which round marks denoted 'pen down' and arrow ends denoted 'pen up'.

The testing process was separated into three parts, as follows:

- Assessment of user preference of the intensity and duration of stimuli, for which three levels of intensity and three lengths of duration were applied to the skin. The preferred level and duration were recorded for later uses on the rest of the experiment tasks. The inter-pulse duration was set as 100 ms throughout the experiment. This part took between 7 and 15 minutes, varying from one participant to another.
- A short training session for all tactograms used in tracing mode, operating at the participant's preferred intensity. The tactograms L and R were also operated in static mode. Each participant was given a maximum of 20 minutes of training time.

- Accuracy testing for all tactograms. Certain letter tactograms (F and H) were generated with a combination of tracing mode and pen-style tactor sequencing due to their complexity. All tactograms were operated once, after the participant had been instructed to respond as quickly as possible.

4.1.3. Empirical Questions

Three empirical questions were set for the test experiment. They were as follows.

- Can spatial acuity of the upper arm be improved – to be less than the ~46 mm two-point discrimination threshold presented in prior studies? (e.g. Cholewiak & Collins, 2003). If so, what is the minimum distance?
- Between deictic (graphic icons) and letter tactograms, which is the most efficient for directional cueing?
- Is the 3-by-3 tactor array adequate for conveying complex tactograms, such as the letters F and H?
- What average pulse intensity and duration are suitable for conveying both types of tactograms?

4.1.4. Instrument for Data Collection

A *during-test* questionnaire with three open-ended and 10 closed questions and answers (QAs) was used to collect quantitative data. QA1-2 captured basic demographic information. QA3-4 concerned user preferences for vibration intensity and pulse duration. QA5 assessed the user's ability to recognise the number of pulses activate on a single tactor; this information can be useful to determine social compatibility. QA6-7 compared the effectiveness of deictic tactograms (operating in tracing mode) and letter tactograms (operating in static mode) for conveying directional cueing. The static mode of stimuli was used to check the possibility of reducing messaging time. The remaining questions assessed user ability to recognise letter tactograms (F, H, L, M, N, R, S) which can be used to convey information about users' similar interests. The during-test questionnaire can be found in Appendix A.2.

4.2.Data Analysis and Results

This section presents a descriptive analysis of user preferences for the intensity and duration of stimuli, and the ability to recognise deictic and letter messages displayed on the vibrotactile interface of the armband. The discussion follows the order of aspects of concern, as presented above in the empirical questions (section 4.1.2), and the order of questions in the questionnaire.

4.2.1. Spatial Acuity, Vibrotactile Intensity and Duration

Regarding the success of the armband development, its final prototype was configured with ~35 mm distance on the low-resolution 3-by-3 tactor array. This prototype assisted the participants in recognising different positions of activating tactors throughout the testing process. This finding showed the potential of a ~35-mm two-point discrimination threshold for the right upper arm, a significant improvement over previously reported result (Cholewiak & Collins, 2003). For user preferences for the activating intensity of stimuli, the case summary in Table 7 shows all participants preferred the level 3 intensity.

Table 7: Case summary for Vibrosign armband test

		User ID	Age	Gender	Preferred intensity level (% duty cycle)	Preferred pulse duration (ms)	Accuracy of pulse number recognition
	1	1	28	Female	3 (100%)	500	Correct
	2	2	45	Female	3 (100%)	500	Correct
	3	3	31	Female	3 (100%)	1000	Correct
	4	4	39	Male	3 (100%)	500	Correct
	5	5	26	Female	3 (100%)	500	Correct
	6	6	22	Male	3 (100%)	1000	Correct
Total	N	6	6	6	6	6	6
	Minimum	1	22	Female	100	500	Correct
	Maximum	6	45	Male	100	1000	Correct
	Median		29.5		100	500	
	Variance		74.167		0	66666.667	

This finding suggests that the 100% PWM duty cycle that draws 3.3-V supply was the most suitable intensity for this configuration of vibrotactile display. The accuracy rates for tactogram recognition varied according to the length of pulse duration. Most participants preferred a 500 ms pulse length. However, it is worth noting that participants who preferred a 1000 ms duration achieved higher accuracy scores for recognising both deictic messages and letters. Nonetheless, all participants could accurately tell the number of pulses generated on a single tactor, with either 500-ms or 1000-ms pulse duration in combination with 100 ms inter-pulse duration.

4.2.2. Deictic Versus Letter Tactograms for Directional Cueing

This assessment was conducted to compare user recognition of directional cueing, between the deictic type (left and right arrows) operating in tracing mode[32] versus letter types (L and R letters) operating in static mode of stimuli[33]. Each type was generated once in a sequence of four random tactograms, after which the participant drew the sequence on the questionnaire. Similar to the deictic tactograms (left and right arrows), the letter L was recognised relatively fast with an accuracy rate of 66.66% (*N=12*). In contrast, users showed difficulty and hesitation in recognising the orientation and number of tactors for representing the letter R. Some participants drew it in the correct orientation, while others drew an upended 'R' (Figure 11). The results showed an accuracy of less than 16.66% (*N=12*) in the user responses (Figure 12).

Figure 11: A drawing of letter R recognised as an upside-down orientation

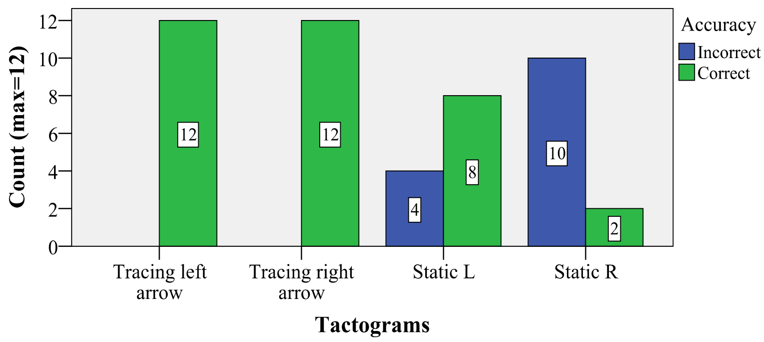

Figure 12: Recognition on tracing deictic and static letter tactograms for directional cueing messages.

User recognition of letter L was speculated as influenced by the small number of required tactors and their positions that made up this tactogram. They were easily distinguishable, unlike those of letter R. Repetition of stimuli, longer training sessions, and a change in operating mode (from static to tracing) might help to improve the recognition of letter R. The latter suggestion derives from the study record of user recognition rates for the letter

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[32] The static mode of arrow tactograms cannot convey the sense of direction, due to the physical configuration of the tactor array.
[33] See Appendix A.1 for tactograms used in this assessment, including the activating tactor positions marked in sequences.

R when operating in tracing mode (see section 4.2.3). The interpretation of deictic tactograms is generally less challenging than those of letters, due to the level of complexity in sensing tactor parameters. The outcome of the comparison for deictic versus letter tactograms in directional cueing suggests that the former is superior; they are more intuitive to recognise, require fewer tactors in stimuli, and need less training time.

4.2.3. Recognition of Letter Tactograms

In the last part of the tactogram recognition assessment, the participant was presented with seven letters (F, H, L, M, N, R, S) one at a time. Each was operated once in tracing mode, after which the participant immediately matched the tactogram from a set of answer choices (See Appendix A.2 for detail). The accuracy varied, with 100% *(N=6)* for L and N; 83.33% *(N=6)* for M; 66.67% *(N=6)* for H, R and S; and 50% *(N=6)* for F. Unsurprisingly, these results (Figure 13) suggest that simple letter tactograms were more accurately recognised than complex ones, on the low-resolution display (3-by-3 tactor array). However, in a more general scenario where the use of complex letter tactograms is unavoidable, expansion of the tactor array – such as a 4-by-4 arrangement – is likely to improve user recognition. The letter R operating in tracing mode achieved better accuracy than when it was operated in static mode (16.66%). This finding implies that tracing mode used with this configuration was more efficient than static mode.

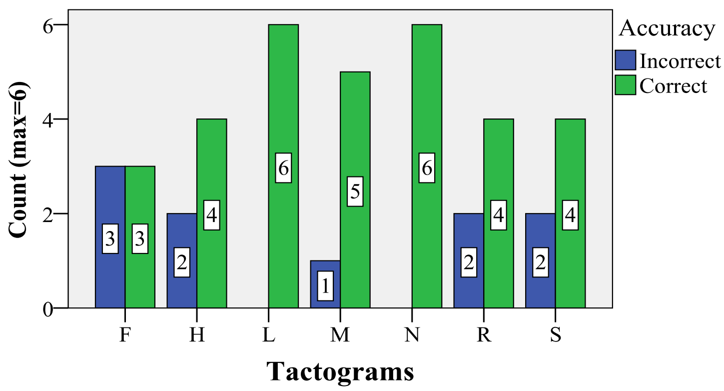


Figure 13: Recognition on seven tracing letter tactograms

4.3. Justification of Main Findings

The initial purpose of this study was to analyse the efficiency of a vibrotactile interface to deliver a certain detail of social cues. However, the study outcome indicated that this was perhaps not the main issue, because participants could accurately perceive certain low-resolution symbols used as test tactograms. The actual disadvantage was mainly related to user experience and practical issues described below.

Time and mental effort required for learning and practice:

- In the experiment, two modes of vibration were tested: static (all required tactors were vibrated at once) and tracing (one-by-one tactors to create a cutaneous-rabbit effect) (Choi & Kuchenbecker, 2012, p. 3). The tracing mode achieved greater accuracy of responses but required longer creation times.
- Test results suggested some degree of impracticality for larger studies where more complex tactograms may be used. Although the tactile sense is intuitive and certain tactograms – such as the deictic type – were recognised instantly, others proved to be more challenging. While the static mode of letter tactograms was difficult to recognise, particularly complex letters such as H and R, it is true that user recognition could be improved by rendering the tactograms in the tracing mode and providing the user with more training sessions. However, doing so will require more learning time, as well as practice and mental effort. There was a concern that these disadvantages of the tracing stimuli would become more apparent if the application were to be implemented with the original plan to associate each letter with a category of the users' mutual interests (section 4.1.1). We concluded that providing more detailed information in the social cues would require additional practice and working memory to process the information which was counterproductive to the original idea of reducing cognitive effort.
- Some drawbacks for user experience were noted. The time required for system operation and user interpretation of tactograms could lead the user to experience quiet moments in social situations. Shy people already exhibit reserved personality traits, and the delays could hinder their efforts at social interaction.

Intrusiveness to physical and social experience of shy users:

- The activation intensity of tactors was required to reach a certain level for the user to be aware of and accurately recognise the tactogram. If the armband were to be used in further studies in which a social situation is simulated, this technical requirement could be a significant distraction to user attention. Shy users are prone to cognitive overload and being distracted by a bodily sensation could compound the problem.

- Regarding the shy user's reserved personality, if this interface were to be incorporated into a local social networking system, where co-location property is a criterion to encourage interaction among strangers, the shy user might find this difficult to navigate. The co-location property does not entail an explicit form of user intention (Lawrence & Payne, 2004) and taking an active role to prompt an interaction may not be favourable to shy users.

Customisation:

- Everyone has different preferences for vibratory intensity and levels of comfort in fitting, meaning that each armband must be calibrated before use. This will be cost ineffective and time-consuming for production of prototypes in the testing process, if further studies are performed.

The outcome of this study suggested the vibrotactile approach in this context as not being suitable for providing information to shy users. It also put forward the idea of providing less detailed information in the social cues. However, the result of its technical development extends the vibrotactile literature relating to the acuity for the upper arm site. The extensive experimentation of the required hardware made it possible to override the highly cited two-point discrimination threshold (section 2.3.3) which contributes to the vibrotactile research community.

Chapter Five

5. Capacity of Peripheral-Visual Cues to Support Social Interaction (Pilot II Study)

Peripheral displays and interaction models of computer-mediated artefacts are known to effectively facilitate subconscious operation in the user (section 2.3.2). Given that the outcome of the prior study (chapter 4) suggested shifting away from the implicit cueing of the vibrotactile approach, the concept of peripheral displays became a more viable approach to support the social interaction of shy people with visual cues. Taking the new approach, this study was designed to investigate the potential of a mutual social cue and its peripheral interaction model when formed into a social object (SO) in regards to the first central research question. The Icebreaker T-shirt (IBT) prototype was developed for this purpose, with a frontal display to inform the wearers of their social compatibility while avoiding disruption to their ongoing social interaction. This prototype was used as a computation-mediated instrument to elicit the study samples in a simulated professional speed-dating situation where the proposed Icebreaker model (section 3.3.1) was implemented. Eleven shy users participated in a mixed-method evaluation process that formed a feasibility assessment of usability and preliminary investigation on user experience in a computation-aided social environment. An audio-video recording of their meeting with strangers provided some evidence to validate the Icebreaker model in improving users' social behaviour and experience. Also, user feedback collected through a *post-test* questionnaire showed that 72.73% of the participants felt IBT was helpful to the first-time meeting with people they were not familiar with.

Nonetheless, the study outcome raised some administrative concerns in working with shy people and indicated some deficiencies of the low-fidelity prototype. This demonstrated the need for improving the strategy for recruitment and iterative design of a more refined quality of the technology in a further study (chapter 6). This chapter is organised in three main parts. It begins with the design and development of study tools including detailed methods used to conduct the experiment. Next, it provides results from a descriptive analysis of both qualitative and quantitative data, generalised in the last section.

5.1. Study Tools and Methods

5.1.1. Development of Icebreaker T-shirt

Design Rationale

Shy people tend to endure cognitive overload and low-key interaction when participating in social situations. The aim for reducing mental load and apparent physical demand of social technology, hence, remained central to the research theme, despite a change in the design direction of the display modality. Further research into the natural approach to designing technology (sections 2.2.2 and 2.3.4) indicated that, by residing in the user background and prioritising the foreground activity (section 2.3.2), a peripheral-visual display could convey information to the periphery – unobtrusive to the users' social cognition and experience.

The social construction of peripheral displays builds on their capacity to provide information in a cognitively lightweight manner, not competing with the joint activity for the users' focal attention. In particular, when designed deliberately with ambiguity about the hidden or unknown commonalities they share with one another and/or with the social context (section 2.1.2), peripheral displays can act as an icebreaker between strangers (e.g. Chen & Abouzied, 2016; Howell et al., 2016; Kytö & McGookin, 2017b; 2017a; Schellekens et al., 2015), promote mutual understanding and facilitate the interpersonal engagement (section 2.3.2). Such ambiguity is commonly represented with low-resolution but highly relational information to the co-users. The cited works in conjunction with the generalisation of the prior study's outcome (section 4.3), caused the researcher to reconsider the idea of reducing the extent of social-cue detail.

Lacking conversation topics is a common challenge for shy people engaging in social situations. On the one hand, it is arguable that providing information-rich social cues – such as those specific compatibility criteria initially planned for the previous study (section 4.1.1) – could provide richer relational resource and increase the opportunity to break the ice. On the other, it could influence reliance on technology and narrow down the conversation topics. To this end, the researcher argues that providing less detailed social cues does not necessarily reduce the opportunity to start conversing. In contrast, it could enrich the role of the *epistemic object* in the cueing display. When the cue is presented with incomplete information, as the literature suggests (section 2.1.2), the interpretation gap can turn the display into a *social object* that augments the rapid relationship between the users and between the user and the social context.

A social object can hold various qualities namely, *personal*, *provocative*, *relational* and *active* (section 2.1.2), all of which can act as an icebreaker between strangers. It does so by asserting itself as an attentional buffer and thus reducing interactional stress. However, shy people have an exceptional degree of psychological tension when encountering strangers. A question specific to this is: which qualities are suitable for designing such a social object and how they can contribute to alleviate the stressful situation. These qualities are further discussed and weighed up in summaries below.

- *Personal* quality of a SO leverages the intimate experience of individuals to create a temporarily close association. This quality would not be suitable for shy people because their excessive self-focus can compromise the awareness of the other person. To engage shy people with the *personal* quality of a SO are likely to encourage them to look inward, promoting self-focus.
- *Provocative* quality makes the concept, embodied in a SO, vivid in the individual user's mind. Without a tangible form (e.g., visual, sound or smell), it can occupy users' attention and draw out their verbal response. This quality would not be suitable for shy people who are unlikely to foresee the positive possibility of joint action. Such users need greater affirmation and a more obvious 'licence' to talk. Engaging shy people without all parties recognising that they all are invited to take part in the conversation would create less assured reactions from all parties.
- *Relational* quality turns a tangible object in a shared environment into an *epistemic* object. Such an object has a question-generating nature and encourages mutual interpretation of the relationship between co-users. *Relational* quality

would be a crucial aspect of SOs for shy people given that it continually exhibits the 'demand character' that requires two or more people to participate. This character should remind the users of what are missing to maintain productive social interaction, hence encourage them to take a more active role in conversation making.

- *Active* quality of SOs can draw immediate attention and reactions from people while turning their co-presence into an active social space. Shy people tend to be occupied by self- and threat-monitoring; this dynamic quality is useful to seize their focus as long as the SO does not hold the user's attention for too long and in an aggressive fashion.

Accordingly, the two suitable SO qualities (*relational* and subdued *active*), if brought together to create an interactive peripheral social display, would make the display a SO that reveals relational information between the users subtly and dynamically. Subsequently, it should draw their attention and influence a conversation without overburdening their effort to focus on and to maintain the interactional routine.

Design Goals

Built on the above design thinking – together with the success of social-proximity applications to promote social awareness of co-located users (section 2.1.2) and the concept of SOs to ease the initial contact between strangers – the goal of this study was to develop a peripheral social display for shy users. In that, it was aimed to facilitate the *Processing of Multi-Self* – the key component of Icebreaker model (section 3.3.1) – in the users, and hence leading them to initiate and maintain a conversation with others in the environment where the model is implemented. As such, this study was conducted to validate its primary goal, the Icebreaker model. Following up on this goal was a conceptualisation of a wearable computer-mediated tool with novel user interfaces to mutually:

- draw the attention of wearers to its social display
- inform the wearers of their compatibility level without requiring their focal demand to trigger and comprehend

Its secondary goals were to test the feasibility of operational practices of working with shy people, to assess the practicalities and limitations of hardware and computation configuration, and to observe the shy-user social behaviour and experience compared to when they did not use any social aid.

Development and Outcome

In order to create the technology above, IBT (Figure 14) was developed with a peripheral display embedded on the frontal area to provide a visual cue that initiated conversation between shy wearers without interfering with their interaction routine. Implementing subtle SO design principles (section 3.3.2) to its user interfaces, the shirt was configured to augment relational information between the wearers after they shook hands. Below discussion presents the design choices and detailed development of two main elements, namely display and sensing, that enabled the IBT to achieve this goal.

Figure 14: Two volunteers are wearing IBT prototypes, with the peripheral social display inlaid in the frontal area to reveal their compatibility after shaking hands.

Peripheral Display as an Augmented Social Cue

Regarding the implementation of the Icebreaker model, users' social profile, mutual interests and associated preferences were used to pre-construct the social compatibility scores and draw up an abstract visual form presented in the IBT's peripheral display. The display on wearer A's shirt provided the cue to wearer B and vice versa. This means that the compatibility display presented on both shirts can be different, depending on how much one person's profile (e.g., age, gender, academic background) matched another's preference (e.g., age, gender, and academic background) and the correspondence between the entertaining interests (e.g., movie, music, literature, and hobby) they both had (Table 8).

This design choice of information content was the resource for establishing the first component of the Icebreaker model ‘Being Aware of Similarities with the Other’. In this respect, the display operated at conceptual and activity levels. At the conceptual level, its compatibility content embodied the cooperation between the wearers. They participated in the same social activity and had evidence of their similar interests and shared social presence augmented. The information on compatibility was presented with ambiguity, triggering the operation at the activity level by representing the information in ways that supported quick reasoning and mental imagining processes, without requiring much effort. This operation was enabled by two metaphorical mappings to enable intuitive application of social knowledge (section 2.3.1). One was the mapping between user input (handshake) and system response, discussed in the following subsection (‘Social context’). Another was the mapping between the compatibility levels on an animated graphic representation of up-down metaphors. Informed by the concept of *pre-attentive* visual features for peripheral attention (section 2.3.2), the mapping was incorporated with the psychological functioning of colours (Elliot, 2015), such as the use of cool and warm coloured round shapes overlaid and arranged on a vertical line to mimic a meter-like symbol. The coolest colour, purple, was at the bottom of the display area and the warmest (red) at the top. The technique for changing the colour and position of coloured strips was informed by the concept of visuospatial mapping (Hegarty & Stull, 2012; Tversky, Zacks, Lee, & Heiser, 2000) discussed in section 2.3.1. It implicates the changing degrees of social compatibility, ranging from 0 to 5 (see Table 8 for mapping rules and pseudo code). Conveying the social compatibility in this way facilitated *ensemble coding* within the user’s internal processing (Alvarez, 2011; Alvarez & Oliva, 2008; Healey & Enns, 2012). The level of compatibility could be perceived instantly and without paying detailed attention to the display.

Table 8: Configuration rules for social compatibility level, including the software’s design background and pseudo code

Background	There is a maximum of five compatibility levels that each wearer could score. It describes how much one wearer (A) was compatible with another wearer (B) level soon after they shook hands. Each wearer was given a compatibility base level of 1, given that they both came to participate in the same event, appeared in the same location and had the same intention, namely meeting someone new. The four other possible levels then came from the matching

	algorithm between the wearers' data that was collected through the pre-test questionnaire.
Rules	There are two categories of user data used in the matching process. The 'synchrony' category contains four demographic items: age, gender, academic level and the subject of study/research/work. The 'likeness' category contains four entertainment items: movie genres, music genres, literature genres, and hobby types. A simple 'binary' algorithm was used to match two users' information at a time. Given below is the pseudo code showing the structure and calculation rules of the matching process.

Pseudo code	//
	// Clear up the previous raw compatible //
	// score and retrieve users' information //
	//
	Set raw compatible score to 0
	Retrieve eight items of my and my partner' dataset from Progmem storage
	
	//
	// Calculate four raw scores of synchrony //
	///
	Do my age range falls into the age groups of the person you like to meet?
	if so, add 1 to my raw compatible score
	else, do nothing
	Do my gender falls into the gender groups of the person you like to meet?
	if so, add 1 …
	…
	…
	
	//
	// Calculate 4 raw scores of likeness //
	//
	Are there any matches between our favourite movie genres?
	if so, add 1 to my raw compatible score
	else, do nothing
	Are there any matches between our favourite music genres?
	if so, add 1 …
	…
	…
	
	//
	// Calculate an average value of the raw compatible score //
	//
	Divide my raw compatible score by 8
	
	//
	// Round off the average compatible score //
	///
	Assess whether the first digit after the decimal point is equal or greater than 5
	if so, round up
	else, round down
	Assign the rounded score to my compatibility level
	
	//
	// Prepare final compatibility level //
	///

	Add the base level 1 to my compatibility level *Return my final compatibility level*

Figure 15: Material and technique used in building soft-circuit display: 12–14 Ω /foot conductive threads (left) acted as heat carrier to strips of 31°C black thermochromic paints (centre), applied over strips of coloured textile paints (right) sewn on the frontal area of IBT.

As the display was intended to inform but not overwhelm, it was given a dynamic behaviour toggling between ‘idle’ and ‘subtle notification’ modes (Figure 16). This characteristic was enabled by a soft-circuit display, made with thermochroic paints and conductive threads, sewn on the shirt-front (Figure 15, right-handed frame). The display rested in the user’s background attention field in idle mode, with content strips remaining black (Figure 15, centre frame). In the subtle notification mode, the black content strips gradually changed (within ~2 seconds at between ~16 to ~18°C room temperature) to various colours (purple, blue, green, yellow and red) after the wearer shook hands with another user. The warmer coloured content strips corresponded to higher compatibility levels.

Figure 16: A demonstration of prototypes of IBT, showing the display in idle (left) and subtle notification (right) modes.

Handshake as Subtle Input for User Interaction

To facilitate the shy users' natural interaction in a social context, the handshaking input was conceptualised through the interactional lens (section 2.2.2) of embodied interaction approach (Dourish, 2004b). It adopted the reality-based interaction (Jacob et al., 2008) and the tangible interaction (Hornecker & Buur, 2006), the handshake facilitates both the user's physical and social experience while engaging with the IBT technology. At the same time, the ideal-shift framework (Fernaeus et al., 2008) is useful to the design steps and allows for viewing the handshaking mechanisms and user interface from a users' perspective. In this regard, it has to be accepted without giving it much thought when pursuing the motif of a specific activity where it is used and as such, it can be 'easily' adopted. Designing technology to support such a view means that its manifestation must not add to the complexity of the task other than to achieving robustness and accuracy. The technology should not impose on the user's physical, cognitive and social contexts. Operating it must be simple or invisible to the conscious awareness, becoming intuitive or 'transparent in skilled use' (Clark, 2003, p. 45). When technology 'disappears' in this way, the user is free to use it without thinking about the 'how-to' (Weiser, 1991), enabling the focus on a more relevant goal in the environment. This handshake gesture was chosen as the sole input to support an implicit form of a user command to create and update the display content on their IBTs. Its operation was embedded seamlessly in both social and physical contexts of the users' ongoing activity, discussed below with some technical challenges.

Social Context

In a scenario where strangers get acquainted, the act of hand gestural input upon the display of the technology is not only disguised as a social routine. It is also used as a way to promote familiarity with the social situation, e.g. making non-verbal communication through physical and eye contact (K. Viney & Viney, 1996), and as means for metaphorical mapping (Antle, Corness, & Droumeva, 2009a; 2009b; Antle, Corness, Bakker, Droumeva, Van Den Hoven, & Bevans, 2009c) between user input to the system response, namely display of social compatibility. The user input, in this sense, required no more than existing social awareness and skills. As emphasised by Jacob et al. (2008), this is one of the main aspects for designing a reality-based interaction style for *social awareness and skills design* theme that offers natural manipulation of digital content.

A handshake is a cooperative act that cannot be performed by accident; it requires two people's intention to reach out to each other, to establish physical contact and a subtle form of social negotiation (Gillespie & O'Modhrain, 2011). It allows a person to gauge another's personality and create a first impression (Chaplin, Phillips, Brown, Clanton, & Stein, 2000). It involves not only the physical and social skills of two people but also cognitive ability to manipulate and interpret the quality and results.

Physical Context

While performing the physical handshake as a social routine, the wearers also trigger the system's *secret handshake* (Ateniese et al., 2007; Cranor et al., 2011; Hou et al., 2016). The *secret handshake* incorporated a gesture recognition technique with an authentication process between radio-frequency identification (RFID) tags and readers of the two computer systems, each embedded on the users' IBTs. This allowed both systems to authenticate a connection and grant information access to one another within less than 2 seconds, hence, less than the common 5-second period of a 'social handshake' (Bernieri & Petty, 2011). This temporal constraint enabled the system handshake to operate unobtrusively to the human handshake and other social routines. By the time the wearers completed the social handshake, the display on their T-shirts had already updated the content given that this system response took only up only ~2 seconds to start, process and fully reveal the information.

The design of this action sequence relates to two notions proposed by Hornecker and Burr (2006), namely *tangible manipulation* and *embodied facilitation* design themes. For the *tangible manipulation*, handshaking input offers a lightweight interaction style. Meanings of the user interaction unfold in small steps to create the physically manipulated digital content. It allows the wearers to test their assumptions about the effect of the handshake quickly. For the embodied facilitation, various dimensions of social interaction between the wearers are enabled and affected by the objects within the subtle and implicit action. This interaction design reflects the interactional lens (section 2.2.2) in which the user's physical context cannot be separated from social settings. The exchange of information and reaching a mutual understanding of actions through shaking hands is coupled naturally through the relational behaviours that link aspects of social interaction and the constant change of computational responses.

Technical Challenge

The synchronicity of social and system handshakes was enabled by embedding an RFID system (a low-cost, low-power reader and passive tag) onto the prototype sleeve-end

(Figure 18, left-handed frame). This allowed for the identity and information of two wearers, stored in each IBT's main circuit controller (Arduino microcontroller's program memory), to be exchanged. The process is illustrated in Figure 17.

In general usage, an RFID application allows multiple tags, one at a time, to be read by a single reader – such as those used in transportation and mass-production industries. These costly and high-precision controlled technologies are unlike the wearable RFID system of the IBT, which is low-cost and available for recognising multiple tags in its vicinity of two readers' transponders at any time when the wearers shake hands. This forms a dense network that poses various data transmission issues, such as tag-tag, reader-tag, and reader-reader collisions (Figure 18, right-handed frame).

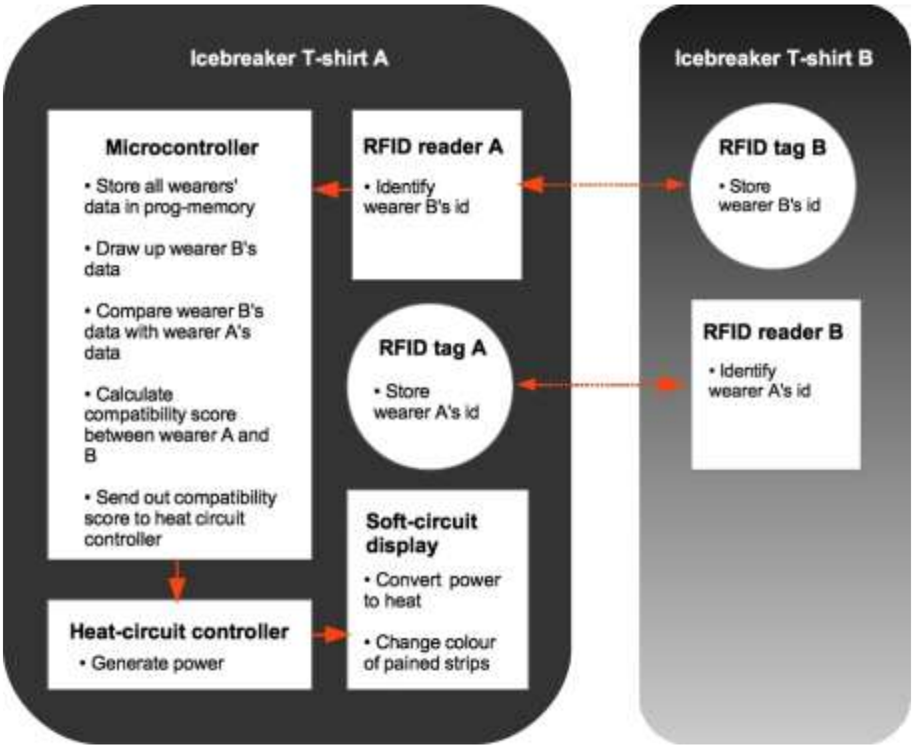


Figure 17: System diagram of IBT showing operational applications, from authentication (between two shirts) of the RFID system to updating the display content of the soft-circuit display.

Figure 18: An RFID system consisting of an ID-12 RFID reader and passive 125 kHz RFID tag, embedded on the sleeve-end of IBT prototype and wired to the main circuit controller (ATmega328 IC in Arduino Pro Mini) using conductive threads (left). When two wearers shake hands (centre), an LED glows to indicate an authentication and data-exchange process occurring. During this period, a dense RFID network (right) is formed, and tag-tag, reader-tag and reader-reader collisions are likely to happen.

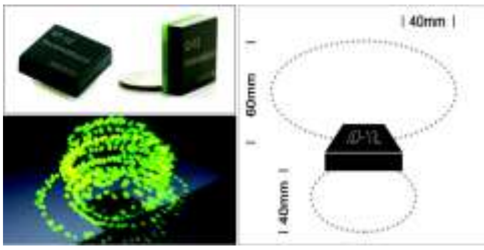


Figure 19: RFID ID-12 reader with a built-in antenna (top left); a diagram of its transponder ranges (right) reimaged based on *Immaterials: The Ghost in the Field* project (bottom-left) – a photographic sequence mapping the same RFID reader specification by Timor Arnall and Jack Schulze at Berg Studio (bottom left). Image (bottom left) retrieved on March 17, 2004, from http://voyoslo.com/projects/immaterials-ghost-in-the-field/

Several solutions appear in literature, such as the use of high-bit tags – known to be effective because they have a built-in ID-customisable circuit to perform sophisticated anti-collision techniques (Bhatt & Glover, 2006). However, the cost of these tags is relatively high compared to the employed 125-kiloHertz tag. Changing the reader's antenna load is another solution that allows for controlling the propagation amplitude and phrase of the reader (Ramakrishnan & Deavours, 2006). This method was not suited to the scenario of this study because of the many limited specifications of the employed ID-12 reader (namely built-in antenna, non-accessible firmware). The way the two RFID readers were constructed in this application meant that interference of transmission was highly probable.

Naïve protocol (Jain & Das, 2006) was employed as the method to avoid collisions by generating randomised temporal intervals between the readings and power-off positions. The probability of reader-tag and reader-reader collisions was reduced to a satisfactory level by quickly switching off the first RFID reader that has already detected the RFID tag of the second system, to allow for immediate operation of the second system.

Summary of Development Outcome

The design choices and technical implementation meant that the final rapid prototype of the IBT was able to augment a social cue on the shirt-front (Figure 20) after two wearers shook hands. Rather than giving detailed information about their social compatibility, its display content was represented in an abstract form intended to promote quick perception. The display also provided a ‘puzzle’ of compatibility to encourage conversation and familiarity with the social situation. As soon as the wearer shakes hands with a new person, its soft-circuit display updates the content in ways that do not distract from their primary activity.

The IBT strictly followed the design principles of ambient-peripheral displays (Mankoff et al., 2003; Matthews, Dey, Mankoff, Carter, & Rattenbury, 2004) to facilitate an unobtrusive form of information perception and comprehension. Users had a passive viewing position of its non-critical information display, presented to their peripheral attention. Although its operational technique required an action (handshake), this gestural input was seamlessly embedded in the social interaction routine. Without the need to learn new skills, the wearer could focus on the social situation, interlocutors and conversation content.

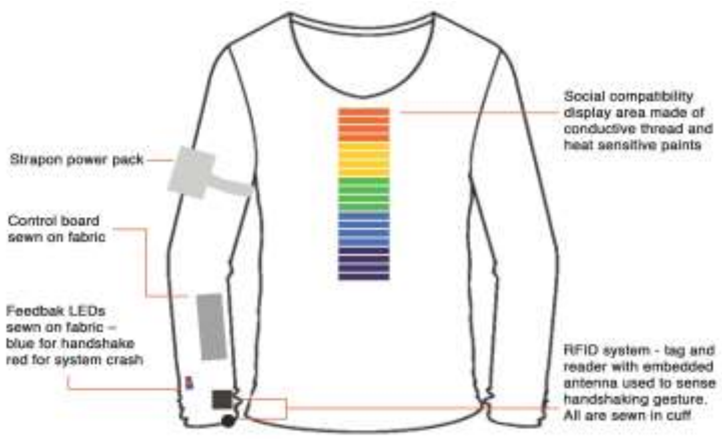


Figure 20: Drawing of Icebreaker T-shirt prototype with features demonstrated

5.1.2. Experimental Design

Participants

Eleven self-reported shy individuals participated in the study consisting of eight women and three men, aged between 21 and 42 years. Each person was unknown to the others, and they were recruited from the University of London institutes through an online questionnaire consisting of three parts (see Appendix B.1). The first and second parts asked about demographics (namely name, age, sex, and academic affiliation) and preferences (namely favourite films, music, sport, hobbies, books) of the respondents and of the people they would like to meet. The third part asked about social fitness, fears, and feelings of shame and anger when encountering strangers. It included ten 5-point Likert-scale questions, extracted from the Henderson/Zimbardo Shyness scale (ShyQ) screening tool (Bortnik, Henderson, & Zimbardo, 2002; Henderson & Zimbardo, 2009). The qualitative data from the first and second parts were used in the matching criteria for calculating social compatibility levels between each pair of participants, while the quantitative data from the third part were used to screen the degree of shyness in the respondents.

Literature has shown that people with severe social anxiety and distress tend to prefer solitary, non-social settings and activities, and that they avoid social situations that have perceived adverse outcomes (Henderson & Zimbardo, 1998). In this regard, special care was taken with the online invitation to recruit shy participants who would be willing to be filmed during the study. The invitation was written in a polite but direct tone, with extensive information and explanation of the aims of the test.

The invitation received 19 responses. Only 16 were chosen; they had answered ‘often’, ‘very’ or ‘extremely’ to the question: *I find myself unable to enter new social situations without fearing rejection or not being noticed*. This first criterion ensured that the IBT was tested by people who, to some degree, had social anxiety. Two people had answered ‘not at all’ to this question, while another was familiar with some respondents beforehand and this would have invalidated the first-time face-to-face meeting environment. Please note the number of test participants was reduced from 16 to 11, due to some participants not turning up on the test date.

Samples and Methods

The handshaking operation technique of IBT was designed applying the intuitive use of technology concept (section 2.3.1) and peripheral interaction models (section 2.3.2) into a social situation. This user input was not distracting the user interaction throughout the ongoing situation nor competing with focal attention on bodily actions in the social routines (namely eye contact, physical and verbal greetings between the wearers). It did not require additional time to integrate user operation into their live social tasks with the handshake native to the user activity the IBT was design for.

Previously mentioned literature (Mankoff et al., 2003; Nielsen & Molich, 1990) regards expert evaluation method as one of the most efficient methods, as it is less costly and time-consuming than other methods (section 3.4.1). However, the research argued here, it does not truly reflect the experiences of shy users in the used case scenario of this study (see the upcoming Subsection: Setup) and cannot provide enough insight into shy users' behaviour and the difficulties that this user group face during encounters with strangers. Similar causes apply to the feasibility test for the peripheral display. For these reasons, the assessment methods were not necessary to be carried out it in a long-term in-situ deployment.

Hence, an audio-video recording method was used to observe user behaviour performing the simulated social situation, and the *post-test* questionnaire to assess their social experience and usability after completing the meeting scenario. The design of this questionnaire is discussed further in the upcoming subsection: Instrument for Data Collection).

Specific design-evaluation criteria (namely *usability, comprehension, awareness distraction* and *time*) were employed following the reviewed literature (sections 2.3.2). These criteria provided information about how the social cues were helpful to the users' social interaction without distracting them from the ongoing activity. The time criterion was useful to assess the average period the users took to make conversation with one another. Together, both qualitative and quantitative data allowed for evaluating the capacity of IBT – whether it influenced an improvement in their social behaviour when meeting with strangers first-time. The assessment criteria, test and analysis methods are listed in Table 9.

Table 9: List of evaluation criteria, test and analysis methods for Pilot II study

Design elements	Variables	Test methods	Analysis methods
Interaction modality	Usability of handshake	Video record	Mixed
Interaction modality	Opinion towards handshake	User feedback through post-test questionnaire	Mixed
Overall technology	Usability of social compatibility display (content and system behaviour) as component for encoruating talks between strangers	User feedback through post-test questionnaire	Mixed
Display	Awareness and distraction of display	Video record	Mixed
Computation-embedded social	Appearance of feeling comfortable with social situation and meeting partner	Video record	Mixed
Social	Time taken to converse with others	Audio record	Quantitative

Testing Tools

Four IBTs, used by rotation, were programmed to maintain the display content for up to 7 minutes. After this time, the heat retained in its conductive thread would dissipate and the display would return to idle mode, with all graphic strips returning to black. Two video-recording devices installed in two corners filmed the user experience, and a Pomodoro timer reminded the participants of the time limits for each meeting session (detail is given in later subsections.)

Setup

Designed as a within-subject study in a laboratory setting, this test was initially planned to include eight small social networking sessions for four people (given the four available IBT prototypes and 16 participants). Each person had three opportunities to meet a stranger during 'with-shirt' sessions, and three in 'without-shirt' sessions. This setup was designed to be efficient in both cost and time and to avoid confounding effects from the learning experience.

Table 10: The first plan for meeting sessions (undeployed): an order of eight social networking sessions planned for 16 expected participants (A–P)

Sessions	w shirt 1	w shirt 2	w/o shirt 1	w/o shirt 2	w shirt 3	w/o shirt 3	w shirt 4	w/o shirt 4
	A	E	A	B	F	C	D	G
	B	H	E	H	I	K	N	J
	C	K	F	I	L	L	O	M
Participants	D	N	G	J	O	M	P	P

As shown in Table 10, four participants would meet other people during a 'with-shirt' session, followed by a 'without-shirt' session. The other four participants met each other in the reverse order. The group allocation rules were described as follows:

- *rule 1* – all participants in a group are unknown to all of the members in other groups.
- *rule 2* – the pre-calculated compatibility levels[34] between each member of any two groups are different, so that the participants have opportunities to see more than one level of the compatibility.

Knowing that shy people tend to avoid social situations, the second plan was prepared, set up as a private one-to-one meeting event (shown in Table 11), so that any absences by participants would not affect the testing-event structure. In the event, five respondents were absent. Hence the first plan for the meeting session plan (Table 10) was abandoned. The second plan Table 12) was therefore deployed with 11 test participants, each of whom experienced a 'with-shirt' and a 'without-shirt' session.

Table 11: The second plan for meeting sessions (deployed): a sequence of 12 professional speed-dating sessions with 11 shy participants (A–K). Participant Z was a member of the research team, who took part as a substitute so that participants A and K could both experience a with-shirt ('w shirt') and without-shirt ('w/o shirt') session, without excessive waiting time between sessions

Sessions	w shirt	w/o shirt	w shirt	w/o shirt	w shirt	w/o shirt	w shirt	w/o shirt	w shirt	w/o shirt	w shirt	w/o shirt
	Z	A	B	C	D	E	F	G	H	I	J	K
Participants	A	B	C	D	E	F	G	H	I	J	K	Z

[34] See Appendix B.3 for records of compatibility levels between test participants

Figure 21: Screenshots from video recording of D in a 'w/o shirt' session, meeting C (left); and during a 'w shirt' session to meet E (right).

Table 12: Demographics of test participants in Pilot II study

	Age	Gender	Academic level	Study/ research subject	ShyQ mean
A	39	Male	PhD	Art and technology	3.1
B	25	Male	Btec	Art and design	2.8
C	19	Female	BEng	Electrical engineering	3.7
D	27	Male	MSc	Computer science	3.2
E	26	Female	MA	Film and television	2.9
F	32	Female	MPhil	Fine arts	2.8
G	20	Female	BSc	Telecommunication	3.0
H	22	Male	MSc	Electronic engineering	2.7
I	24	Female	PhD	Sound and vision	3.6
J	42	Female	Lecturer	Computer science	3.4
K	28	Female	PhD	Social science	3.1
Total Mean	27.64				3.12

There were some concerns in working with shy people and conducting the test in a sensitive manner, especially with those who inclined towards extreme social anxiety. As shown in Table 12, most participants scored close to the mean cut-off score ($M=3.6$) on the ShyQ social anxiety tool (Bortnik et al., 2002). The following strategies might be better in future similar studies: 1) arrange concurrent one-to-one meetings so that absence would cause minimal effect on the setup; 2) recruit people who have lower social anxiety; 3) do not use audio-video recording devices. Like the initial setup plan, this second plan was deployed because of cost limitations, time efficiency and to avoid possible confounding effects of technology usage.

Test Procedure

The experiment consisted of three consecutive processes: the introduction, demonstration and testing processes. During a 30-minute introduction, all participants were seated together in a waiting room and were asked not to make any form of contact with each other. They were then informed that they would meet strangers while wearing an IBT with a handshake feature, which would produce a social-compatibility display on the shirt-front. It was made clear to the participants that the display content would be the result of matching their information (collected from the questionnaire they had responded to in the recruitment process), stored in each IBT.

In the demonstration, two research team members each wore an IBT and they performed a meeting session to demonstrate how the clothing worked. The participants were allowed to test the shirt with the research team members if they so wished. This part was planned to last 20 minutes but it continued for 45 minutes, because five participants wanted to try out the shirt before the test.

During the testing, two participants were allowed into the meeting room at a time, where they were given a maximum of 10 minutes (reminded by a Pomodoro timer at minutes 8 and 10) and asked to greet one another with a handshake. The same procedure was followed for both with-shirt and without-shirt sessions. They were free to end the sessions at any time. Each participant then completed the feedback form before moving on to the second meeting session.

5.1.3. Empirical Questions

Five empirical questions were set to guiding the data collection and analysis on the social behaviour and experience of shy users during their first-time encountering with strangers. These questions are listed as follows:

- Can a handshake gesture be used as user input, without interrupting the routine of social interaction between strangers?

- Can similarities (namely social profile and preferences) between strangers be used to encourage talking in first-time meetings?

- Can the peripheral display be used as an augmented social cue to facilitate mutual awareness and understanding of information, without distracting shy users' attention from the social interaction routine?

- In comparison with meeting without technical aids, can the IBT help shy people to feel more comfortable when meeting strangers?

- What is the average time for which shy people converse with each other in a first-time meeting?

5.1.4. Instrument for Data Collection

To investigate the potential and limitations of the IBT, qualitative and quantitative data were collected in three ways, all of which were hard-coded. From the pre-test questionnaire (Appendix B.1), the information was fed into the social compatibility matching software written in C and C++ program of Arduino environment. This data manipulation resulted in pre-calculated compatibility levels, stored on the system controller in all IBTs, and thus available for immediate retrieval by the *secret handshake*. Data from the audio-visual recordings were used to observe total times the users conversed with one another and to compare their meeting experiences while using and not using the IBT. Data from the *post-test* questionnaire (Appendix B.2) were classified into three groups consisting of closed- and open-ended questions (QA). QA1-3 asked about handshake in general and as a requirement in the experiment, while QA4 about user attitudes on the knowledge of having shared interests and compatible preferences with newly-met people and QA5 about the helpfulness of the augmented social display to their meeting with strangers in the meeting sessions. The latter was structured for additional comments allowing for further understanding of their chosen answers.

5.2.Data Analysis and Results

This study was designed as a feasibility testing on the interaction model of the novel computer-mediated social aid (Icebreaker T-shirt) and an initial observation on the user behaviour. Qualitative-based user feedback and the observed behaviour were examined using descriptive data analysis with results enriched by users' additional comments given to specific choices of closed-ended questionnaire questions. In the following four subsections are the analysis results regarding the required handshake, pre-knowledge about interaction partner, awareness on the augmented social cues and social behaviour.

5.2.1. Opinions on Handshake

The suitability of the handshaking user input was examined based on user feedback given through the *post-test* questionnaire and video recordings. The overall feedback was positive, as illustrated in Figure 22. Specifically, when asked whether the required handshake had any impact on their attitude towards the meeting partners, 72.73% of 11 participants said it did. They further correlated the strength of the grip and sincerity – the stronger the grip, the more sincere and open they judged the other person to be. Examples of comments below provided a greater understanding of their opinions:

> ***'I sometimes associate the strength of handshake with sincerity and openness.'***
> ***'Handshake can reveal if the person is sincere or not.'***
> ***'I don't like limp handshakes just if it feels too loose/soft I may think they're not very keen to talk/meet new people.'***

Regarding the question about how they felt about handshakes in general and whether they had positive or negative experiences with it during the meetings, 90.91% of 11 participants said that they had no negative thoughts about handshakes. They also reported no negative experiences performing it in the meeting sessions because it is a common way of greeting unfamiliar people. Only one participant (9.09% of 11) gave negative feedback. She commented:

> ***'I felt it was awkward/disruptive because I had to wait for the device ['s secret handshake] to operate completely before I can start a proper chat.'***

The video showed that this participant had some difficulty operating the RFID sensing device on the cuff. Thus, her negative feedback on handshakes was related to a technical problem of the prototype rather than the handshake as a social gesture in which the user input disguised within.

This technical disruption was partly caused by the RFID naïve-protocol used to control the active and sleep intervals of the RFID reader, and by the use of conductive threads for the soft-wiring technique. While this approach reduced the chance of two readers colliding, it increased the chances of a system crash owing to occasional drops in the voltage supply (carried via conductive threads from the main system controller). This is a known issue during the system test operation, leading to an implementation of a *catch* solution by resetting the internal operation of the RFID system when the event occurred. Although this solution was robust to the problem, it was apparently not efficient enough.

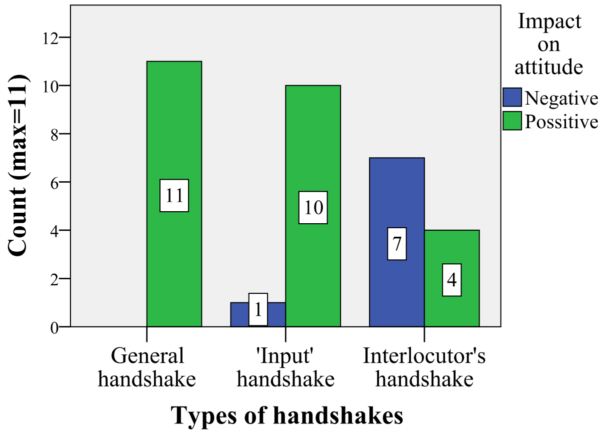


Figure 22: Opinions on handshakes

5.2.2. Impact of Prior Knowledge about Strangers

In the Icebreaker model (section 3.3.1), pre-knowledge about strangers included as the first component to influence the user's familiarity with the social situation. The potential and limitations of this component were assessed through two QA questions (results shown in Figure 23). On the question regarding the pre-knowledge given before the meeting started, 54.55% of 11 users provided positive responses when told they had something in common with the people they were about to meet. Some comments were:

> ***'I want to know more about that person or how friendship or relationship could develop.'***
> ***'It's common ground to start a conversation.'***
> ***'It's a great thing to find someone having something in common with you.'***
> ***'There was always a safe place for knowing a similarity.'***

Almost half (45.45% of 11 users) gave answers based on conditions. Some said they might or might not want to know more about the other person, depending on the following conditions: first impression, the outcome of the conversation with that person, and the type of commonalities. Some users explained their concerns as:

> ***'"yes" for professional commonalities, "no" for personal commonalities.'***
> ***'[It depends on] how useful it is to maintain connection with that person – if the person is helpful to my networking.'***

To the usability evaluation of the augmented social cue given in the display content, 72.73% of 11 users found the compatibility level helpful to their conversation with others. Comments in this regard included the following:

> ***'It was easier to start a conversation.'***

'Chat about it could solve the awkward silence.'
'[I]t gave a sense of having things in common to begin the conversation.'
'It gave us an initial topic to talk about, something we both were interested in – whereas when we didn't have the shirt, I felt we were only trying to make small talk and that I don't think I'm so shy after all or maybe because I was in an enclosed area.'

In contrast, 27.27% (three of 11 users) did not find the social cue helpful. They explained:

'I couldn't tell if the display had changed.'
'It didn't show the compatibility – it seems to encourage an artificial comfort.'
'I didn't think the strength was related to personalities.'

These comments suggest that negative feedback about the display was not an effect of its content or appearance, but the technical issues. The conductive thread used as a heat carrier and incorrect interpretation of the displayed content seemed to account for such negative views.

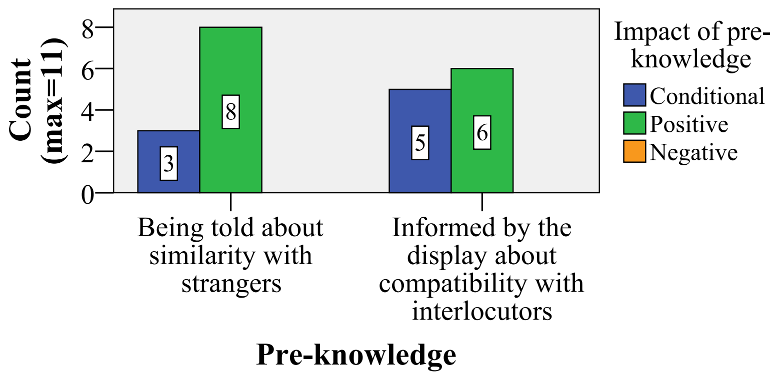


Figure 23: Impact of knowing about similarities with others

Informed by the administrative records, the three users (of 11) who gave negative feedback had participated in the final three with-shirt sessions. There was a chance that by the time of their meeting sessions, the temperature of the testing environment had risen due to previous occupancy of the space. The temperature threshold for thermochromic paints to change colour is ~31°C or higher. When the room temperature is well above this threshold, the soft-circuit display can exhibit continual coloured strips without reverting to the idle mode.

5.2.3. Awareness of and Distraction by Augmented Social Cue

The impact of the augmented social cue on the user appearance and behaviour was examined based on whether it distracted user attention from the ongoing situation.

Comparing their presence in 'with-shirt' and 'without-shirt' sessions, the results showed three categories of user behaviour corresponding to the change of content of the augmented social display (Figure 24). The first group, 27.27% of 11 users, paid attention soon after they shook hands and did not start talking until the display fully updated its content. Some continued to observe the changing content while others inspected the technical detail of the social display. Their conversations were about finding out reasons for the level of compatibility between them, as determined by the software.

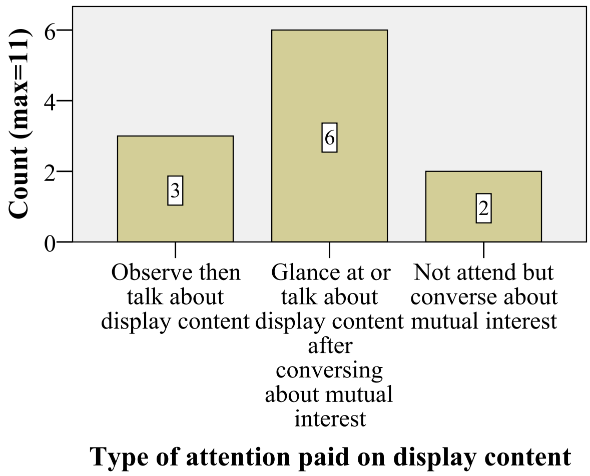


Figure 24: Degrees of user attention paid to peripheral display of augmented social cue

The second group was made up of 54.55% of the users. They had started conversing straight away after shaking hands. Four of them periodically glanced at the display, whereas the other two paid more attention to it towards the end of the conversion. Conversation among users in this group started with general topics relating to their study and research, such as academic affiliation and professional background, before moving onto topics of mutual interest.

The last group, 18.18% (of 11 users), did not physically pay attention to the display at all. However, their discussion based on mutual interests – much like the conversation made by the first and second groups.

5.2.4. Feeling Comfortable and Relaxed

In order to determine if the users appeared more relaxed when using the IBT, the audio-video recordings were used to compare the social behaviour (e.g., sitting back, leaning in, moving closer and touching the chin, hair or jewellery, and tone of voice) in the two sessions. Illustrated in Figure 25, the data show marked differences between the records of user behaviour in both meetings.

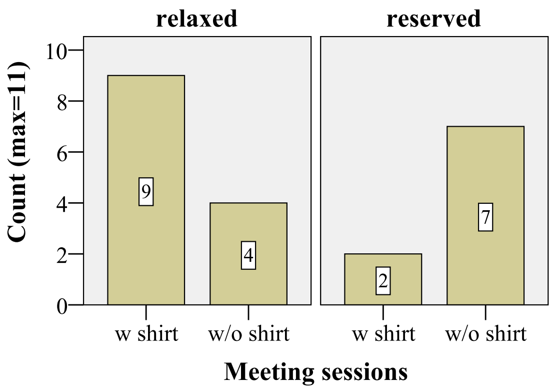


Figure 25: Differences between user appearance

Approximately half (45.45% of 11 users) appeared more relaxed in the 'with-shirt' sessions. This user group tended to converse for longer, with more variety of conversation topics; the average time for conversation was 8 minutes. Two people spent longer than the maximum given period (10 minutes) and had to be reminded that the session had ended. For the other half (54.55% of 11) who did not appear as relaxed, the video recordings showed they seemed to be concerned with two technical issues. One was the awareness on the recording device; the participants tended to glance at the camera and spoke in a significantly lower voice. Another was the weight of the main circuit-board fastened to the sleeve of the prototype T-shirt. Some participants compensated the latter by bending their arm to support the weight, while others rested their lower arms on thighs. These actions increased the feeling of physical comfort but potentially constrained their social performance entailing bodily movement and thus not appearing relaxed.

5.3.Justification on Main Findings

The primary goal of this study was to validate the Icebreaker model – grounded in the natural approach for designing computer-mediated social technology – as being able to influence shy users' processing of their relational information towards interpersonal engagement with one another: making and maintaining a conversation. The study outcome indicated the model held potential and promise for this purpose. The foundation and key components, of which were 'Being Aware of Similarities' and 'Processing of Multi-Self as a Social Object', are superimposed on the features and manifestation of the IBT. These components were evident to encourage users taking a more active role in social interaction. All participants (100% of 11) appeared to pay attention to the social cue, either by glancing and/or talking about mutual interests with the interlocutor during the meeting sessions. Of this behaviour, most participants appeared relaxed towards one another, rather than reserved – behaviour common to socially anxious individuals. This finding verified the third and fourth components of the model – that is, 'Initiating and Maintaining Conversation' with others and hence 'Becoming Familiar with the Social Context'.

In addition, this study revealed that the peripheral social display and interaction model of IBT was feasible to present information to the users' periphery with minimal distraction from the ongoing social routines. Results showed 90.91% of the 11 users gave positive feedback on the handshake input, and 72.73% found the augmented social cue was helpful in initiating conversation with strangers. The researcher posits this success as enabled by the subtle interaction technique for operation and the dynamic, public and unobtrusive characteristics of its visual display. The shirt front was augmented with a computer-embedded social cue to publicly show similarities between the wearers. In other words, it was designed as a joint affordance (section 2.2.1) making the users mutually aware of the information they co-created in a joint social action. Such similarities were represented through the use of ambiguity as a design tool for social cueing content. This incidence supports previous research (e.g. Chen & Abouzied, 2016; Howell et al., 2016; Kytö & McGookin, 2017a; 2017b; Schellekens et al., 2015) into the capacity of low-resolution information displays that exhibit social cues relating to the change in the social context. Furthermore, the subtle-peripheral form of user input (*secret handshake*) was disguised in the socio-cultural routine, allowing the user to implicitly trigger and update the display content without the need for training or learning of new skills. Such features and system behaviours facilitated low-cognitive and low-key actions that matched the mental and physical preferences of shy people.

Regarding the two requisite qualities of SOs suitable for shy users, outlined in the design rationale (section 5.1.1) and the proposed design principle for subtle SOs (section 3.3.2), the findings informed the significant roles these qualities perform. The *active* quality is fundamental to attracting user attention while the *relational* is crucial to giving shy people a 'ticket' to talk. It did so by making explicit the relationship through the interpretative gap placed between the users. This gap, or puzzle, became the resource for coordinating social cognition and led the users to maintain the conversation, as evident in the analysis results (section 5.2.3).

The concepts of SOs and peripheral displays, in general, seem to contradict one another but not within the scope of this thesis. Indeed, a SO draws attention to itself to instigate conversation, while a peripheral display is transparent to the user's focal attention despite presenting information to their periphery. However, in this instance the combination of SO and peripheral design reserve user attention for the central aspect of the social situation, not for the object or the design itself. While SOs act to reduce direct attentional stress between strangers, peripheral displays assist by not distracting their attention from the ongoing event. The two concepts converge and complement each other in catering for the cognition deficits in shy users (section 2.1.1).

Despite producing positive findings, the outcome of this study emphasised the importance of a high-fidelity prototype in peripheral user-interface research. This was reflected in the IBT's rapid prototype that lacked the robustness of the *secret handshake* (section 5.2.1) and soft-circuit display (section 5.2.2) systems to overcome the unpredicted testing condition and thus, occasionally failed to update the social cues. This shortcoming caused the user attention to fixate on the technology, rather than upon the cuing content, hence made it difficult for the augmented social cue to disengage from the users' thoughts and inspection and to shift back to reside in their periphery. Such problems is known intrinsic to early prototypes in designs for peripheral user interfaces (Matthews et al., 2009) and it indicates the need for more seamless integration of devices in the user environment. Nonetheless, the users reported IBT to encourage a positive feeling and initiate conversation. This agrees with McCarthy and colleagues' (2002) findings that showed the capacity of SO manifestation to subtly facilitate serendipitous actions even when its displayed information did not correspond to the user's interests.

Regarding the first research question (RQ1), these findings pointed to the subtlety of the interaction model and user interfaces as key to manipulating a computer-mediated SO for aiding the social interaction of shy users. In particular, its user-interaction model needs to engage the user without distracting their focal attention from the ongoing social tasks. Similarly, its manifestation needs to reside seamlessly in the social convention of the environment and offer information in ways encouraging shy users to subconsciously apply existing social skills and knowledge to the relationships with one another and the social context.

To introduce a new tool that eases the established and complicated social challenges for this user group, it needs to offer a persuasive outlook with immediate improvement to overcome a certain degree of their limitations, but in a ‘natural’ and unobtrusive manner. The findings in this study indicated these design characteristics worth pursuing further. Hence, it was set out as the assumption for RQ2, constituted as a set of design criteria for developing SO for shy people (section 3.3.2).

Next, we look into these characteristics more systematically – towards the generalisation of the advantages given by the use of a subtle technology, instead of non-subtle, to facilitate social interaction in people with social anxiety. The investigation required an iterative design of technology implemented with the design principle, presented in the next chapter alongside a more systematic evaluation of its usability and user experience.

Phase III

Chapter Six

6. Advantages of Facilitating Social Interaction with Subtle Social Object (Final Study)

A subtle-peripheral display, when used as a social object (SO), was evident (chapter 5) to effectively facilitate shy users' social interaction. Such evidence led to hypothesising the subtleties of computer-mediated social technology as the key to improving the user's social behaviour and experience. Icebreaker Jacket (IBJ) was an iterative designed prototype featuring the subtleties. Its mutual display of social cues was refined as well as its system operation optimised to avoid the obtrusiveness of technology posted on user experience. In response to the second central research (RQ2), the characteristics of IBJ were examined in comparison with those of a non-subtle social interaction aid. Drawing on the success of Icebreaker T-shirt (IBT) in Pilot II study, the concept of subtlety remained in the process of design iteration, whereas the mixed methods for user evaluation and data analysis were restructured in more comprehensive ways using multiple questionnaires for quantitative and qualitative samplings. This study design allowed for overcoming the challenge of peripheral interface evaluation and achieving detailed investigation of user behaviour in a laboratory-based social setting, where nine zero-acquaintance socially anxious recruits met in the presence of subtle-public and overt-private social cues. User feedback was hard-coded in ways suitable for quantitative-based analysis and complementation with qualitative results. Findings indicated that benefits, features and appearance and functioning behaviour of the subtle cues were less distracting, more helpful and led the user to a more satisfying social experience. The finding led to the generalisation of the design principle for subtle SOs proposed as a design guideline for subtle SOs for shy users (sections 3.3.2 and 7.2.2). Like the previous study chapters, this chapter provides the narrative for the design and development of study tools in the first part, including the design of the experiment and the required tools. Next is the detailed description of data prior to an inferential analysis using null-hypothesis statistical testing (NHST) and practical statistics testing (PST) approaches. Finally, it completes with a justification of the main findings drawn together the qualitative and qualitative data collected from Phase I research (section 3.1.1) up to the current research stage.

6.1.Study Tools and Methods

6.1.1. Development of Icebreaker Jacket

Design Rationale

Prior study outcome (chapter 5) indicated the possibilities as well as caveats of using peripheral interfaces in designing a subtle SO. For the possibilities, the outcome indicated the *relational* and subdued *active* qualities of SOs as hybridising characteristics in managing attention of the users towards constructive change in their social behaviour. Hence, this approach was further examined in the current study – comparing the characteristics of subtle SO characteristics to non-subtle – in response to the second central research question (RQ2), and for which the subtle benefits, features and behaviours were hypothesised as being superior in facilitating social interaction of the prospective users. Nonetheless, the outcome highlighted the concerns on the effects of low fidelity prototypes that could undermine social experience (sections 5.2.1 and 5.2.3). Specifically, in this instance, when the system handshake mis-communicated the user identification and information exchange, it disrupted the flow of the social routine. Similarly, when the soft-circuit display failed to update the compatibility level, the technology became an object that captured user attention, rather than immediately diverting it onto the social cueing content. Such disruptions to the social experience were caused by the initial choice of design materials and technical configuration methods that resulted in the unrefined 'look and feel' of the t-shirt prototype. Improvements of these aspects are described in the upcoming subsection: 'Development and Outcome'.

There is no conforming standard in Human-computer Interaction (HCI) research to define the prototype qualities. Requirements vary according to and depending on the design stages (Buchenau & Suri, 2000; B. Buxton, 2007; Houde & Hill, 1997; W. Jones, Spool, Grudin, Bellotti, & Czerwinski, 2007; Lim, Stolterman, & Tenenberg, 2008; Virzi, Sokolov, & Karis, 1996). Among these stages, design for usability testing (W. Jones et al., 2007) and improving user experience (Buchenau & Suri, 2000; Houde & Hill, 1997) were the focus of the current research stage. Design for users' *experience prototype* (Buchenau & Suri, 2000), in particular, allowed for the intended user (of this research) to act upon, use and think with it – in the same way they would do if it became available for everyday use. This quality of prototype is consistent with *look-and-feel* prototypes (Houde & Hill, 1997, p. 3), aimed for drawing out 'the concrete sensory experience [...] while using it' while enhancing the users' other contexts – such as a social situation, convention and routine. It follows that an *experience* prototype emphasises 'the experiential aspect of whatever representations are needed to successfully (re)live or convey an experience with' an artefact' (Buchenau & Suri, 2000, p. 424). This emphasis is consistent with *needs* (Alben, 1996) – the first user-insight component specified in the design principles for subtle SOs (section 3.3.2) – and concerned with satisfying the user needs and bringing about change and contributing to their social circumstances. The design aim to improve the social experience, hence, was taken as the main approach for iterative design for the user interface of the higher fidelity prototype used in this study.

Design Goals

Drawing on the achievements and concerns as mentioned above, the iterative design was aimed at improving the subtlety of the technology where possible, while retaining its capacities to engage user attention and generating the interpretative gap in their social relationship within the context of use. Accordingly, this aim was broken down into design goals listed as follows:

- optimise the subtlely of the user interfaces following the approach to designing the experience prototype mentioned above.
- improve system robustness to overcome unintended conditions (section 5.2.2) of the test environment

Development and Outcome

Continuity of Conceptual Design from Icebreaker T-shirt

To meet the users' needs in a social situation, the original prototype IBT was designed to counterbalance their common cognitive-behavioural predispositions, namely excessive self-assessment and threat vigilance, known to induce cognitive overload and social-cognition distortion (sections 2.1.1). Taking these advantages further, the IBT provided an augmented social cue with positive content constructed with relational information between each user pair. The preliminary validation of this concept, through the low-cognitive demanding peripheral display and subtle-peripheral interaction modality in Pilot II study, demonstrated that the IBT prototype could offer reward to shy users' needs and improve their social experience. Hence, there was no change required in the conceptual design elements for which the overall aim was to make the technology transparent to operate and available to think with. This concept was iterated in the functionality of the improved version of the prototype, namely IBJ (Figure 26). The subtlety of the handshaking operation and the host object for the peripheral display were upgraded to improve the functionality.

Figure 26: Icebreaker Jacket prototypes, each with a textile clip-on Social Badge for updating social compatibility levels between two wearers

Enhanced Subtle Aspects in Icebreaker Jacket

Drawing on the *calm* technology approach together with the attention paid to the 'bare-bones' parts of the IBT, it follows that any unconventional elements in a design artefact can prevent it from being transparent to the user's attentional focus. This knowledge led the researcher to reconsider the choice of a host object; the t-shirt had limited features for embedding hardware and thus gave it a human-machine hybrid look, for the prototype itself as well as the wearer which appeared to be unnatural to the social context. In contrast, the newly chosen host object, namely a jacket, provided sufficient structure for the integration of all required hardware. This made the technology appear as an ordinary piece of clothing as seen in Figure 26. In addition, users of a novel interactive system often get overly excited or engrossed by the system response (Mankoff et al., 2003), making it more challenging for computation to 'disappear' into the background. In this respect, system manifestation as well as any extra requirements to operate it needs to be trivial enough so as not to distract the user's attention away from the central activity in the social situation, but noticeable enough to generate curiosity and prompt conversation. Such requirements led to a modification of the system handshake and display of social cues described below.

Radio-Frequency Identification System for Secret Handshake Operation

Based on an observation on the user experience with IBT, its radio-frequency identification (RFID) system was, firstly, giving cyborg looks and an unusual feeling of the required handshake. With a 25-by-26-by-4 mm physical footprint of the RFID reader, it could feel like holding two hard objects when the wearers shook hands, in addition to the occasional collision of the RFID network. All these problems were caused by the RFID reader choice (Innovation ID-12). Despite its low cost, this off-the-shelf module consumed minimal power and is practical to be integrated with a wide range of near-field sensing applications. However, it has a built-in antenna that makes challenging the hardware alteration required for the used case scenario of the current research. These problems were resolved by replacing the original RFID system with a combination of a Seeed RDM630 RFID reader circuit and external antenna. The pair was configured in a way suitable for sensing the low-cost passive RFID tags – the remained part employed in the previous system prototype. This change in hardware choice provided three following benefits:

- The reader circuit was readily for integrating into the main system controller, hidden in a pocket of the jacket.
- The external antenna is thin and compact enough to be embedded between a double-layer of fabric in the cuff area. Together with the above benefit, this removed the technical system of the *secret handshake* beyond users' sight.
- The separation between the reader circuit and antenna allowed for anti-collision events (namely reader-reader and reader-tag) methods to be easily implemented. This separation also provided a precise and direct alignment between the reader

of System A and the tag of System B (see the left-handed frame of Figure 18 in chapter 5). This configuration also allowed for an extension of the distance between the reader and the tag within the same system, to remove the tag from the reader's transponder range and avoid tag-tag collisions during the physical handshake. This outcome was partly achieved by limiting antenna load to ~1 V, causing the transponder range to be reduced to ~40 mm, thereby not reading the tag of own system.

It is worth noting that this RFID configuration can reduce but not eliminate the probability of interference. This limitation was inherited from the dense RFID network formed by the technical configuration of the used case scenario, leading to an inevitable effect on the system handshaking behaviour that embraced the human handshaking behaviour in the social routine.

To ensure that the collisions would not interfere with the users' social experience, a *random protocol* for tag-reading schedules was chosen to replace the *naïve protocol*; this method is known for overcoming reader-reader and reader-tag collisions in a dense network (Jain & Das, 2006). This was enabled by generating random lengths for readings and intervals. The random lengths (1000-2000 ms) was a solution to ensure each new reading would cover the period of the human handshake. As a result, no RFID network collisions occurred during the functional testing nor the user evaluation processes.

Peripheral Display for Augmenting Social Cue

Pilot II study verified the concept and functionality of the display to be adequate. Its appearance did not detain the users' attention away from the social situation, although many discussed its content. This user behaviour was expected owing to the display designed to be a SO. The findings showed that the original design, on the frontal area of the shirt, was not a problem but the choice of material was. The use of conductive threads as heating elements initially seemed ideal. However, the heat in the threads did not dissipate quickly enough when the room temperature increased above the thermochromic paints' threshold (section 5.2.2), causing some disruption to the display's resetting process. This problem was resolved by replacing the material of the heating element – from five 12 Ω/foot conducive threads to 5.6 Ω SMD resistors and redesigning the display as a clip-on textile badge (Figure 27) on the chest area. The thermochromic paints were retained. This solution provided improvements to the overall system operation, discussed below.

- Changing from conductive threads to SMD resistors solved not only the heat dissipation issue but also increased the speed of heat generation. This change made the display update the content more rapidly, while retaining its subtle features.
- Using SMD resistors as heating elements also reduced unnecessary power loss, which was partly achieved by replacing the five sub-heating circuits with an 8-channel source driver (Allegro 2987).
- As a result, the overall power consumption of the jacket was driven by 5V/1000mAh for 12-hour operating cycles, instead of the 11V/2875mAh used to supply the T-shirt circuit. This system logistic made the device lighter and smaller to incorporate into the main circuit controller (Figure 28) hidden in the pocket of the jacket.

By improving the display robustness further benefits were obtained in its manifestation and user interaction model. This by-product enriched the look and feel of the new display; it was more compact and held a greater degree of high fidelity than the soft-circuit display inlaid in the t-shirt-front (Figure 15). User interaction was enhanced by repositioning the badge on the chest area, the display remaining within the user's visual field when they made eye contact and talked to one another[35]. Despite all these benefits, this new design facilitated low-cognitive demands on visuospatial thinking (section 2.3.1), enabled by using colours, shapes and spatial arrangements of graphical elements to convey the meaning of displayed content.

[35] The human visual field covers ~200° horizontal and ~135° vertical area when fixed on an object (Card, Mackinlay, & Shneiderman, 1999b, p. 24).

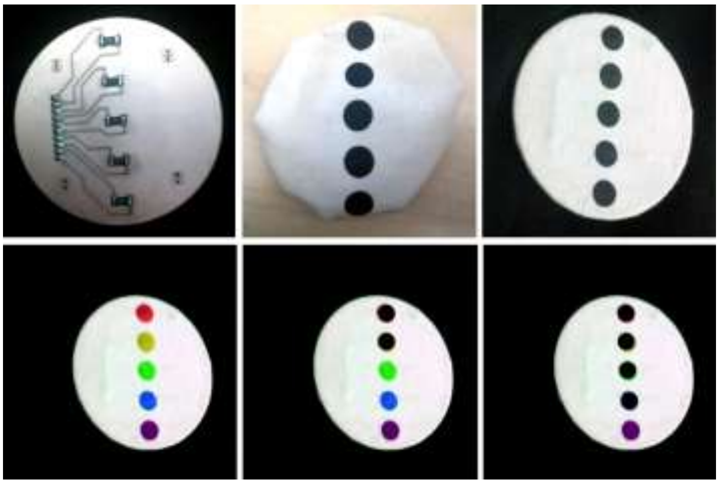


Figure 27: A printed circuit board of the Social Badge of IBJ. Five 5.6Ω heating elements soldered on (top left); a textile cap with double-layered paints – textile paints at bottom and thermochromic paints on top (top centre); the printed circuit with the textile cap mounted on, showing the idle mode of the display (top right). When heated to 31°C, the display changes colour to reveal possible compatibility levels: level 5 (bottom left), level 3 (bottom centre) and level 1 (bottom right).

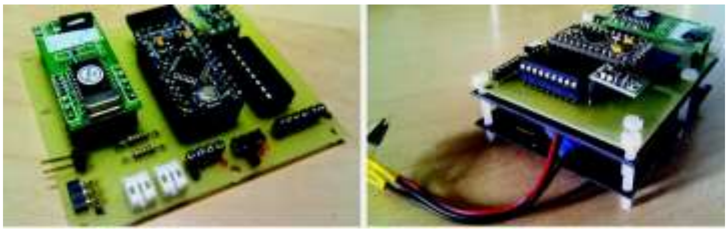


Figure 28: Main circuit controller of IBJ. Left panel shows the top PCB hosting RDM630 125- kiloHertz RFID reader module, 5V Atmega328P Arduino Pro Mini microcontroller, Allegro 2987 driver used as five sub-heat circuits, and plug-and-play style connectors for RFID antenna wired from the cuff and for heating elements wired from the badge. Right panel shows the top board stacked on two 3.7V/1000mAh Lithium batteries for

Summary of Development Outcome

This optimisation of subtlety provided not only improvement on the overall user interfaces but also the back-end configurations of the technology. The IBJ (Figure 29) appears to be an ordinary jacket with its clip-on Social Badge revealing the social compatibility between wearers soon after they shook hands. Taking on the role of a subtle SO, the badge behaviour draws their attention and generates curiosity about their social relationship, by changing the colours of its meter-like graphic in a non-obtrusive fashion.

The main circuit is also available for future implementation of wireless module choices (e.g. Bluetooth, WiFi or NFC) suitable for both local and online networks, and an extension of program memory can be used to store a large database. Together with the textile cover, the badge can be redesigned to suit various event themes at a low-cost.

Figure 29: A diagram of Icebreaker Jacket prototype with its features[36]

6.1.2. Experimental Design

The design of the experiment was intended to serve the primary and secondary goals of this study. For the main, it accommodated the comparison of subtle and non-subtle characteristics of social objects, towards defining the key advantages of facilitating social interaction in anxious people with subtle technology. In addition, it provided a platform for understanding whether and how the augmented social-cueing content affected the users' social experience. These objectives expanded on the Pilot II study results by which the users only indicated the subtle SO helpful to their meeting experience. Its testing process was not equipped to determine how the characteristics of the employed cueing content (namely social compatibility) had an impact on the users' social experiences.

The initial outcome was further investigated here (through Empirical Questions 5 and 10 in section 6.2) towards a justification of the characteristics of the cueing content, specifically, on the constructive meaning acquired from the social compatibility scores. The decision for using positive and affirmative awareness in the cueing information derived from the knowledge that shy people are overly sensitive to perceived social threats (section 2.1.1) or negative messages in social situations. Hence, making a positive social signal a priority could effectively attract and maintain user attention as evident in the prior study.

[36] Note that the available hidden camera feature was not employed in the study owing to ethical considerations (section 3.4) regarding shy users' preference of anonymity.

Following on from these design intents, the primary assumption for this experiment was set out as:

> *subtle characteristics (section 3.3.2) of the social object were superior to those of the non-subtle;*

and the secondary as:

> *there was a relationship between the levels of social compatibility and the extent of its impact on the users' social experience.*

This subsection presents details of the experimental design including materials and methods employed as required in the data analysis of this study.

Participants

Self-reported socially anxious people were recruited from among the students, staff and researchers at the Queen Mary University of London by email invitation. The email invited people who sometimes found it difficult to interact with strangers socially and wanted to make new friends in a professional speed-dating environment. The mailing content was different from the recruiting message used in Pilot II study that called for shy people specifically – posited to be the cause of no-shows (section 5.1.2). Also, the email invitation for this study stated that respondents would have an opportunity to test out the IBJ, described as computation-embedded clothing designed to make meeting strangers less challenging. To participate, they had to complete a *pre-test* questionnaire (Appendix C.1) with three parts (further details given in section 6.5). The information collected in the first part was used to draw up preliminary criteria for selecting respondents not known to the others. To meet this crucial requirement, they were chosen from different schools or research groups and academic levels.

Samples and Methods

Central to objective of this study was the validation the assumption that key characteristics of a subtle SO were superior to those of the non-subtle. The subtle characteristics were constituted into the design principle (section 3.3.2) and implemented in the manifestation and interaction model of the Social Badge, whereas the non-subtle characteristics were defined by the demand for users' focal attention and apparent physical effort, replicating those of 'un-transparent' or 'in-your-face' social technologies

(Clark, 2003, p. 36). These non-subtle characteristics were established in the appearance and interaction model of a handheld Social Card set – the comparative SO designed specifically to provide social cues in an obtrusive manner (further details given in the following subsection).

To evaluate how these characteristics differ in their effects, the sampling was set to measure the degree to which the peripheral display of the subtle SO could support the nature of social interaction, and enhance the social experience for anxious users compared to the focal-demand display of the non-subtle SO did. The subtle SO was given the role of an aiding tool to advance the users' social cognition and behaviour. It did so by giving them a 'ticket to talk', and advancing their intent to socialise with the interpretation gap about their social relationship. Accordingly, these aspects were translated into the social experience and outcome of using both types of SO in order to define the extent to which the subtle SO was of greater value to the user. Samples such as the degree of usefulness, user satisfaction and awareness of the SO were collected for comparison via closed-end questionnaires in which additional comment fields for users' detailed opinions were available.

Among the criteria, usefulness and user satisfaction were the main aspects. The details of helpfulness explain how each type of SO aids conversation for socially anxious users. Their satisfaction explains how worthwhile they feel it is for the SO to be present in the social environment, which they already find demanding. User feedback on the usability helped defining the advantages of as an aid to cope better with social routines and to improve the outcome of central tasks required by the social activity. Hence the importance of usability and user-experience criteria were equally addressed in this study, listed in Table 13.

Table 13: Evaluation criteria and test methods for final study: comparison of usability and user-experience between peripheral-attention demand SO (Social Badge) and full-attention demand SO (Social Card, see further detail in the following subsection: Testing tools).

	Criteria	Test methods	Analysis methods
Display as a social object (SO)	Capacity of peripheral SO to aid initiating, providing content and lengthen conversation	Compared with using focal SO and not using any SO	Quantitative
Display modality	Usefulness of peripheral SO to the central activity	Compared with using focal SO	Quantitative
	Satisfaction of social experience of having peripheral SO in the user environment	Compared with having focal SO and not having it	Quantitative
	User preference for modalities of SO	Ranking for having peripheral, focal and non-SO in the user environment	Quantitative
	Degree of attention paid to peripheral SO	Compared with attention paid to focal SO	Quantitative
Display content	Psychological impact of the level of social compatibility	Compare the impact of lower and higher social compatibility levels	Mixed

In Pilot II study, some shy participants appeared concerned about the presence of the video camera causing the Hawthorne Effect in the collected data (section 3.2.2). Therefore, all measures in the Final study were made through questionnaires administered during and after the experimental event (discussed further in section 6.5).

Testing Tools

For the IBJ a database was used that stored all participants' profiles and preferences on the program memory of its main circuit. This configuration enabled the calculation of compatibility levels for two wearers during their handshake. The Social Badge was programmed to maintain its content for up to 5 minutes. After this time, the heat retained in its heating element would dissipate to set the graphic meter to idle mode, with all dots losing their colour and returning to black.

As mentioned, the Social Badge as a peripheral display was compared with a focal display. A set of eight Social Cards, cut in round shapes to resemble the Social Badge, was used for this purpose. Its user interaction model required the user's full attention to search for a card that represented the matching information between the user and the other person (namely social compatibility level). Figure 30 illustrates a complete set of

Social Cards produced for participant B with pre-calculated compatibility levels with all expected interaction partners printed on it.

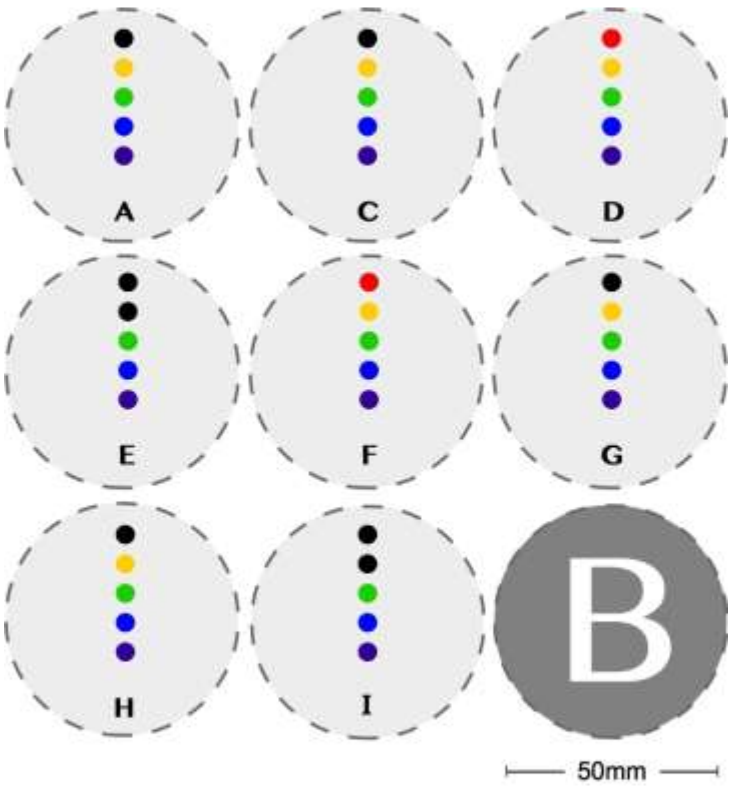


Figure 30: Example of eight cut-outs Social Cards designed for participant B[37]. Each card represents the pre-calculated compatibility between B and each other participants whom he had a chance to meet in the testing event. The bottom-left diagram illustrates their reverse sides, indicating the user's ID.

In addition to the IBJs with the Social Badge, ordinary jackets with the same look and feel (without a badge and cuff LED) were used, to avoid a confounding effect of the IBJ in meetings without the Social Badge. Two questionnaires were used for data collection to gain user feedback during and after the test event (section 6.5).

Setup

Treatments

Like the feasibility assessment, this confirmatory assessment was designed as a within-subject study. This allowed for a comparison of the usefulness and impact of the peripheral augmented social cue (Social Badge) with other display modalities. Three social situations were designed to have two strangers paired at any one time. These

[37] Note that the ID and compatibility levels shown in Figure 30 do not replicate the real dataset. They are only present here for readability reason.

situations differed by the display modalities of social cue and their interaction demands. The first social situation was augmented with Social Cards demanding full attention ('card meeting'). The second was meetings where the Social Badge demanded only peripheral attention ('badge meeting'). The third had no additional object for the social cue ('no-soObj meeting'). The event was structured in this way to validate the main assumption that that thesocial behaviour and experience of anxious users could be improved when the subtle-peripheral display of augmented social cues was present.

Test Environment

To create a social event at which everyone had an opportunity to meet six unknown people, the testing situation was designed to imitate a professional (non-romantic) speed-dating event. Three tables, each with two chairs, were set up to create three meeting zones where participants could move freely from one table to the next (Figure 32). Each zone had a sign indicating the meeting mode (Figure 31) related to the social tools offered: score card, badge and no-tool (no augmented social cues).

The reason speed-dating was chosen as a design for the test environment was discussed in section 3.6.1. Furthermore, a speed-dating event appeared (in Pilot II study) to be a supportive setting that helped regulate levels of social interaction according to the users' own capacity. These factors are important in social situations for people who find collaborative and sharing experiences with others challenging (Colle et al., 2017). In addition, speed-dating provides many features useful to user evaluation of peripheral displays. Particularly, its quick assessment intervals, between meeting sessions, allow for tenable time slots for applying a data sampling technique to prompt feedback from the user. A *during-test* questionnaire was used for this purpose, further details are discussed in section 6.5.

Figure 31: Diagram of meeting area, separated into three meeting zones: badge, card and no-tool (namely no-soObj). Each zone was marked with a written sign to remind users of the meeting mode required in each zone.

Figure 32: The actual meeting area with three meeting zones, simulating a speed-dating event. The room was a 4-by-4.5 m Performance Lab at the Media and Arts Technology research space, Queen Mary University of London.

Test Process

Introduction and Demonstration

Before the test event, participants were given an overview of the IBJ's features. It started with a short demonstration of using Social Cards, followed by instructions on how to navigate and a code of conduct when entering the social networking area. All participants were informed that the presentation of social compatibility on Social Cards and Social Badges derived from matching two participants' profiles and mutual preferences.

Group Allocation

To optimise the small number of test participants, nine people were separated into three groups. Literature suggests using randomised methods in designing experiments for HCI behavioural studies (Lazar, Feng, & Hochheiser, 2017, p. 33). Such methods help to eliminate intentional or unconscious influences by the researcher, but were not applicable to this study because of its small sample and unique requirement regarding groups of unknown participants. Some participants were studying at the same schools and/or course; fully randomised allocation might have compromised the requirement of people not knowing each other. Group allocation was thus non-random, with the condition that each group had three participants, all completely unknown to the members of the other two groups. Under these rules, the social situation became unfamiliar to all participants.

Test Rules

There was a set of rules the participants had to follow. Each participant was required to 1) wear an IBJ; 2) carry a set of social score cards; 3) start each meeting with a handshake; and 4) interact socially with a stranger, met at the event. The use of Social Cards was allowed only in the card zone; the use of IBJ's Social Badge was allowed only in the badge zone (Figure 31 and Figure 33).

Procedure

Figure 33 illustrates how three meeting sessions were organised to allow each of nine participants (A, B, C, D, E, F, G, H and I) to meet six unknown people. The meetings were broken into three 27-minute sessions, each containing three 6-minute rounds[38], with a 3-minute feedback session after each round. In each session, two groups of participants were allowed into the meeting area at a time. One group was assigned a non-mobile role: they remained throughout that session in the position at which they were placed on entering the area. Examples were participants A, B and C in Figure 33, who were assigned the non-mobile role in session *i*. Another group was assigned to rotate in an anti-clockwise direction to meet the next person in the following round. Examples are participants D, E and F in Figure 33, who were assigned the anti-clockwise role in session *i*. On completion of each session, the non-mobile group members were directed to a separate resting area. The anti-clockwise group stayed in the meeting area for session *ii*, in which they were asked to assume a non-mobile role.

Running the meeting event this way meant each participant had six opportunities to meet a stranger. This allowed 54 user feedback reports to be collected during the three meeting sessions, and nine more at the end of the testing event. Eighteen datasets were collected from each of the three meeting zones (namely badge, card, and no-soObj). The study took

38 Similar periods were used by Melchior and Cheek' (1990) in their experiment with self-reported shy people conversing with strangers. It is also the maximum time generally used in one-to-one speed-dating events (Turowetz & Hollander, 2012).

around 90 minutes to complete the 18 meetings, after which all participants were asked to give final feedback through a *post-test* questionnaire, marking the end of the event.

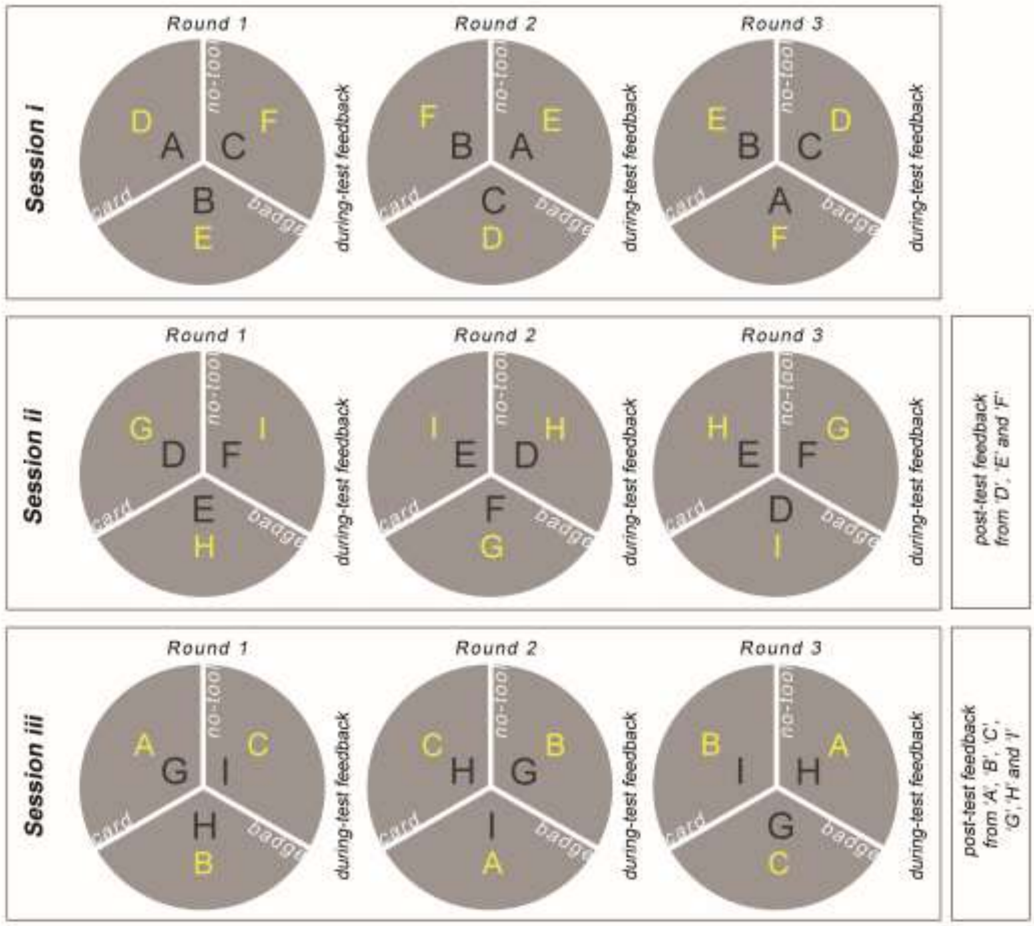


Figure 33: Schedule for three meeting sessions. Each session contained three 5-minute rounds, with a 3-minute questionnaire period (*during-test* QA).

6.2.Empirical Questions

In gathering the evidence for validating the assumptions (section 6.1.2), this study was conducted as a mixture of between-subject and within-subject studies. Such design allowed for comparisons across the three meeting modes, namely card, badge and no social-object display and two display modalities, namely Social Card (focal display) and Social Badge (subtle-peripheral display).

The following empirical questions (EQs) were formulated as guidelines for data collection and analysis. These EQs are categorised under four IV groups, each with a list of detailed questions relating to DVs of interest. The questions are:

Group 1 – Comparison among three meeting modes

- EQ1 – how and which meeting mode is most helpful to making conversation?
- EQ3 – which meeting mode provides the most satisfying social experience? Between 'having augmented social cues' in the meeting and 'not having cues', which meeting condition is more satisfying?
- EQ4 – which meeting mode is preferred?

Group 2 – Comparison between focal and peripheral displays

- EQ2 – which display modality makes the content more helpful to the overall social experience?
- EQ6 – which display modality does the user pay more attention to?

Group 3 – Comparison between social compatibility levels

- EQ5 – do higher compatibility levels have a greater impact on the attitude of the users towards their meeting partners?

Group 4 – Regarding different degrees of social anxiety among users, were any relationships identified between the levels of the user's anxiety, namely anxiety score measured with Mattick and Clark's (1998) social interaction anxiety scale (SIAS), and the ...

- EQ7 – preferred visibility of social cues (e.g. badge holds the greatest level of visibility, card the second, and no social cue the least)?
- EQ8 – user's satisfaction with specific meeting modes?
- EQ9 – helpfulness of social cues presented on the peripheral display?
- EQ10 – the impact of social compatibility on the user attitudes to meeting partners?
- EQ11 – user awareness of the display content of both modalities?

6.3.Data Collection Instruments

Users' self-reports through a questionnaire was the only method of data collection in this final study. Three questionnaires (QAs) – *pre-test*, *during-test* and *post-test* – are described below along the purposes and usages:

Pre-test QA (Appendix C.1) was used in the recruiting process as part of the invitation email. It comprised three parts, with close-ended questions designed to collect information about users' 1) demographics, 2) social preferences and 3) social anxiety. In part 2, respondents were asked to state the information they wished to find in potential meeting partners (e.g. field of research, study or work; academic status; and hobbies). Information from parts 1 and 2 was used to form criteria in the matching process and a compatibility score between each potential pair of users. Part 3 was the Mattick and Clarke's (1998) SIAS for assessing a person's anxiety when interacting with others. This part contained 20 psychometric statements, each offering five choices (from 0 to 4; maximum = 80 points from the 20 statements). The points from this part defined the SIAS score of each participant, needed in the data analysis.

During-test QA (Appendix C.2) included eight questions (namely seven 5-Likert and one open-ended) for all three meeting modes (no-soObj, card and badge). They were posed at every interval between meeting rounds. The participant had to complete the answers within 3 minutes, before moving on to meet the next interlocutor. The 3-minute period was crucial and was strictly timed, to 1) eliminate in-depth thoughts and manipulation of feedback; 2) reduce bias in self-reporting (discussed below); and 3) collect evidence that indicated whether – and the degree to which – the participant had paid attention to the social compatibility level[39] presented on each SO.

Post-test QA (Appendix C.3) consisted of 15 questions, clustered as closed- and open-ended. It was given to each participant after their second meeting session, when they had completed their overall testing. For example, as illustrated in Figure 33, participants D, E and F responded to this questionnaire after session *ii*; whereas A, B, C, G, H and I responded after session *iii*. In contrast to the *during-test* QA, response time was not strictly limited, due to the nature and number of the questions. Also, the goal was to draw reflective user feedback after repetitive experiences using different modalities of SOs and meeting modes.

The difference between the *during-test* and *post-test* questionnaires was not only the number of questions and time they required for completion, but also their features. The *during-test* QA was a quick feedback tool for gathering information about user response to small tasks, interaction details, attitudes toward interlocutors, ability to recognise and

[39] See Appendix C.5 for records of compatibility levels between test participants

understand the information presented on the SO, and user satisfaction. In contrast, the *post-test* QA score was used as a metric to assess the usability of peripheral display of social cues. It also allowed the user to reflect and express their overall meeting experience within the technology-embedded social situation. User responses from both questionnaires were coded into numerical data for quantitative analysis, as presented in subsections below.

6.4.Data Analysis and Results

This section presents six data-analysis series, corresponding to the empirical questions described in section 6.4. The first two series evaluated the usefulness of technology while the remainder focused on user experience in meeting strangers under different conditions, distinguished by display modalities for augmented social cues. Where possible, differences in user feedback given by the non-shy and shy groups, as classified by Peters' (2000) 36-SIAS[40] cut-off score, were examined. Those whose SIAS scores were less than 36 were classified as non-shy; those who scored 36 or higher were classified as shy. Each of six series (sections 6.4.1-6.4.6) provides details for simple descriptive and inferential statistics. The results were used for NHST and PST. The estimation of effect sizes, as required by PST, did not only quantify the magnitude of the difference, direction of the effect of interest, and the strength of the association between the user SIAS scores and variables of interest. It also substituted the limitation of large *p*-value results that were influenced by the small-sized samples available for all analysis series.

6.4.1. Helpfulness to Conversation Making

Overview of Analysis

Corresponding with EQ1, this analysis series compared the capacity of the card, badge and no-soObj meeting modes in helping participants to converse with strangers. In pilot study 2, users said that having the technology present was helpful to their meeting with strangers. This final study investigated in more detail the concept of such helpfulness. In the *post-test* questionnaire, participants were asked how helpful each meeting mode was to their conversation, since each meeting was arranged differently. To learn how these modes were helpful, three classifications of helpfulness (easing conversation initiation; promoting conversational topics; and helping to extend the duration of conversation)

[40] Measured on the social interaction anxiety scale (SIAS) (Mattick & Clarke, 1998), included in the *pre-test* questionnaire.

were defined. User responses for each mode were compared in three tests of difference, based on these classifications. In addition, the data were organised as obtained from three user groups (namely, non-shy, shy and overall-user groups). The latter group refers to all nine users.

Tests of Difference

Analysis Design and Data Preparation

The tests of difference examined user responses, collected from questions 11 to 13 of the *post-test* questionnaire. The tests were constructed as within-subject analyses; all nine users acted as the providers of ‘case’ and ‘control’ samples (namely ratings on three classifications of helpfulness for all meeting modes (namely badge, card and no-soObj). The user ratings for one meeting mode were paired with their responses to a second meeting mode; this approach provided paired scores for testing the difference (e.g., ‘badge vs. card’, ‘card vs. no-soObj’, and ‘badge vs. no-soObj’). User ratings were grouped according to non-shy, shy and all users. This approach yielded four, five and nine paired samples per meeting mode, as shown in the case summary table (Table_Apx C-1 in Appendix C). The number of non-shy and shy samples was extremely small when examining the three sub-classifications of helpfulness separately. Therefore, all ratings were combined to form an overall ‘helpfulness rating’ per user.

In all analysis groups, user response for each mode was treated as a DV. Two levels were translated to a binomial scale, with 0 indicating ‘not helpful’ and 1 meaning ‘helpful’. The meeting mode was treated as an IV with three categories (badge, card and no-soObj). The comparison for DV data was made in pairs, restricted by the chosen statistical method, discussed in the following subsection, where details about the characteristics of each group are also discussed. The test hypothesis is given as follows.

Test Hypothesis

- Users found the badge mode the most helpful, and no-soObj the least helpful, for initiating conversation, finding more conversation topics, and encouraging longer conversations.

Descriptive Statistics

This part describes the data used to investigate all three user groups, starting with the overall-user group and moving to non-shy and shy. The users' responses for mode were analysed as a bar chart, clustered for the binomial feedbacks of helpfulness. This chart was generated to observe the overall users' rating for each meeting mode (Figure 34). The charts revealed that the badge mode was the only environment in which users found it easier to initiate conversation and talk for longer, with more varied topics. The card mode was the least helpful for making longer conversation, and the no-soObj mode was the least helpful for encouraging more conversation topics.

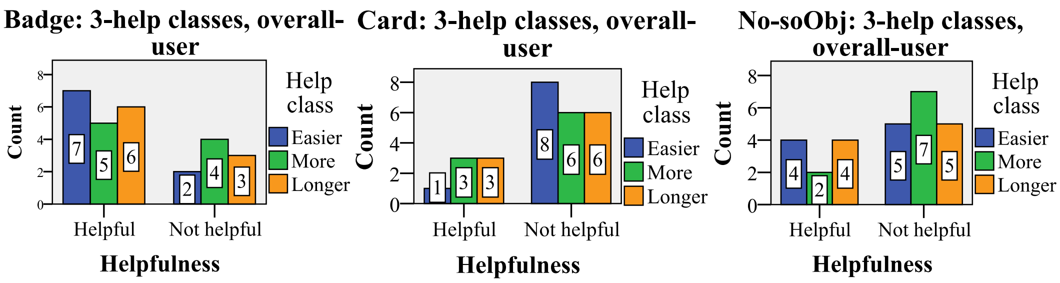


Figure 34: Clustered bar charts showing 3-class helpfulness ratings on three meeting modes, by overall-user group.

The clustered bar charts helped to make the comparisons for mode and helpfulness explicit. However, they lacked information such as the proportions of positive versus negative responses (helpful and not helpful) for each mode. They also did not show the change in responses when paired modes were compared. By setting up a 2 x 2 case-control contingency table (Agresti, 2002) for each pair of modes (see Table_Apx C-2 in Appendix C), presenting the differences in user ratings for each pair more clearly.

The badge-versus-card comparison showed that positive responses for the badge increased (namely changed from 'not helpful' to 'helpful') by 67% for easier initiation of conversation, and by 22% for more conversation topics. The badge ratings decreased by 33% for longer conversations. The badge-versus-no-soObj comparison showed that positive responses for the badge increased in all helpfulness classifications. They increased by 34% for easier to initiate conversations and more conversation topics, and 22% for encouraging longer conversations. The card-versus-no-soObj comparison showed that positive responses for the card increased by 33% for easier-to-initiate conversation, and 11% for more topics. However, the positive responses for the card dropped (namely changed from 'helpful' to 'not helpful') by 11% for longer conversations.

In an overview of these results (Figure 35), both non-shy and shy groups found the badges more helpful for conversation than not helpful. The card and no-soObj modes received more negative than positive ratings from both shy and non-shy users, as seen in a 2 x 2 case-control contingency table for each pair of modes (Table_Apx C-3, Appendix C). The badge-versus-card comparison showed that positive response from non-shy users increased by 33%, and from shy users increased by 47%. Similarly, the badge-versus-no-soObj comparison showed that positive responses from non-shy users increased by 25% and from shy users increased by 33%. In contrast, the badge-versus-no-soObj comparison showed that positive responses from non-shy users dropped by 8% and from shy users dropped by 13%.

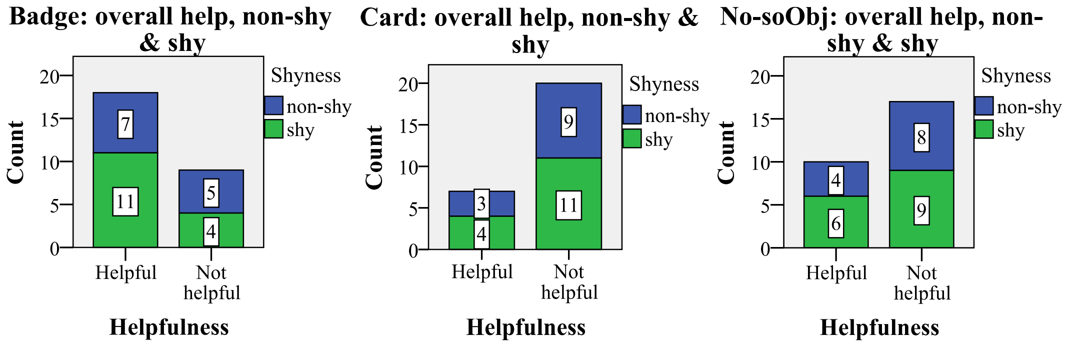


Figure 35: Stacked bar charts showing overall-helpfulness ratings on three meeting modes, by non-shy and shy groups.

Brief summary: The descriptive results supported the hypothesis that the badge meeting mode was the most helpful for conversation-making. However, the results did not allow for a determination of statistical significance, hence further analyses were needed.

Inferential Statistics

The outcome of descriptive analysis revealed some variation in user response rates for helpfulness across the paired meeting-modes. The NHST procedure called McNemar test (McNemar, 1947) with continuous correction (Edwards, 1948) was used to examine whether these changes (namely from ‘helpful’ to ‘not helpful’ or vice versa) were statistically significant at the $p<0.05$ level. Following this test structure, the proportions of changes in the positive responses of the ‘case’ meeting mode were compared to the proportions of changes in the positive response of the ‘control’ meeting mode (namely in the badge-versus-card comparison, badge was set as ‘case’ and card as ‘control’). This was to test the hypothesis that the proportion of ratings for paired modes differed, which would mean the null hypotheses (no difference between modes) could be rejected.

For the PST method, Cramer's phi coefficient (φ) for 2 x 2 tables (Cramér, 1962) was used instead of the common odds ratio (OR) (Ferguson, 2009). The OR resulted in NaN[41] due to zero entries for certain cell frequencies, which made it impractical to compare one effect size to another. Cramer's phi worked well to quantify the magnitude and direction of the changes in the user responses for any two meeting modes. A confidence interval for each phi effect size was obtained using the bootstrap[42] technique. Presented below, the test results are separated in three groups according to three types of users.

Overall-user Group

In this group, three classifications of helpfulness for the meeting modes were examined (class 1: help ease initiating conversation; class 2: help generating more conversation topics; and class 3: help in lengthening conversations). The analysis for each class was performed for three paired modes: 'badge vs. card' in pair 1, 'badge vs. no-soObj' in pair 2, and 'card vs. no-soObj' in pair 3. This analysis examined whether the difference in proportions for each pair was statistically and practically significant. The outcome for each pair was illustrated in a cross-tabulated bar chart (a result of McNemar test) and in tables of statistical and practical significance outputs. The structure for arranging data in all cross-tabulated bar charts was the same as that used to construct the 2 x 2 contingency tables for descriptive analysis (namely 'control' mode in rows and 'cases' in columns). Feedback from nine users was collected from each meeting mode.

Helpfulness Class 1: Helps to Initiate Conversation

The results of NHST[43] and PST (Table 14) appeared in conflict in two comparisons and in agreement in one comparison. The conflicting results are discussed as followed.

For the 'badge vs. no-soObj' comparison, results showed no statistically significant difference at $p<.05$ but were practically significant, with a positive 'large' effect size, based on Cohen's guidelines (Becker, 2000). Similarly, for the 'card vs. no-soObj' comparison, results showed no statistically significant difference at $p<.05$ but were

[41] NaN stands for 'Not a Number', a result of unpresentable floating points of outcome from a calculation.
[42] Using default 1000 samples available in SPSS statistical package
[43] See Figure_Apx 10 in Appendix C for graphical outputs of NHST results

practically significant, with a negative ‘large’ effect size. In other words, the NHST results indicated that users did not report differences in initiating conversations depending on the mode; in contrast, the PST results indicated that users found initiating conversations in badge mode easier than in no-soObj mode. They also found initiating conversation easier in no-soObj than in card mode.

For the non-conflicting results of the ‘badge vs. card’ comparison, results showed both statistical significance at p=.031 and practical significance, with a difference in user rating above Cohen’s threshold. This means the users found initiating conversation in badge mode easier than in card mode.

Table 14: Numerical results of McNemar tests (rectangle marks) and phi coefficient (φ) estimation (oval marks) of proportion changes in helpfulness class 1 (namely from ‘easier’ to ‘not easier’) of three comparative meeting modes, rated by overall-user group.

		Badge vs. Card	Badge vs. No-soObj	Card vs. No-soObj
Total N		9	9	9
Test Statistic		4.17	1.33	0.80
Degree Of Freedom		1	1	1
Exact Sig.(2-sided test)		0.031	0.250	0.375
Phi		0.19	0.48	-0.32
95% CI for Phi	Lower	0.10	0.20	-0.76
	Upper	0.50	1.00	-0.16

Brief summary: Based on the NHST outcome alone, the overall group rated ‘initiating conversation’ easier with badges than with cards. However, when the results of PST were included (Figure 36), strong evidence was noted that users found the badge more helpful than the card or no-soObj modes. Users also found no-soObj more helpful than card mode.

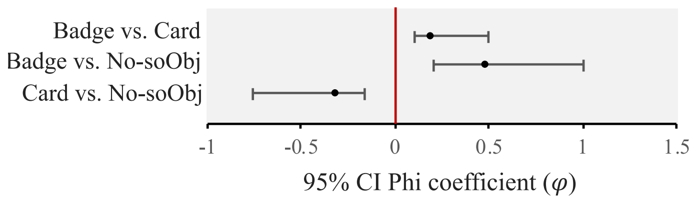


Figure 36: Forest plot showing effect sizes of proportion changes of helpfulness class 1 (namely from ‘easier’ to ‘not easier’) within in three comparative meeting modes, rated by overall-user group.

Helpfulness Class 2: Help Facilitate Conversational Topics

Similar to the above test results, there were two points of conflict between NHST[44] and practical statistics results (Table 15). For the 'badge vs. card' comparison, results showed not statistically significant at $p<.05$ but were practically significant, with a positive 'very large' Cohen's effect. Similarly, for the 'badge vs. no-soObj' comparison, results showed no statistical significance at $p<.05$ but were practically significant, with a positive 'very large' effect size. In other words, the NHST results indicated that users did not find these paired meeting modes facilitated more conversation topics, whereas the PST results indicated that users found the badge mode helped (more than either the card or no-soObj modes).

For the non-conflicting results from the 'card vs. no-soObj' comparison, the results showed neither statistical nor practical significance. This indicated that, users did not find either the card or the no-soObj meeting mode facilitated more conversation topics.

Table 15: Numerical results of McNemar tests (rectangle marks) and phi coefficient (φ) estimation (oval marks) of proportion changes in helpfulness class 2 (namely from 'more' to 'not more') of three comparative meeting modes, rated by overall-user group.

		Badge vs. Card	Badge vs. No-soObj	Card vs. No-soObj
Total N		9	9	9
Test Statistic		0.50	1.33	0.00
Degree Of Freedom		1	1	1
Exact Sig.(2-sided test)		0.500	0.250	1.000
Phi		0.63	0.48	0.19
95% CI for	Lower	0.32	0.19	-0.38
Phi	Upper	1.00	1.00	0.80

Brief summary: The NHST results suggested no difference between any meeting modes in terms of facilitating conversation topics. However, the effect sizes (Table 15; Figure 37) from the PST results indicated the badge mode was more effective than either the card or no-soObj modes.

[44] See Figure_Apx 11 in Appendix C for graphical outputs of NHST results

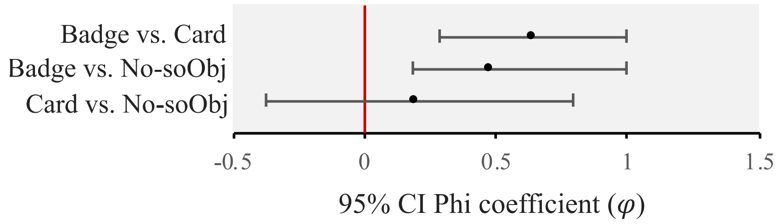


Figure 37: Forest plot showing effect sizes of proportion changes of helpfulness class 2 (namely 'more' to 'not more') within three comparative meeting modes, rated by overall-user group.

Helpfulness Class 3: Helps to Extend Conversation

The testing of this helpfulness class showed two points of conflict between NHST[45] and PST (Table 16) results. For the 'badge vs. card' and 'badge vs. no-soObj' comparisons, the results showed no statistical significance at p<.05 but were practically significant, with positive large to very-large effect sizes (based on Cohen). In other words, the NHST results indicated that users did not find these two modes different in encouraging longer conversations. However, the PST results showed an evidence of badges encouraging longer conversations more than the card or no-soObj conditions did. For the non-conflicting results of the 'card vs. no-soObj' comparison, results showed neither statistical nor practical significance. Hence, users did not find either the card or no-soObj mode encouraged longer conversations.

Table 16: Numerical results of McNemar tests (rectangle marks) and phi coefficient (φ) estimation (oval marks) of proportion changes in helpfulness class 3 (namely from 'longer' to 'not longer') of three comparative meeting modes, rated by overall-user group.

		Badge vs. Card	Badge vs. No-soObj	Card vs. No-soObj
Total N		9	9	9
Test Statistic		1.33	0.50	0.00
Degree Of Freedom		1	1	1
Exact Sig.(2-sided test)		0.250	0.500	1.000
Phi		0.50	0.63	0.32
95% CI for Phi	Lower	0.19	0.30	-0.38
	Upper	0.80	1.00	0.80

45 See Figure_Apx 12 in Appendix C for graphical outputs of NHST results

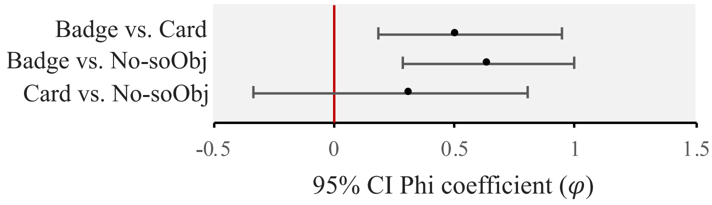


Figure 38: Forest plot showing effect sizes of proportion changes of helpfulness class 3 (namely 'longer' to 'not longer') within three comparative meeting modes, rated by overall-user group.

Brief summary: Considering the outcome of NHST alone could lead to a conclusion that there was no significant difference among all meeting modes. However, the effect sizes (Figure 38) from PST suggested that users found the badge mode encouraged them to make longer conversations, compared with the no-soObj and card modes.

Non-shy Group

As mentioned, the examination of three sub-classifications of helpfulness could not be made separately for the non-shy and shy groups because the samples were too small. For non-shy users, all their ratings[46] (four in each class) were combined to provide 12 data points of 'overall helpfulness'. Like other tests of difference in this series, McNemar tests for NHST and phi coefficient (effect size) for estimations for PST processes were employed.

Overall Helpfulness

All NHST results in this group disagreed with those from PST, as shown in McNemar test outputs[47] and phi effect-size calculations (Table 17). NHST results showed no statistical significance (at .05 significance level) in the change of user responses for all comparative meeting modes. This suggested that non-shy users did not find any difference in making conversion across all meeting modes. In contrast, PST results showed two practical significances with positive directions of change. For the 'badge vs. card', the change appeared close to the 'very large' effect size of Cohen's guidelines, and for 'badge vs. no-soObj', above the 'very large'. In addition, the PST results showed practical significance with a negative direction of change, close to a 'very large' effect

[46] see Table_Apx C-1 in Appendix-C for case summary

[47] See Figure_Apx 13 in Appendix C for graphical outputs of NHST results

size for ‘card vs. no-soObj’. This suggested that non-shy users found the badge mode more helpful to their conversation-making than the card or no-soObj modes. They also found no-soObj more helpful than card mode.

Table 17: Numerical results of McNemar tests (rectangle marks) and phi coefficient (φ) estimation (oval marks) of proportion changes in overall helpfulness (namely from ‘helpful’ to ‘not helpful’) of three comparative meeting modes, rated by non-shy group.

		Badge vs. Card	Badge vs. No-soObj	Card vs. No-soObj
Total N		12	12	12
Test Statistic		2.25	1.33	0.00
Degree Of Freedom		1	1	1
Exact Sig.(2-sided test)		0.125	0.250	1.000
Phi		0.49	0.60	-0.41
95% CI for Phi	Lower	0.24	0.32	-0.73
	Upper	0.85	1.00	-0.17

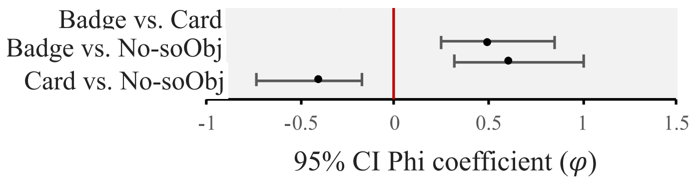


Figure 39: Forest plot showing effect sizes of proportion changes of the overall helpfulness (namely ‘helpful’ to ‘not helpful’) within three comparative meeting modes, rated by non-shy group.

Brief summary: Considering the outcome of NHST alone, no difference was noted among all meeting environments in terms of helping non-shy users to converse with other people. In contrast, the PST outcome (Figure 39) indicated that this user group found the badges significantly more helpful to their conversations than the no-soObj or card environments. In addition, they found the no-soObj mode more helpful than the card mode.

Shy Group

Following the same analytical approach, all ratings from shy users for the three sub-classifications of helpfulness were combined to form 15 rating data points for ‘overall helpfulness’. The ratings were examined using the McNemar test for NHST and phi effect-size calculation for PST processes.

Overall Helpfulness

There was a conflict in the NHST and PST results, a controversy of *p*-values (section 3.4.1) showed up in the result of the comparison of ‘badge vs. no-soObj’. It yielded *p*=.063, indicating not statistically significant (Table 18). The coefficient estimation resulted in practical significance, with a magnitude of change close to 'very large' (Cohen). In other words, NHST[48] results suggested that shy users did not find the badge more helpful than no-soObj, whereas PST indicated that they did.

Nonetheless, the two results were not in conflict. For the 'badge vs. card' comparison, the results showed both statistical significance (*p*=.016) and practical significance, with a positive change with a magnitude above 'large'. For the 'card vs. no-soObj' comparison, the results showed no statistical significance (at .05 significance level) or practical significance. These results suggested that shy users found the badge mode significantly helpful to their conversation-making, but felt no difference between card and no-soObj modes.

Table 18: Numerical results of McNemar tests (rectangle marks) and phi coefficient (φ) estimation (oval marks) of proportion changes in overall helpfulness (namely from 'helpful' to 'not helpful') of three comparative meeting modes, rated by shy group.

		Badge vs. Card	Badge vs. No-soObj	Card vs. No-soObj
Total N		15	15	15
Test Statistic		5.14	3.20	0.25
Degree Of Freedom		1	1	1
Exact Sig.(2-sided test)		0.016	0.063	0.625
Phi		0.36	0.49	0.43
95% CI for Phi	Lower	0.16	0.23	-0.15
	Upper	0.63	0.80	0.85

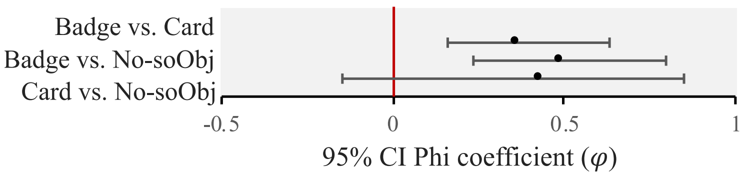


Figure 40: Forest plot showing effect sizes of proportion changes of the overall helpfulness (namely 'helpful' to 'not helpful') within three comparative meeting modes, rated by shy group.

Brief summary: Considering the outcome of NHST alone indicated that shy users found the badges more helpful than the cards, regarding their conversation-making. However, the PST outcome suggested that shy users found the badge mode more helpful than either the card or no-soObj modes.

Summary of Analysis

[48] See Figure_Apx 14 in Appendix C for graphical outputs of NHST results

This analysis series was conducted to test the hypothesis that the badge mode was the most helpful to users in making conversation; card mode came second; and meetings without SOs were the least helpful. Due to the limited number of samples, only the three sub-classes of helpfulness (‘easier’, ‘more’ and ‘longer’ conversations) could be applied in the assessment of the overall-user group (nine users). When assessing the helpfulness ratings by non-shy and shy users, the samples became simply too small (four and five people respectively) to parse into NHST and PST methods. Hence the evaluation was only made on the three sub-classes as ‘overall helpfulness’.

Following is a summary of all main results from the analyses. The NHST yielded large *p*-values possibly due to small samples. Estimation of phi effect sizes using the PST approach was therefore a substitute, on which the summaries below are based.

Tests of Difference:

- For overall users, evidence supports the hypotheses that the badge meeting mode was better for initiating conversation than either the card or no-soObj modes. The badge mode also helped more in initiating conversation, facilitated more conversation topics, and encouraged longer conversations. However, evidence indicated the no-soObj mode was more helpful to the overall-user group than card mode for initiating conversation. In addition, no results suggested that either the card or no-soObj mode was superior for facilitating conversation topics or longer conversations.

- For non-shy users, evidence supported the hypothesis that the badge mode improved their conversation-making over the card and no-soObj modes. However, this user group found no-soObj more helpful than cards – a result that differed slightly from the hypothesis.

- For shy users, moderate evidence supported the hypothesis that badges improved their conversation-making more than the card mode. Evidence that badges supported their conversations more than the no-soObj mode did was strong. However, there was no notable difference between the benefits of the card versus no-soObj modes.

6.4.2. Helpfulness to Meeting Experience

Overview of Analysis

These analyses were similar to the above series (section 6.4.1) in terms of assessing the usefulness of the technology. The difference is that while the above series examined specific classes of helpfulness related to the modes, the next series evaluated the overall helpfulness of the social cues. These cues corresponded to EQ2 and EQ9. For EQ2, users' ratings of the helpfulness of the Social Badge were compared to the Social Card. Three tests of difference were conducted to find out which display modality made the social cues more helpful to the overall meeting experience. The data for non-shy, shy and overall users were also examined. For EQ9, two tests of association were conducted to find out whether there was a correlation between the degree of social anxiety and the extent to which the user found each display modality useful to their meeting experience.

Tests of Difference

Analysis Design and Data Preparation

These tests of difference examined user responses to questions 4 and 5 of the *post-test* questionnaire. They were constructed as within-subject analyses, because each participant was subjected to both badge and card displays. The helpfulness of the displays was measured on 5-point Likert scales and converted to 5-point scores (from 1 for 'not very helpful to 5 for 'very helpful'). These became ordinal samples for DVs.

The helpfulness rating for card was used as the 'control' sample, and the badge as the 'case'. The display modality was set as the IV with two levels (namely badge and card). Therefore, the comparison between DV samples (e.g. helpfulness of badge vs. card) was repeated three times for the three user groups (non-shy, shy and overall). The test hypothesis is given as follows.

Test Hypothesis

- Users find the badge display more helpful than the card display when meeting with strangers.

Descriptive Statistics

This section describes the characteristics of the samples used to compare users' helpfulness ratings, categorised into non-shy, shy and overall-user groups. Figure 41 illustrates the frequency distribution of ratings for the badge and card displays, for comparison and to identify characteristics of each sample. Their numeric characteristics are listed in the key features table (Table_Apx C-4 in appendix C), which shows features such as measures of central tendency, dispersion and skewness.

The non-shy datasets were most skewed, whereas the shy and the overall-user groups had skewness values close to zero. These results implied the non-shy and overall groups did not perceive much difference in the helpfulness of badge versus card displays. Among these users, shy people found the badge more helpful to their meetings than the card display.

To make the distinction between the paired samples in all user groups more explicit, a parallel boxplot (Figure 42) was used as a visual aid. It suggests that shy users agreed more about the degree of card helpfulness than they did about the degree of badge helpfulness. When focusing on the average value of all datasets, the median of badge dataset in all user groups appeared greater than the median of card dataset. This implies that on average, all user groups found badges more helpful than cards.

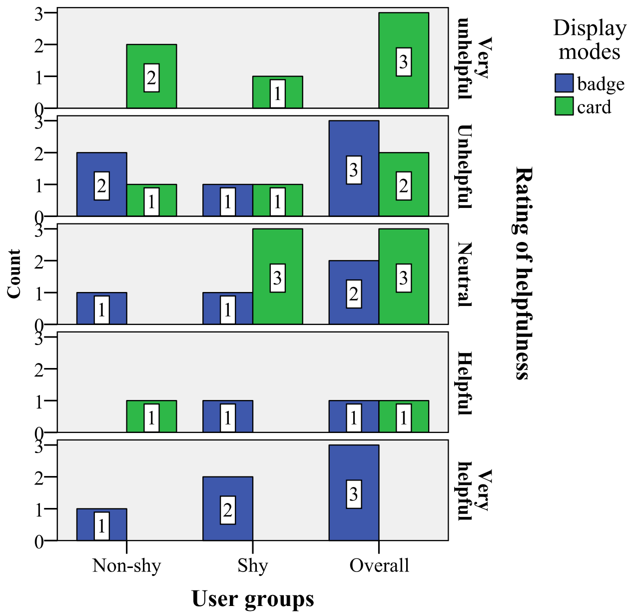


Figure 41: Group-case bar chart showing overall-helpfulness ratings on badge and card displays, by three user groups.

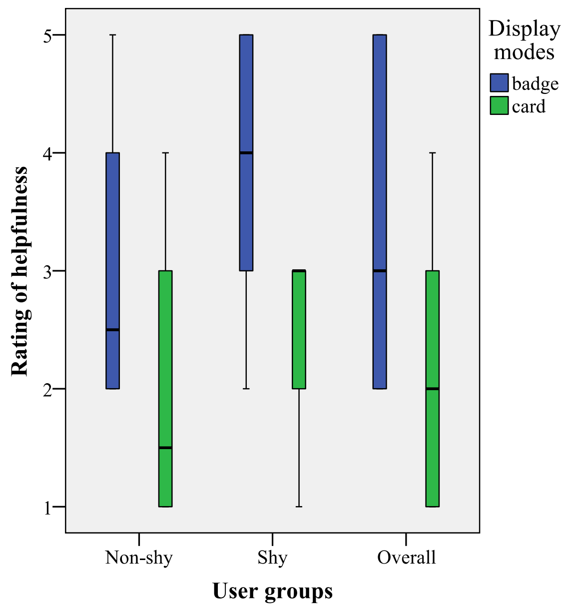


Figure 42: Parallel boxplots comparing overall-helpfulness ratings on badge and card displays, by three user groups.

Brief summary: Descriptive analysis showed that all datasets held some degree of skewness, addressing the need for a nonparametric statistical method in the following inferential analysis. In the comparison of average ratings for each pair of samples in all user groups, the results appeared to support the hypothesis that users found badges more helpful than cards, during their meetings.

Inferential Statistics

Because all three user groups found the badge and card displays different in assisting their meetings with strangers, these differences were examined whether yielding statistically and practically significant. The Wilcoxon signed-rank test was used as a statistical method for NHST, and Cohen's *d* effect-size estimation for PST. Wilcoxon signed-rank test was used to study whether the difference between the paired samples (namely, badge rating and card rating) was statistically significant at the .05 level, under the null hypothesis that their medians were equal. However, this method assumes the distribution of the paired differences was symmetrical (Laerd Statistics, 2017). A histogram (with a normal curve) was generated to see if the differences between the paired samples for all user groups met this assumption. The results, shown in Figure 43, indicated that the distribution of differences in non-shy samples was relatively symmetrical whereas those for shy and overall users were not. A statistical examination of the skewness of shy and overall-user samples was further conducted which resulted in -1.23 and -.50, respectively. These skewness values fell within acceptable limits for asymmetry, namely ±2 (Field, 2013; Gravetter & Wallnau, 2014; Trochim & Donnelly, 2006). Thus all the paired samples were suitable for the Wilcoxon signed-rank test.

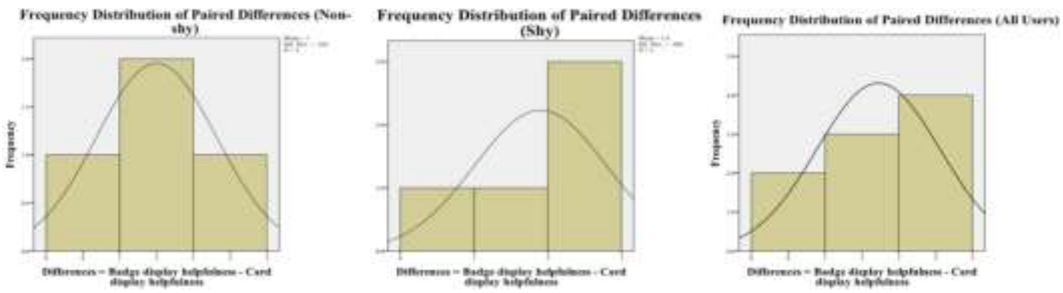


Figure 43: Histograms (with normal curves) showing distributions of difference between helpfulness ratings on badge and card, rated by non-shy (left), shy (middle), and overall-user (right) groups.

In each group, the differences between paired samples were computed by subtracting the ratings for card-mode from the ratings for badge-mode. This meant card was used as a 'control' sample and badge as a 'case' sample. This logic derived from an interest in whether the badge display led users to perceive it was more helpful to their meetings than the card display was. Hence, positive differences (of badge rating minus card rating) would mean that badges were more helpful than cards, and vice-versa for negative differences (namely cards were more helpful than badges). These differences were visually observed in the output bar chart of the Wilcoxon signed-rank test, illustrated as part of the test result of all user groups, and accompanied by the Cohen's *d* effect-size and its confidence interval (CI).

For non-shy ratings, the graphical outputs of NHST (top-left bar chart in Figure_Apx 15 in Appendix C) shows three positive-, zero negative-, and one tie- differences in the ratings. This means three non-shy users found badge displays more helpful than cards. No-one said the opposite, while one person said there was no difference between the displays. The increase in helpfulness rating *(Mdn=1)*, from card *(Mdn=1.50)* to badge *(Mdn=2.50)*, was neither statistically significant nor practically significant. This is indicated by a large asymptotic *p*-value (sig.) and CI for Cohen's *d* effect-size that approached zero (Table 19).

Table 19: Numerical results of Wilcoxon signed-rank test (rectangle marks) and Cohen's *d* effect size estimation (oval marks) of differences between helpfulness ratings on badge and card displays, by three user groups.

		Non-shy	Shy	Overall-user
Total N		4	5	9
Test Statistic		6.00	10.00	28.00
Standard Error		2	3	6
Asymptotic Sig.(2-sided test)		0.102	0.059	0.015
Cohen's *d*		0.71	1.25	1.01
95% CI for	Lower	-0.72	-0.10	0.02
Cohen's *d*	Upper	2.14	2.60	1.98

For shy ratings, the top-right bar chart shows four shy users found the badge (*Mdn=4)* display more helpful than the card *(Mdn=3).* None said the opposite, while one said there was no difference. However, like the non-shy results, this difference was neither statistically nor practically significant, because of the large *p*-value and the near-zero CI for effect size.

The result for the overall-user group was different from the other groups. The bottom-left bar chart in Figure_Apx 15 (in Appendix C) shows seven users found the badge (*Mdn=3*) more helpful than the card (*Mdn=2*) display, and two people said there was no difference. Both NHST and PST tests indicated that the difference was significant, close to 'very large' on Cohen's table.

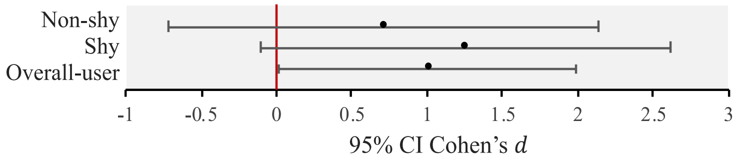


Figure 44: Forest plot showing effect sizes of differences between helpfulness of comparative displays (namely badge more helpful than card), rated by three user groups.

Brief summary: Users seemed to find the badge display more helpful than the card. This was both statistically and practically significant for the overall-user group, but not for the smaller (shy and non-shy) groups individually.

Tests of Association

Analysis Design and Data Preparation

In testing the relationship between users' SIAS scores and their ratings of helpfulness of the displays, the DV samples used in the tests of difference were retained as the DV in two tests of association. One test assessed whether SIAS score correlated with badge rating; another test assessed SIAS score and card rating. Nine cases were used in each DV sample, according to the number of participants in the experiment. Each of nine cases in both rating samples was paired with the SIAS score (IV) of the user who provided the rating, as shown in the case summary table (Table_Apx C-5 in Appendix C). The test hypothesis is given as follows.

Test Hypothesis

- There is an association between the degrees of SIAS score and helpfulness of display. The greater the user's anxiety, the more helpful they find the display.

Descriptive Statistics

The characteristics of both DV samples in this analysis did not differ from those used in the tests of difference (namely, ratings on badge and card) because the same datasets were the same as used in the tests of difference. However, their main features as shown in the key features table (Table_Apx C-6 in Appendix C) showed some degree of non-normal distribution. Therefore Shapiro-Wilk test of normality was employed to test all samples; the results (Table 20) showed that the badge distribution was significantly non-normal. This required a nonparametric test when choosing an inferential statistical method.

Table 20: Results (Sig. values) of Shapiro-Wilk test of normality of SIAS scores and helpfulness ratings on both displays

	SIAS score	Helpfulness rating on badge	Helpfulness rating on card
Statistic	0.93	0.83	0.88
df	9	9	9
Sig.	0.443	0.041	0.172

In a primary observation on the distribution of helpfulness ratings varied in relation to the SIAS scores, a scatterplot was used as a visual aid with R^2 value as a coefficient of determination (Figure 45). The plots indicated that the relationships existed, with a close to ‘large’ effect size of Cohen’s benchmark (Becker, 2000), with R^2=.19 for the ‘SIAS corr. badge’ case and R^2=.17 for the ‘SIAS corr. card’ case.

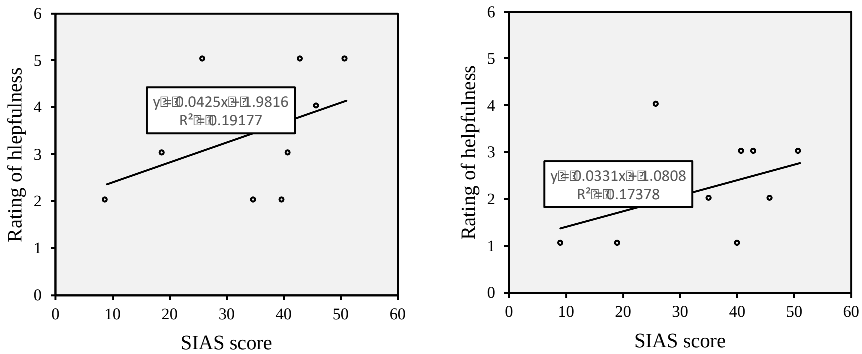


Figure 45: Scatterplots (with ‘fit’ line values) showing relationships between SIAS scores and helpfulness ratings on badge (left) and card (right) displays.

Brief summary: The R^2 coefficient values indicated that the relationships between the SIAS scores and the helpfulness ratings on both displays existed. However, as previously discussed, an R^2 value determination is based on the test assumption that the IV is predefined (McDonald, 2014a). Contrasting to the datasets obtained in this study, the IV sample was obtained using a randomised technique. Therefore, further analysis of these relationships is discussed in the following section.

Inferential Statistics

The outcome of descriptive analysis showed that an association existed between both paired samples (SIAS score and helpfulness rating for badge; and SIAS score and helpfulness rating for card). It also showed that the ratings for card were not normally distributed. This led to the selection of Spearman’s rho as the method for NHST; this method does not assume a normal distribution, unlike other statistical tests of association.

Using Spearman's rho, both paired samples were tested against the same null hypothesis, for which there was no monotonic relationship between the samples in either pair. The test was repeated in two cases (badge and card) to determine whether user ratings for either display were correlated significantly with the SIAS score. The test also signified the strength of the relationship in the correlation coefficient (*r*) parameter, part of PST.

On the association testing between badge ratings (ranging 2–5) and SIAS scores (ranging 9–51), the results of NHST and PST (Table 21) did not agree. There was no statistical significance, but there was practical significance at a 'very large' magnitude of association. This result corresponded with the preliminary analysis (Figure 45, left).

For the association testing between card ratings (2–5) and SIAS scores (9–51), both NHST and PST results (Table 22) showed no significant relationship.

Table 21: Numerical output of Spearman's rho test (rectangle marks) and correlation (*r*) estimation (oval marks) on the relationship between SIAS scores (9–51) and helpfulness ratings (2–5) on Social Badge, rated by overall-user group.

				SIAS score	Helpfulness rating
SIAS score	Correlation Coefficient			1.00	0.54
	95% CI for Correlation Coeffectient		Lower		0.09
			Upper		0.80
	Sig. (2-tailed)				0.136
	N			9	9
	Bootstrap[c]	Bias		0.00	-0.02
		Std. Error		0.00	0.30
		95% CI	Lower	1.00	-0.17
			Upper	1.00	0.96
Helpfulness rating	Correlation Coefficient			0.54	1.00
	95% CI for Correlation Coeffectient		Lower	0.09	
			Upper	0.80	
	Sig. (2-tailed)			0.136	
	N			9	9
	Bootstrap[c]	Bias		-0.02	0.00
		Std. Error		0.30	0.00
		95% CI	Lower	-0.17	1.00
			Upper	0.96	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Table 22: Numerical output of Spearman's rho test (rectangle marks) and correlation (r) estimation (oval marks) on the relationship between SIAS scores (9–51) and helpfulness ratings (1–4) on Social Card, rated by overall-user group.

				SIAS score	Helpfulness rating
SIAS score	Correlation Coefficient			1.00	0.45
	95% CI for Correlation Coeffectient		Lower		-0.30
			Upper		0.86
	Sig. (2-tailed)				0.224
	N			9	9
	Bootstrap[c]	Bias		0.00	-0.05
		Std. Error		0.00	0.37
		95% CI	Lower	1.00	-0.54
			Upper	1.00	0.94
Helpfulness rating	Correlation Coefficient			0.45	1.00
	95% CI for Correlation Coeffectient		Lower	-0.30	
			Upper	0.86	
	Sig. (2-tailed)			0.224	
	N			9	9
	Bootstrap[c]	Bias		-0.05	0.00
		Std. Error		0.37	0.00
		95% CI	Lower	-0.54	1.00
			Upper	0.94	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

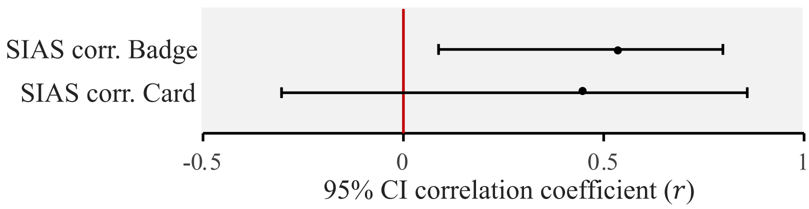


Figure 46: Forest plot showing effect sizes of correlation between SIAS scores and helpfulness ratings on badge and card displays, rated by overall-user group.

Brief summary: There was not enough evidence to suggest that a relationship exists between SIAS score and helpfulness of card display. However, the PST results suggested a correlation between SIAS score and helpfulness of badge display: the higher the SIAS score of a user, the more they found the badge helpful.

Summary of Analysis

This series of analyses examined the difference in the degree of helpfulness of the full-attention and peripheral modalities of SOs (Social Card and Social Badge), and whether the level of helpfulness was influenced by the degree of social-interaction anxiety. It was hypothesised that the badge was more helpful than the card, and the more severe the user's anxiety, the more helpful they found the badge – and the card less helpful. Like other analysis series, the following summary of test results was based on the outcome of PST, as substituting for the large *p*-values yielded by NHST.

Tests of difference:

- Consistent with the hypothesis, there was as evidence that the badge display was more helpful to the overall-user group than the card display. When users were categorised as non-shy and shy, the samples were too small for testing the hypothesis.

Tests of Association:

- There was evidence supporting the hypothesis that the degree of user's social-interaction anxiety influenced the extent to which they benefited from the badge display (not card). The higher the anxiety, the more they felt the badge helped in their meeting a stranger.

6.4.3. Impacts of Cued Content

Overview of Analysis

Corresponding to EQ5 and EQ10, these analyses assessed the impact of the content of social cues on user attitude towards meeting new people. Having seen different social-compatibility scores by the time they had completed all required meeting sessions, they were asked to rate the effect of these levels. For EQ5, the rating (higher or lower) was examined in three tests of difference to compare the impact of both levels on non-shy, shy and overall users. Two tests of association were conducted for EQ10 to find out whether there was an association between the degree of anxiety and the impact of levels of social compatibility.

Tests of Difference

Analysis Design and Data Preparation

These tests of difference examined users' responses to questions 6 and 7 of the *post-test* questionnaire. They were constructed as a within-subject study. Each participant had witnessed different social compatibility levels (1–5) presented on the display over several meeting sessions, after which they were asked how seeing these higher or lower levels affected their attitudes toward the meeting partner. There were three possible answer choices (negative impact, neutral and positive impact). These were then scored as -1 (negative) to 1 (positive). To determine whether – and how – compatibility levels impacted the participant's attitude, the social compatibility score (presented on the display) was assigned as the IV and the impact level as the DV. The IV had two levels (high and low) and required three comparative tests for each user group (non-shy, shy and overall). The test hypothesis is given as follows.

Test Hypothesis

- Higher social compatibility scores have greater impact on the user's attitude towards their meeting partners than lower scores do.

Descriptive Statistics

The primary examination of the sample characteristics started with a group-case clustered bar chart (Figure 47). It was unsurprising to see that higher compatibility scores had no negative impact on all user groups. What was surprising was that lower compatibility scores had a positive effect on users, most of whom were shy. A key features table (Table_Apx C-7 in Appendix C) and a parallel boxplot (Figure 48) were generated to reveal detailed characteristics of these samples. They indicated that lower compatibility scores had less impact than higher scores across all user groups. Non-shy users tended to be unaffected by the levels of social compatibility. In contrast, shy users' positive attitudes were mainly influenced by their witnessing higher compatibility levels. However, lower compatibility levels also influenced shy users' positive attitudes.

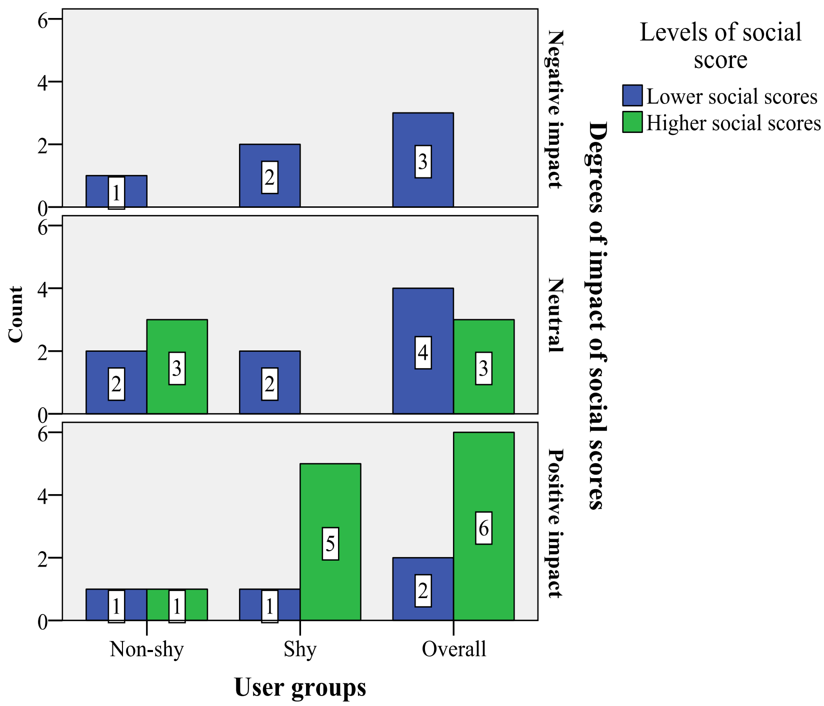


Figure 47: Group-case bar chart showing impact rates of lower and higher social-compatibility scores, by three user groups

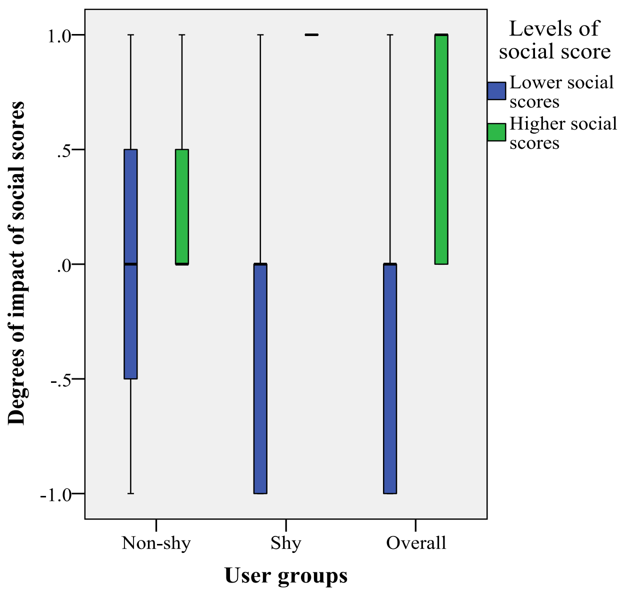


Figure 48: Parallel boxplots comparing impact rates of lower and higher social-compatibility scores, by three user groups.

Brief summSary: This primary observation on the characteristics of these datasets informed that non-shy users' attitudes were not affected by the information about social compatibility. In contrast, shy user' attitudes were affected and to a greater degree. Although their positive attitudes seemed to be influenced by seeing higher social compatibility scores, some shy users reported that lower compatibility scores also influenced their positive attitudes.

Inferential Statistics

To see whether the difference in impact of social-compatibility scores was statistically significant, Wilcoxon signed-rank test (because of the small samples for non-shy, shy and overall-user groups) was used. Their ratings of the effect of higher and lower compatibility scores were paired to compare the median values, as required by the Wilcoxon test. This test assumes the sample distributions are symmetrical. Therefore, a bar chart with a normal curve was generated for each sample to see if it met this assumption. The charts showed that the distributions of paired differences in all sample sets were relatively symmetrical (Figure 49), making the test a valid one.

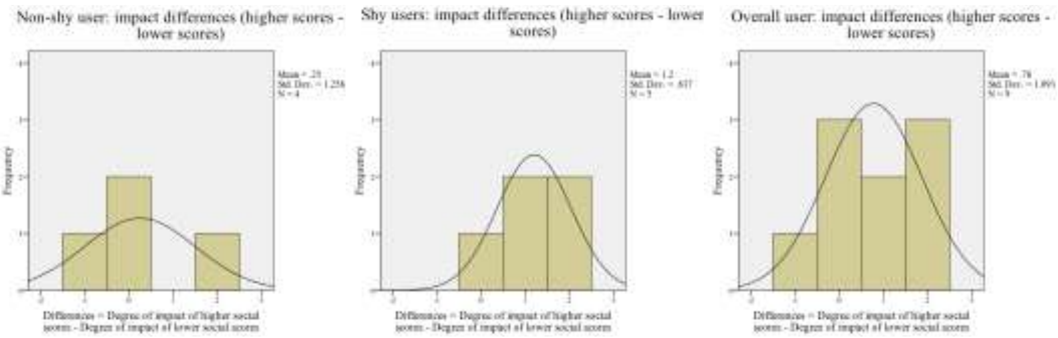


Figure 49: Histograms (with normal curves) showing distributions of difference between impact rates of higher and lower social-compatibility scores, rated by non-shy (left), shy (middle), and overall-user (right) groups.

The difference between each pair of samples was obtained by subtracting the median for the impact of lower compatibility scores from that of higher compatibility scores. This logic derived from an interest in seeing whether higher social-compatibility scores could influence the user to feel optimistic about their meeting partner. A positive difference between paired samples reflected the change in favour of higher social score (higher minus lower), and any negative difference reflected the change in favour of lower social score (lower minus higher). Like other analyses with the Wilcoxon signed-rank test, a .05 significance level was used to define whether NHST results were statistically significant. These results are presented visually (Figure_Apx 16 in Appendix C) and numerically

(Table 23) that also shows the results from PST (Cohen's *d* and range of estimation that determined the magnitude and direction of a difference between samples).

For the non-shy and shy groups, the NHST[49] and PST results agreed. There was no significant difference in the impact for varying degrees of social compatibility. This seemed to be an inherent feature of small samples. When they were combined to form a larger sample (overall users), some differences in the test results became more apparent. Although NHST yielded a relatively low *p*-value, it was not significant (*p*=.068) at the .05 significance level. However, PST results indicated a practical significance of the difference in the impact of the levels of social compatibility, with a magnitude close to 'very large' on Cohen's effect size benchmark, in favour of higher social compatibility levels.

Table 23: Numerical results of Wilcoxon signed-rank test (rectangle marks) and Cohen's *d* effect size estimation (oval marks) of differences between impact rates on higher and lower social-compatibility score, by three user groups.

		Non-shy	Shy	Overall-user
Total N		4	5	9
Test Statistic		2.00	10.00	19.00
Standard Error		1.12	2.69	4.66
Asymptotic Sig.(2-sided test)		0.655	0.063	0.068
Cohen's *d*		0.37	1.35	1.02
95% CI for	Lower	-1.03	-0.02	0.32
Cohen's *d*	Upper	1.77	2.73	1.71

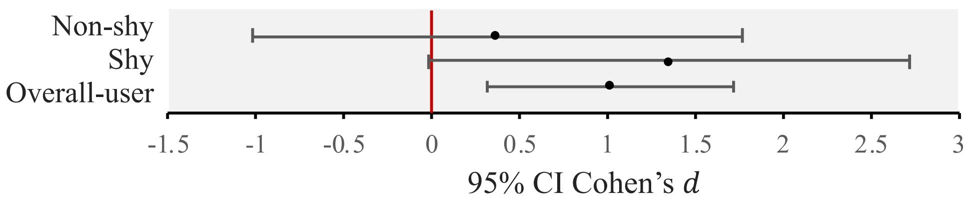


Figure 50: Forest plot showing effect sizes of differences between impact rates of social-compatibility scores (namely higher scores have greater impact than lower), by three user groups.

Brief summary: Users' attitudes seemed to be more affected by high social-compatibility scores than by lower scores. This conclusion is based on feedback from the overall-user group, for which the data were pooled to provide a larger sample.

Tests of Association

[49] See Figure_Apx 16 in Appendix C for graphical outputs of NHST results

Analysis Design and Data Preparation

In the examination of relationship between users' social-interaction anxiety and the impact of social-compatibility scores, the DV samples as used for the overall-user group in the tests of difference remained in these tests of association. Both samples of the score levels were related with each user's SIAS score (the IV), as shown in the case summary table (Table_Apx C-8 in Appendix C). The test of association in this series required two repetitions, based on the number of social-compatibility scores (namely, lower and higher). The test hypothesis is given as follows.

Test Hypothesis

- There is an association between social-interaction anxiety and degree of impact of social-compatibility scores (higher or lower) on the user's attitude towards the meeting partner. The higher the user's anxiety, the greater the impact of the score.

Descriptive Statistics

The initial observation on the required datasets was made by generating a key features table (Table_Apx C-9 in Appendix C), and running Shapiro-Wilk test of normality. The results indicated non-normal distributions in the ratings on the impact of lower and higher social-compatibility scores (Table 24). These addressed the need for a nonparametric statistical method for tests in the inferential analysis.

Table 24: Results (Sig. values) of Shapiro-Wilk test of normality of SIAS scores and impact rates on lower and higher social-compatibility scores

	SIAS score	Impact of lower scores	Impact of higher scores
Statistic	0.93	0.84	0.62
df	9	9	9
Sig.	0.443	0.055	0.000

The relationships between the variables were examined using scatterplots with 'fit' line values (R^2), to see whether the SIAS scores were associated with the degree of impact of the social score. The results (Figure 51) showed that the relationships existed (namely, R^2=.09 for the 'SIAS score corr. impact of lower social score' case and R^2=.54 for the 'SIAS score corr. impact of higher social score' case).

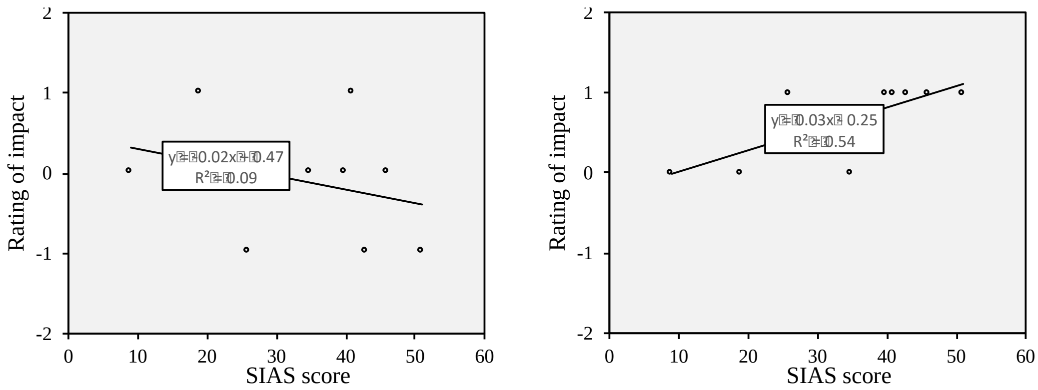


Figure 51: Scatterplots (with 'fit' line values) showing relationships between SIAS scores (from 9 to 51) and impact rates (from -1 to 1) of higher (left) and lower (right) social scores, rated by overall-user group.

Brief summary: This primary data observation revealed that the SIAS scores appeared associating with both ratings on the impact of lower and higher social-compatibility scores. The R^2 for SIAS score as correlated with lower social scores was close to zero, but considered greater than the minimum threshold of Cohen's benchmark for effect size and hence worth further investigated.

Inferential Statistics

The descriptive analysis showed there was a relationship between SIAS score and the degree of impact of the social scores on the user's attitude, regarding the augmented social display used in the experiment. This section presented the outcome of NHST and PST regarding this relationship. Spearman's rho was used as the testing method for NHST, at .05 significance level. The null hypothesis was that a monotonic relationship did not exist between matched samples. Given that there were two social score levels to investigate, the test was performed on two cases. One case was for testing the relationship between SIAS score and the degree of impact of lower social score, and another between SIAS score and the degree of impact of higher social score.

The test results indicated a statistically and practically significant relationship between SIAS scores and the degree of impact of higher social-compatibility scores with a 'huge' correlation magnitude (Table 26) based on Cohen's benchmark, between SIAS scores and the higher social-compatibility scores.

Table 25: Numerical outputs of Spearman's rho test (rectangle marks) and correlation (*r*) estimation (oval marks) on the relationship between SIAS scores (9 to 51) and impact rates (-1 to 1) on lower social-compatibility scores, rated by overall-user group.

				SIAS score	Impact of lower social score
SIAS score	Correlation Coefficient			1.00	-0.36
	95% CI for Correlation Coeffectient		Lower		-0.83
			Upper		0.40
	Sig. (2-tailed)				0.347
	N			9	9
	Bootstrap[c]	Bias		0.00	0.02
		Std. Error		0.00	0.34
		95% CI	Lower	1.00	-0.87
			Upper	1.00	0.46
Impact of lower social score	Correlation Coefficient			-0.36	1.00
	95% CI for Correlation Coeffectient		Lower	-0.83	
			Upper	0.40	
	Sig. (2-tailed)			0.347	
	N			9	9
	Bootstrap[c]	Bias		0.02	0.00
		Std. Error		0.34	0.00
		95% CI	Lower	-0.87	1.00
			Upper	0.46	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Table 26: Numerical outputs of Spearman's rho test (rectangle marks) and correlation (*r*) estimation (oval marks) on the relationship between SIAS scores (9 to 51) and impact rates (-1 to 1) on higher social-compatibility scores, rated by overall-user group.

				SIAS score	Impact of higher social score
SIAS score	Correlation Coefficient			1.00	0.73
	95% CI for Correlation Coeffectient		Lower		0.13
			Upper		0.94
	Sig. (2-tailed)				0.025
	N			9	9
	Bootstrap[c]	Bias		0.00	-0.03
		Std. Error		0.00	0.16
		95% CI	Lower	1.00	0.32
			Upper	1.00	0.90
Impact of higher social score	Correlation Coefficient			0.73	1.00
	95% CI for Correlation Coeffectient		Lower	0.13	
			Upper	0.94	
	Sig. (2-tailed)			0.025	
	N			9	9
	Bootstrap[c]	Bias		-0.03	0.00
		Std. Error		0.16	0.00
		95% CI	Lower	0.32	1.00
			Upper	0.90	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

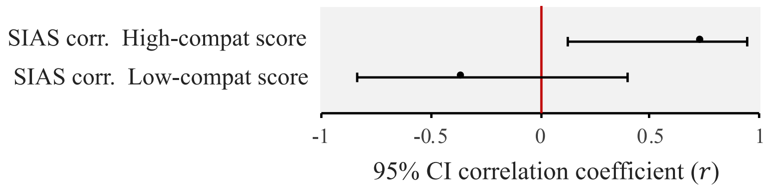


Figure 52: Forest plot showing effect sizes of correlation between SIAS scores and impact rates on higher and lower social-compatibility scores, rated by overall-user group.

Brief summary: Spearman's rho test results indicated that users' positive attitudes tended to correlate with higher social-compatibility scores. Spearman's rho typically does not distinguish between DV and IV. However, arranging IV (SIAS score) on the horizontal axis and DV (degree of impact) on the vertical axis yielded the scatterplot (Figure 51, right). This allowed for the conclusion that the degree of impact of higher social scores was influenced by the degree of social-interaction anxiety.

Summary of Analysis

This analysis series test two hypotheses relating to the impact of social compatibility levels displayed on the Social Badge and Social Card. The first was made under a hypothesis that higher levels have a greater impact on user attitudes towards the meeting than do lower levels. Like other analysis series involving comparative hypotheses, the first required three tests of difference to examine the relevance of this hypothesis for all user groups (non-shy, shy and overall users). The second was made under a hypothesis that there is an association between the degree of social-interaction anxiety and the degree of impact of higher or lower score levels. This required two tests of association. Main findings are listed as follows.

Tests of Difference:

- Comparing degrees of impact of lower and higher social scores, there was evidence suggesting the attitude of the overall-user group towards their meeting partners was influenced only by higher social compatibility scores, not by lower scores. The samples were too small to conduct statistical tests on the shy and non-shy users' feedback separately.

Tests of Association:

- There was evidence suggesting that the severity of a user's social-interaction anxiety influenced the way higher social compatibility levels impacted their attitudes towards the meeting partners; the higher the anxiety, the greater impact of the higher social-compatibility scores become.

6.4.4. Satisfaction with Meeting Experience

Overview of Analysis

For the responses to EQ3 and EQ8, user-satisfaction ratings for social experience in all meeting modes (in relation to user SIAS scores) were compared. Several statistical analyses were carried out using tests of difference and tests of association. For the tests of difference, the ratings of satisfaction given to three meeting modes were compared. This was to identify which mode offered the best meeting experience, and whether the augmented social cues present in the meeting provided a better user experience compared with no cues present. For tests of association, user satisfaction was examined to see if users' SIAS scores correlated with satisfactory ratings for experience, for all meeting modes and conditions.

Tests of Difference

Analysis Design and Data Preparation

These tests of difference examined user feedback from question 8 of the *during-test* questionnaire, structured as between-subject analysis. Three comparative samples (satisfactory ratings on badge, card and no-soObj meeting modes) were drawn from non-identical sources. Each of nine participants participated in unequal numbers of each meeting modes. For detail, see case summary table (Table_Apx C-10, in Appendix C) that shows each sample containing 18 cases, some of which were provided by participants who participated once in each meeting mode while some participated repetitively in each meeting mode, regarding the nature of RTCs. Therefore, all three samples were treated as obtained from non-identical (namely non-matched) user groups. Participants were asked to rate their satisfaction on a 5-point Likert scale, which was later mapped onto an ordinal 5-score format (1 for 'very unsatisfied' and 5 for 'very satisfied'). To examine which meeting mode offered the most satisfied experience and which meeting condition ('with-social-cue' and 'without-social-cue') offered better experiences, four related pairs of samples were prepared for four comparative cases ('badge vs. card', 'badge vs. no-soObj', 'card vs. no-soObj', 'with-social-cue vs. without-social-cue'). For the comparison of the with and the without social cues, data for the badge and card meeting modes were pooled and used as a ‘with-social-cue’ set. Data from no-soObj meeting mode was used as a ‘without-social-cue’ set. The comparison of every pair was repeated three times, once for each user group (non-shy, shy, and overall users). The test hypotheses are given as follows.

Test Hypotheses

- Badge meeting mode provides the most satisfying social experience, and no-soObj mode provides the least satisfying social experience.
- User experience is more satisfying when an augmented social cue is present (regardless of whether badge or card display) than when no cue is present.

Descriptive Statistics

On the observation of sample characteristics, a cluster bar chart (Figure 53–Figure 56) and key features table (from Table_Apx C-11 to Table_Apx C-14 in Appendix C) were generated for each related pairs of samples. Together they revealed that none of the meeting modes and conditions received a ‘unsatisfied’ rating. The lowest rating for badge mode was ‘neutral’; for other modes the lowest rating was ‘unsatisfied’. Most non-shy users rated their experience in no-soObj mode relatively high compared to card mode. Their experiences for badge and no-soObj modes did not seem different. Experiences with and without augmented social cues did not differ. Shy users seemed most satisfied with their experience in badge mode, and more satisfied with the social-cue meeting condition than without-cue.

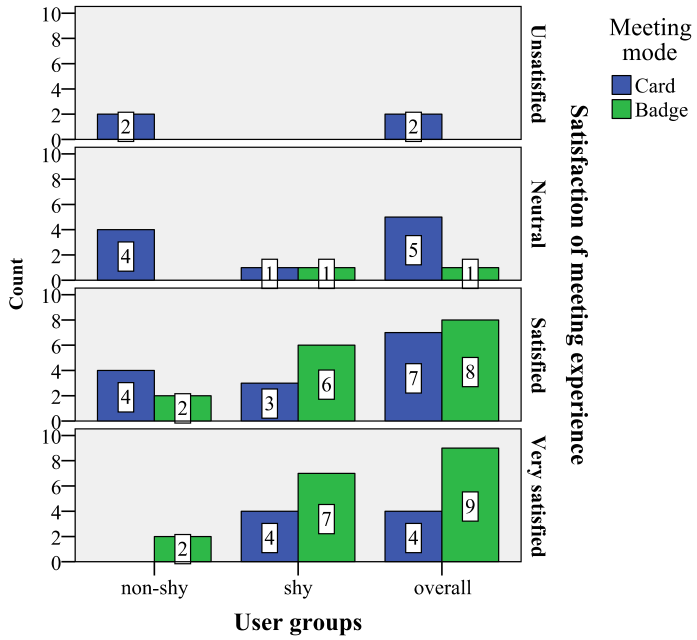


Figure 53: Group-case bar chart showing frequency distributions of satisfactory ratings on meeting experiences in two comparative meeting modes (namely 'badge vs. card'), rated by three user groups.

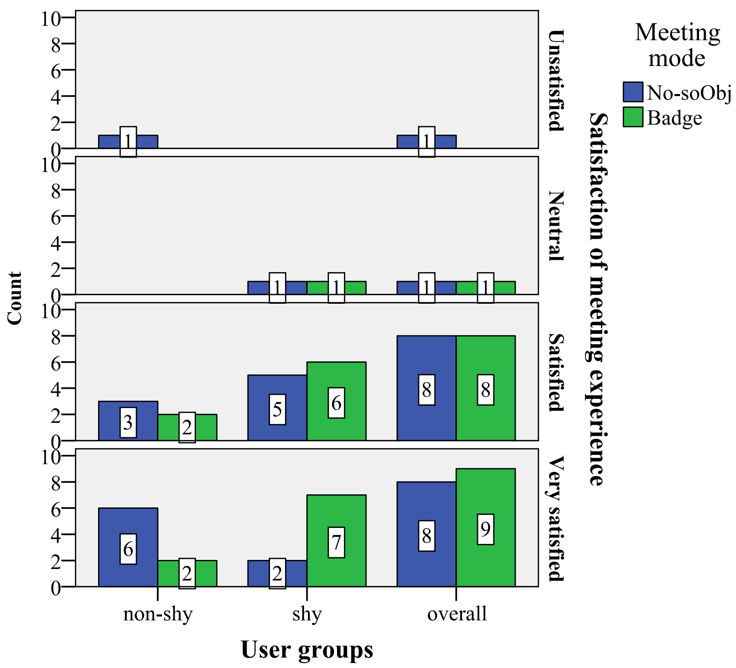


Figure 54: Group-case bar chart showing satisfactory ratings on meeting experiences in two comparative meeting modes, by three user groups.

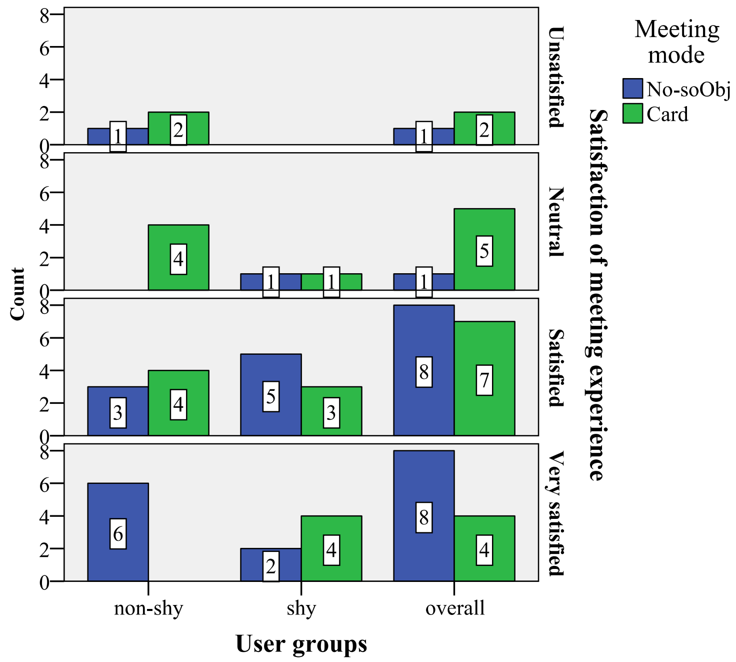


Figure 55: Group-case bar chart showing satisfactory ratings on meeting experiences in two comparative meeting modes, by three user groups.

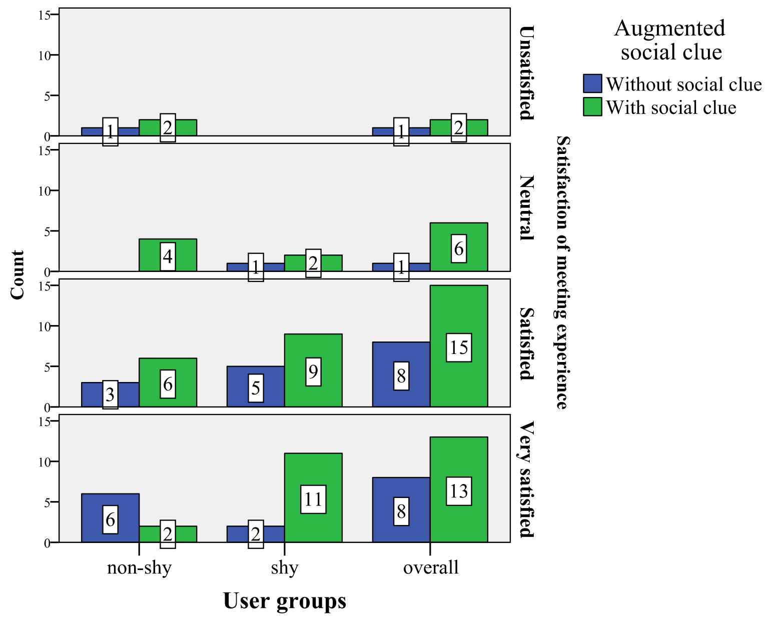


Figure 56: Group-case bar chart showing satisfactory ratings on meeting experiences in two comparative meeting conditions, by three user groups.

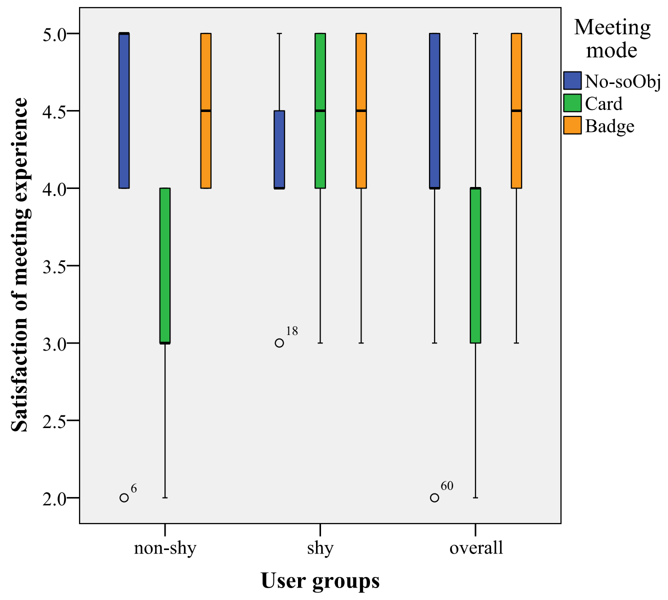


Figure 57: Parallel boxplots comparing satisfactory ratings on meeting experience in three comparative meeting modes, rated by three user groups.

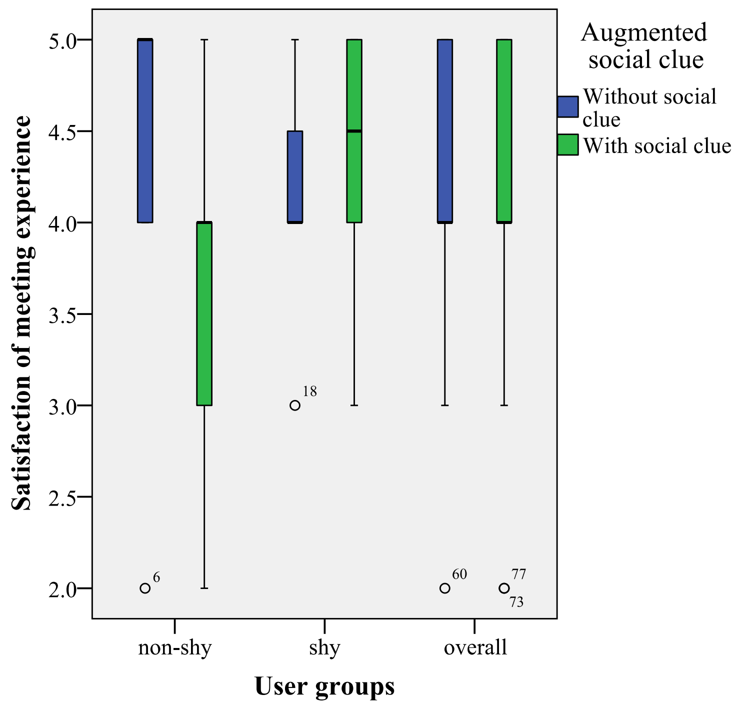


Figure 58: Parallel boxplots comparing satisfactory ratings on meeting experience in two comparative meeting conditions, by three user groups.

The differences in sample characteristics became more explicit when observed in parallel boxplots (Figure 57, Figure 58). The most satisfying meeting experience for non-shy users was in no-soObj mode; the least was in card mode. This contrasted with shy users, who were least satisfied with the no-soObj experience. Similarly, non-shy users seemed more satisfied with their experience in the without-social-cue meeting condition than any other.

Brief summary: This primary observation on the sample characteristics suggested that shy users seemed most satisfied with the badge and with-social-cue meeting experiences. In contrast, non-shy users seemed most satisfied with the no-soObj and without-social-cue meeting experience.

Inferential Statistics

To examine whether the differences in each non-pair of samples were statistically and practically significant, Mann-Whitney U test (at .05 significance level) was used for NHST and Cohen's *d* effect size for PST. With a hypothesis set out as the medians of samples in each pair were equal (Mann & Whitney, 1947), the test assumes that the distributions of any pair of non-matched samples are similar, otherwise the comparison of samples needs to be made on the mean ranks instead of medians (M. Hollander, Wolfe, & Chicken, 2014; Wilcox, 1992). Bi-histogram charts (Figure 59 to Figure 62) provide a visual aid for testing this assumption. They revealed that only the shy samples in the 'badge vs. card' case, the shy and overall-user samples in the 'badge vs. no-soObj' cases, all samples in the 'card vs. no-soObj' cases, and the overall-user samples in the 'with-social-cue vs. without-social-cue' case met this assumption. Therefore, these comparative pairs of non-matched samples were assessed using their medians. Other groups were assessed based on their mean rankings.

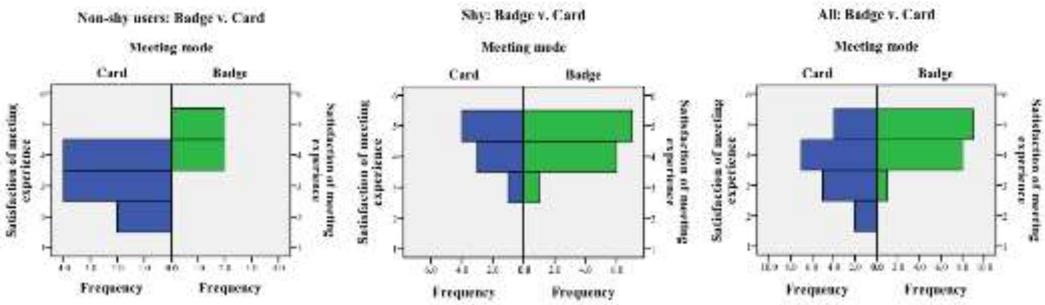


Figure 59: Bi-histograms comparing distribution shapes between satisfaction ratings on badge and card meeting modes, rated by non-shy (left), shy (middle), and overall-user (right) groups.

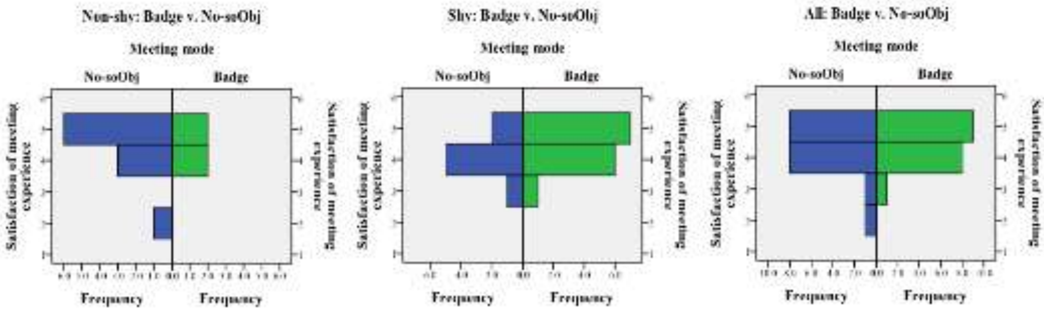


Figure 60: Bi-histograms comparing distribution shapes between satisfaction ratings on badge and no-soObj meeting modes, rated by non-shy (left), shy (middle), and overall-user (right) groups.

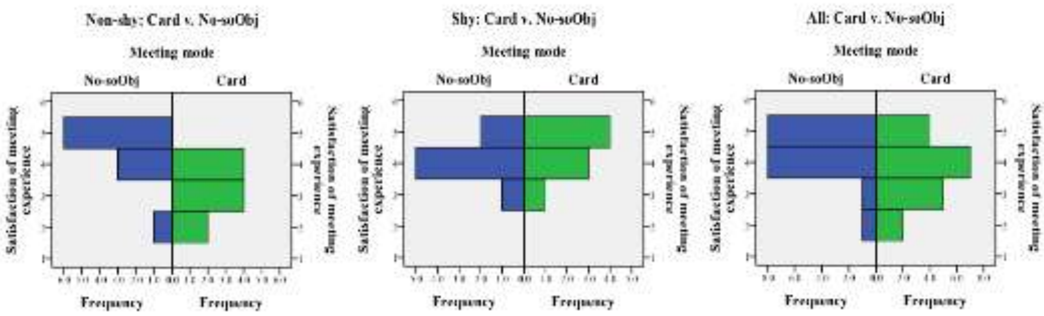


Figure 61: Bi-histograms comparing distribution shapes between satisfaction ratings on card and no-soObj meeting modes, rated by non-shy (left), shy (middle), and overall-user (right) groups.

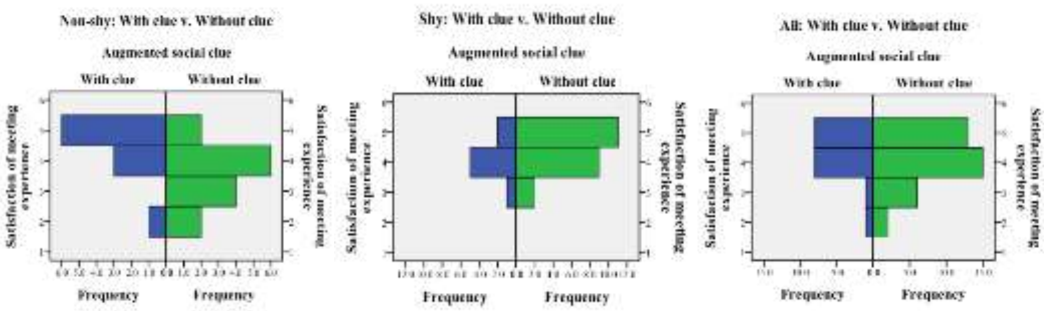


Figure 62: Bi-histograms comparing distribution shapes between satisfaction ratings on with-social-cue and without-social-cue meeting conditions, rated by non-shy (left), shy (middle), and overall-user (right) groups.

Badge vs. Card Mode

To compare users' satisfaction ratings for the badge and card meeting experiences, both NHST and PST (Table 27; Figure 63) were used. The results showed significant differences only for the non-shy and overall-user groups. They indicated a 'huge' (non-shy group) and 'large' (overall-user group) effect sizes in favour of badge experience, basing on Cohen's benchmark.

Table 27: Numerical results of Mann-Whitney U test (rectangle marks) and Cohen's *d* effect size estimation (oval marks) of differences between satisfactory ratings on meeting experience in badge and card meeting modes, by three user groups.

		Non-shy	Shy	Overall-user
Total N		14	22	36
Mann-Whitney U		36.00	57.50	232.50
Std. Error		6.70	13.17	29.59
Std. Test Statistic (Z)		2.39	0.11	2.38
Asymptotic Sig.(2-sided test)		0.017	0.909	0.017
Cohen's *d*		1.75	0.08	0.90
95% CI for	Lower	0.42	-0.79	0.21
Cohen's *d*	Upper	3.08	0.95	1.58

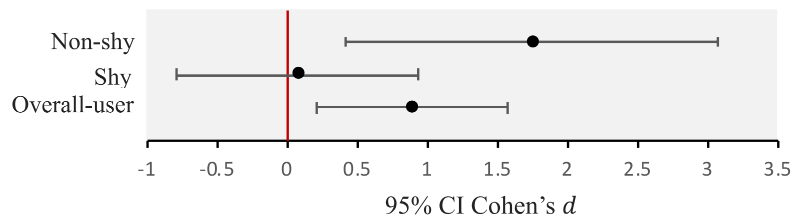


Figure 63: Forest plot showing effect sizes of differences between user satisfaction on meeting experience (namely badge meeting is more satisfied than card meeting), rated by three user groups.

Brief summary: The non-shy and overall-user groups found the meeting experience in badge mode to be more satisfying than the card meeting mode. The shy user group found no real difference in terms of satisfaction.

Badge vs. No-soObj Mode

For the comparison between badge and no-soObj meeting experiences, NHST and PST (Table 28; Figure 64) results showed no significant difference for any user group.

Table 28: Numerical results of Mann-Whitney U test (rectangle marks) and Cohen's *d* effect size estimation (oval marks) of differences between satisfactory ratings on meeting experience in badge and no-soObj meeting modes, by three user groups.

		Non-shy	Shy	Overall-user
Total N		14	22	36
Mann-Whitney U		19.00	70.50	175.50
Std. Error		6.21	13.17	28.40
Std. Test Statistic (Z)		-0.16	1.10	0.48
Asymptotic Sig.(2-sided test)		0.872	0.271	0.635
Cohen's *d*		0.11	0.47	0.23
95% CI for	Lower	-1.05	-0.41	-0.43
Cohen's *d*	Upper	1.27	1.35	0.88

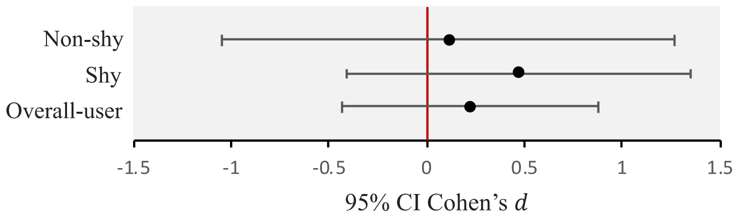


Figure 64: Forest plot showing effect sizes of differences between user satisfaction on meeting experience (namely badge meeting is more satisfied than no-soObj meeting), rated by three user groups.

Brief summary: No users seemed to find their meeting experiences in any meeting mode more satisfying than another.

Card vs. No-soObj Mode

The results of both NHST and PST showed that only the difference in satisfactory ratings for the non-shy group was statistically and practically significant (Table 29; Figure 65), with a magnitude size above 'very large' according to Cohen's benchmark, in favour of no-soObj mode.

Table 29: Numerical results of Mann-Whitney U test (rectangle marks) and Cohen's *d* effect size estimation (oval marks) of differences between satisfactory ratings on meeting experience in card and no-soObj meeting modes, by three user groups.

		Non-shy	Shy	Overall-user
Total N		20	16	36
Mann-Whitney U		15.00	39.00	106.50
Std. Error		12.70	8.64	29.75
Std. Test Statistic (Z)		-2.76	0.81	-1.87
Asymptotic Sig.(2-sided		0.006	0.418	0.062
Cohen's *d*		-1.36	0.36	-0.62
95% CI for	Lower	-2.33	-0.63	-1.29
Cohen's *d*	Upper	-0.39	1.35	0.05

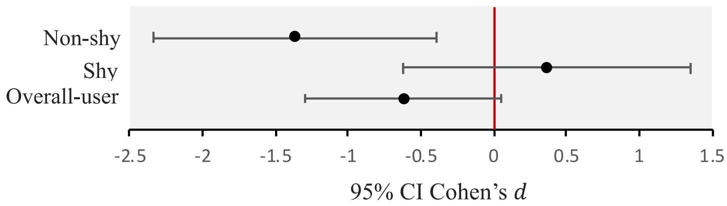


Figure 65: Forest plot showing effect sizes of differences between user satisfaction on meeting experience (namely card meeting is more satisfied than no-soObj meeting), rated by three user groups.

Brief summary: Only non-shy users appeared to be more satisfied with their meeting experience in no-soObj mode than card mode. This evidence did not support the hypothesis.

With-social-cue vs. Without-social-cue Condition

There was a conflict in the NHST and PST results (Table 30) for the comparison of user satisfaction in their experiences in with-social-cue and without-social-cue meeting conditions. The difference in the ratings by overall-user groups was not statistically significant but was practically significant. Other test (NHST and PST) results for the comparison of non-shy and shy samples appeared in agreement. The difference in non-shy ratings was statistically and practically significant in favours of the without-social-cue meeting condition. The effect size of the difference was indicated 'large' based on Cohen's benchmark. No significant difference was noted for the shy samples.

Table 30: Numerical results of Mann-Whitney U test (rectangle marks) and Cohen's *d* effect size estimation (oval marks) of differences between satisfactory ratings on meeting experience in with-social-cue and without-social-cue meeting conditions, by three user groups.

		Non-shy	Shy	Overall-user
Total N		24	30	54
Mann-Whitney U		34.00	109.50	282.00
Std. Error		16.25	19.27	50.59
Std. Test Statistic (Z)		-2.22	1.12	-0.83
Asymptotic Sig.(2-sided test)		0.027	0.265	0.406
Cohen's *d*		-0.87	0.43	3.74
95% CI for	Lower	-1.72	-0.39	2.83
Cohen's *d*	Upper	-0.02	1.25	4.64

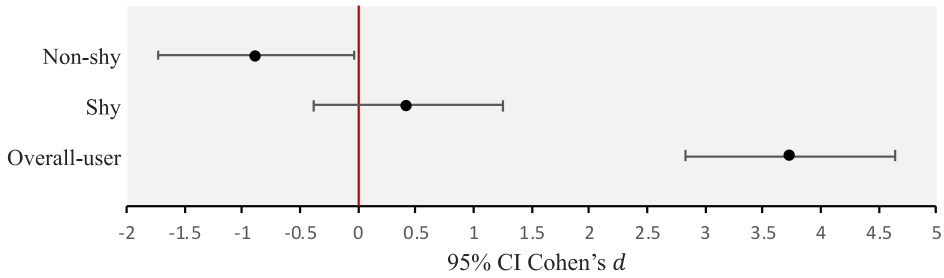


Figure 66: Forest plot showing effect sizes of differences between user satisfaction on meeting experience (namely with-social-cue meeting is more satisfied than without-social-cue meeting), rated by three user groups.

Brief summary: User feedback was examined separately for the non-shy and shy user groups. Non-shy users were more satisfied with the meeting experience of in which no social cue was present. However, when the samples were pooled, users appeared more satisfied with meeting experiences that included the presence of an augmented social cue.

Tests of Association

Analysis Design and Data Preparation

The tests of association in this series were conducted to examine whether the degree of users' satisfaction ratings for meeting experience correlated with the degree of their social anxiety. As in the tests of difference, all five ratings on meeting experience (namely, badge mode, card mode, no-soObj mode, with-social-cue condition and without-cue condition) are remained in these tests of association. Each rating was related with the SIAS score of the participant. The association test was repeated five times according to the number of rating samples described above. The test hypothesis is given as follows.

Test Hypothesis

- There is a relationship between the degree of social-interaction anxiety and the level of meeting satisfaction for each meeting mode and condition.

Descriptive Statistics

Given that five satisfactory rating samples remained in this analysis, this yielded five cases of related samples (SIAS correlated with badge; with card; with no-soObj; with with-social-cue; and with without-social-cue) for testing of association. An initial examination of characteristics of these samples was conducted by generating a key features table for each pair (Table_Apx C-15, Table_Apx C-16 in Appendix C). A visual inspection of these features indicated that a degree of non-normal distribution appeared in almost all samples. This was confirmed by the outcome of the Shapiro-Wilk test of normality (Table 31), which revealed that at least one of the two samples in every related pair did not pass the normality test. These results led to a requirement for a non-parametric statistical method to test the relationships.

Table 31: Results (Sig. values) of Shapiro-Wilk test of normality of SIAS scores, and satisfactory ratings on meeting experiences in three meeting modes and two meeting conditions

	Case 1 Badge		Case 2 Card		Case 3 No-soObj		Case 4 With clue		Case 5 Without clue	
	SIAS score	Rating	SIAS score	Rating	SIAS score	Rating	SIAS score	Rating	SIAS score	Rating
Statistic	0.82	0.74	0.91	0.89	0.85	0.77	0.89	0.83	0.85	0.77
df	18	18	18	18	18	18	36	36	18	18
Sig.	0.003	0.000	0.104	0.033	0.008	0.001	0.002	0.000	0.008	0.001

On inspecting the relationship of these related samples in a scatterplot with a fitted line R^2 value (Figure 67; Figure 68), the user SIAS score was found associating with their satisfaction ratings for meeting experience in card mode (R^2=.52). The lowest association was for badge last (R^2=.01). Although this relationship value was close to zero, it was not too trivial to investigate further, according to the minimum Cohen's benchmark of R^2=.01 (Becker, 2000).

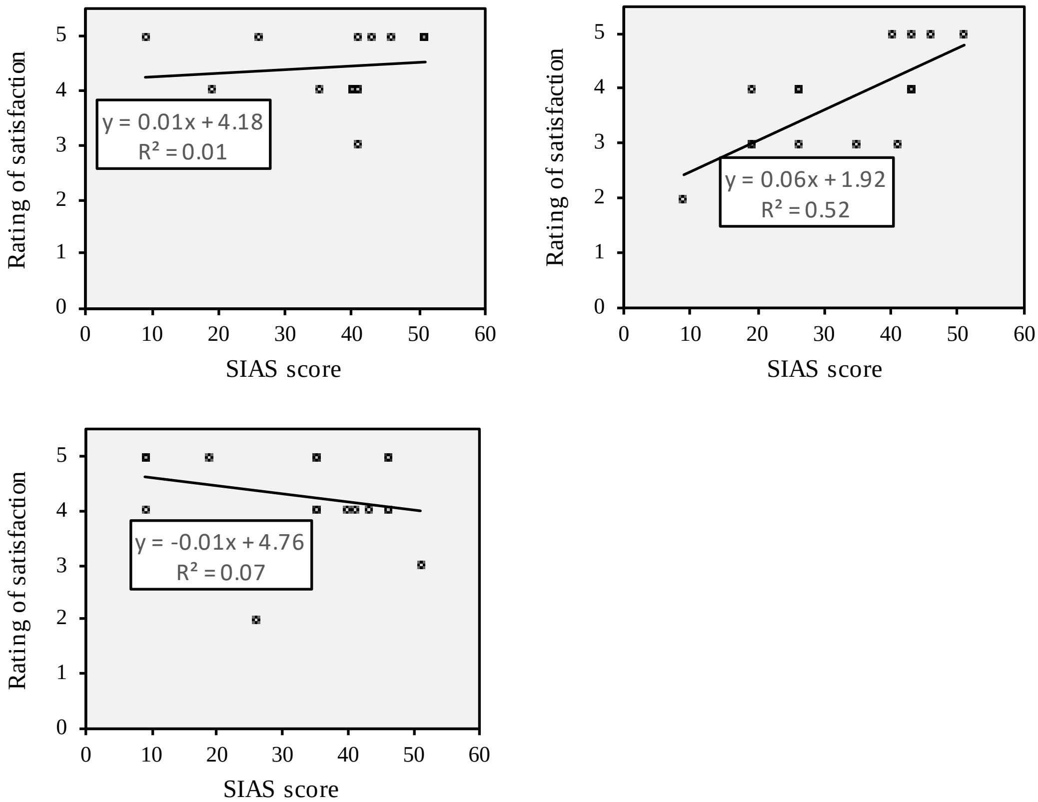


Figure 67: Scatterplots (with 'fit' line values) showing relationships between SIAS scores and satisfactory rates on badge (top-left), card (to-right), and no-soObj (bottom-left) meeting modes.

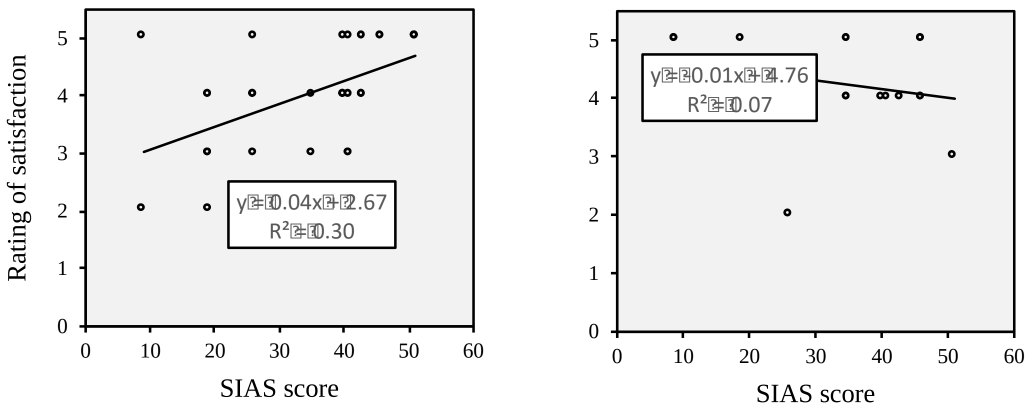


Figure 68: Scatterplots (with 'fit' line values) showing relationships between SIAS scores and satisfactory rates on with-social-cue (left) and without-social-cue (right) meeting conditions.

Brief summary: This primary observation of the characteristics of samples suggested various degrees of relationship between the non-matched samples. Although some relationships appeared weak (such as 'SIAS corr. badge', 'SIAS corr. no-soObj', and 'SIAS corr. without-social-cue'), they showed sufficient associations for more extensive inferential statistics. Overall, these results partially supported the hypothesis that SIAS score was correlated with user satisfaction about the meeting experience.

Inferential Statistics

This analysis series examined whether the degree of the user's social-interaction anxiety (IV) was associated with the degree of their satisfaction on the meeting experience (DV). Five tests of association were conducted according to the numbers meeting modes (three) and meeting conditions (two), through NHSTs (.05 significance level) and PSTs for the relationship between these variables. Given that the IV was measured on a continuous scale and the DV ordinal, and some samples of DV were not normally distributed, Spearman's rho (ρ) was used to test the null hypothesis that the IV and DV were not correlated (ρ=0). As previously mentioned, Spearman's rho does not distinguish DV from IV. However, the interpretation of whether IV had any influence on DV was enable by assigning an IV sample on the horizontal axis and DV sample on the vertical axis of a scatterplot (e.g. Figure 67 and Figure 68). The outcome for rho indicates the strength of the relation. Thus, the additional estimation for effect size is not required, but for its 95% CI.

The results for NHST and PST agreed for all test cases. The users' SIAS scores appeared statistically and practically significant in their correlation with satisfaction ratings for meeting experiences in card mode (Table 33), with a magnitude of association above 'huge' (according to Cohen's benchmark), and meeting experiences in with-social-cue condition (Table 35) with a magnitude of 'very large').

Table 32: Numerical outputs of Spearman's rho test (rectangle marks) and correlation (ρ) estimation (oval marks) on the relationship between SIAS scores (9–51) and satisfactory ratings (1–5) on meeting experience in badge meeting mode, rated by overall-user group.

				SIAS score	Satisfaction
SIAS score	Correlation Coefficient			1.00	0.43
	95% CI for Correlation Coeffectient		Lower		-0.04
			Upper		0.75
	Sig. (2-tailed)				0.074
	N			18	18
	Bootstrap[c]	Bias		0.00	-0.02
		Std. Error		0.00	0.24
		95% CI	Lower	1.00	-0.11
			Upper	1.00	0.83
Satisfaction	Correlation Coefficient			0.43	1.00
	95% CI for Correlation Coeffectient		Lower	-0.04	
			Upper	0.75	
	Sig. (2-tailed)			0.074	
	N			18	18
	Bootstrap[c]	Bias		-0.02	0.00
		Std. Error		0.24	0.00
		95% CI	Lower	-0.11	1.00
			Upper	0.83	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Table 33: Numerical outputs of Spearman's rho test (rectangle marks) and correlation (ρ) estimation (oval marks) on the relationship between SIAS scores (9–51) and satisfactory ratings (1–5) on meeting experience in card meeting mode, rated by overall-user group.

				SIAS score	Satisfaction
SIAS score	Correlation Coefficient			1.00	0.72
	95% CI for Correlation Coeffectient		Lower		0.38
			Upper		0.89
	Sig. (2-tailed)				0.001
	N			18	18
	Bootstrap[c]	Bias		0.00	-0.01
		Std. Error		0.00	0.14
		95% CI	Lower	1.00	0.35
			Upper	1.00	0.90
Satisfaction	Correlation Coefficient			0.72	1.00
	95% CI for Correlation Coeffectient		Lower	0.38	
			Upper	0.89	
	Sig. (2-tailed)			0.001	
	N			18	18
	Bootstrap[c]	Bias		-0.01	0.00
		Std. Error		0.14	0.00
		95% CI	Lower	0.35	1.00
			Upper	0.90	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Table 34: Numerical outputs of Spearman's rho test (rectangle marks) and correlation (ρ) estimation (oval marks) on the relationship between SIAS scores (9–51) and satisfactory ratings (1–5) on meeting experience in no-soObj meeting mode, rated by overall-user group.

				SIAS score	Satisfaction
SIAS score	Correlation Coefficient			1.00	-0.33
	95% CI for Correlation Coeffectient		Lower		-0.69
			Upper		0.16
	Sig. (2-tailed)				0.181
	N			18	18
	Bootstrap[c]	Bias		0.00	0.00
		Std. Error		0.00	0.25
		95% CI	Lower	1.00	-0.75
			Upper	1.00	0.24
Satisfaction	Correlation Coefficient			-0.33	1.00
	95% CI for Correlation Coeffectient		Lower	-0.69	
			Upper	0.16	
	Sig. (2-tailed)			0.181	
	N			18	18
	Bootstrap[c]	Bias		0.00	0.00
		Std. Error		0.25	0.00
		95% CI	Lower	-0.75	1.00
			Upper	0.24	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

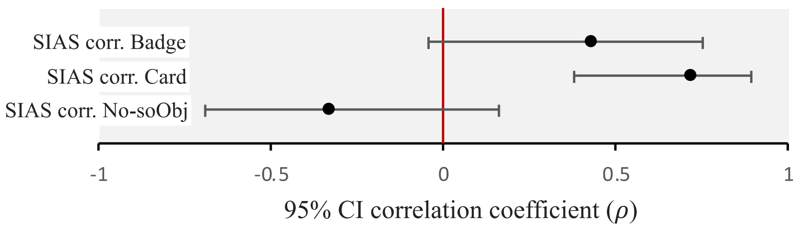


Figure 69: Forest plot showing effect sizes of correlation between SIAS score and their satisfaction with meeting experiences (namely in badge, card and no-soObj meeting modes), rated by overall-user group.

Table 35: Numerical outputs of Spearman's rho test (rectangle marks) and correlation (ρ) estimation (oval marks) on the relationship between SIAS scores (9–51) and satisfactory ratings (1–5) on meeting experience in with-social-cue meeting condition, rated by overall-user group.

				SIAS score	Satisfaction
SIAS score	Correlation Coefficient			1.00	0.59
	95% CI for Correlation Coeffectient		Lower		0.32
			Upper		0.77
	Sig. (2-tailed)				0.0002
	N			36	36
	Bootstrap[c]	Bias		0.00	-0.01
		Std. Error		0.00	0.14
		95% CI	Lower	1.00	0.27
			Upper	1.00	0.81
Satisfaction	Correlation Coefficient			0.59	1.00
	95% CI for Correlation Coeffectient		Lower	0.32	
			Upper	0.77	
	Sig. (2-tailed)			0.0002	
	N			36	36
	Bootstrap[c]	Bias		-0.01	0.00
		Std. Error		0.14	0.00
		95% CI	Lower	0.27	1.00
			Upper	0.81	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Table 36: Numerical outputs of Spearman's rho test (rectangle marks) and correlation (ρ) estimation (oval marks) on the relationship between SIAS scores (9–51) and satisfactory ratings (1–5) on meeting experience in without-social-cue meeting condition, rated by overall-user group.

				SIAS score	Satisfaction
SIAS score	Correlation Coefficient			1.00	-0.33
	95% CI for Correlation Coeffectient		Lower		-0.69
			Upper		0.16
	Sig. (2-tailed)				0.181
	N			18	18
	Bootstrap[c]	Bias		0.00	0.01
		Std. Error		0.00	0.26
		95% CI for	Lower	1.00	-0.78
		Sig.	Upper	1.00	0.21
Satisfaction	Correlation Coefficient			-0.33	1.00
	95% CI for correlation		Lower	-0.69	
			Upper	0.16	
	Sig. (2-tailed)			0.181	
	N			18	18
	Bootstrap[c]	Bias		0.01	0.00
		Std. Error		0.26	0.00
		95% CI	Lower	-0.78	1.00
			Upper	0.21	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

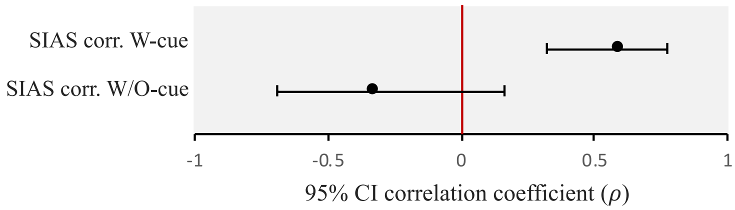


Figure 70: Forest plot showing effect sizes of correlation between SIAS scores and satisfaction rates on meeting experiences (namely with-social-cue meeting and without-social-cue meeting conditions), rated by overall-user group.

Brief summary: There was evidence suggesting that the degree of users' social anxiety was associated with their satisfaction with the meeting experience when augmented social cues were present. The greater the user's anxiety, the more satisfied they were with the presence of cues.

Summary of Analysis

These analysis series were conducted to investigate three hypotheses. The first and second were that users found the badge mode the most satisfying experience, with the card being second and the no-soObj mode least satisfying. The meetings that have augmented social cues present were expected to gain greater satisfaction than those without cues, regardless of the modality of the SO. The third was that an association exists between SIAS scores and satisfaction in social experience. While the NHST returned nonsignificant outcomes, the PST yielded significant results, as summarised below.

Tests of Difference:

- The results indicated that users were more satisfied with their meeting experience in badge mode than in card mode. They were more satisfied with their meeting experience in meetings where an augmented social cue was present than those in which cues were absent. There was not enough evidence to draw conclusions when the user data were separated as shy versus non-shy groups.

Tests of Association:

- There was evidence suggesting that the degree of user's interaction anxiety influenced their satisfaction in meeting experiences with an augmented social cue present. The more severe their anxiety, the greater their satisfaction.

6.4.5. Preferred Meeting Mode

Overview of Analysis

This analysis was the second series that examined how the technology satisfied the users. The previous series investigated this issue based on the users' immediate feedback, given in the *during-test* questionnaire. This next series was based on reflective feedback given in the *post-test* questionnaire, corresponding to two empirical questions (EQ4 and EQ7*)*. For EQ4, the preferred meeting mode was identified by differences in preferential rankings of the badge, card and no-soObj meeting modes – separately in the three user groups basis (non-shy, shy and overall-user groups). For EQ7, the preferred degree of continuous visibility of augmented social cue (badge, card or no-cue) was investigated to find out if it was associated with the degree of user social anxiety. Two types of data analysis were conducted for this series, starting with tests of difference for EQ4, followed by a test of association for EQ7.

Tests of Difference

Analysis Design and Data Preparation

The tests of difference examined user feedback from question 10 of the *post-test* questionnaire, structured as a within-subject study. Each participant was subjected to all meeting modes (namely, badge, card and no-soObj), which meant they acted as their own 'control' as well as 'case'. Therefore, mode of meeting was assigned as IV, with three factors; the users' preferential rating on the three modes was assigned as DV. Their preference was measured on a 3-level ordinal scale (first, second and least preferred), with the raw scores then being reversed scored. This yielded 3 for first choice, down to 1 for least preferred mode. The comparison between ratings on meeting mode was made in pairs at a time. Thus, three tests of difference were required for each of three user groups, one for each of the three comparative pairs (namely 'badge vs. card', 'badge vs. no-soObj' and 'card vs. no-soObj'). This made up nine tests of difference, presented in the following sections. The test hypothesis is given as follows.

Test Hypothesis

- Users prefer the badge meeting mode to card mode, and they prefer the card mode to the no-soObj mode.

Descriptive Statistics

This section presents detailed characteristics of the three DV samples as a clustered bar chart (Figure 71) and table of key features (Table_Apx C-17 in Appendix C). Together the analyses revealed that most users preferred the badge meeting mode and liked the card mode least. No users chose card as their first choice. Most samples displayed some skewness, but only the badge and card samples for the shy-user group exceeded the acceptable asymmetrical limits of ±2 (Field, 2013; Gravetter & Wallnau, 2014; Trochim & Donnelly, 2006). Yet this set a requirement for nonparametric statistic methods for all tests of difference in this analysis series.

The main features (median and variance) of all samples are compared in a parallel boxplot chart (Figure 72), illustrating that shy users' ratings for all meeting modes were much more unified than those of the other groups. In general, non-shy users preferred no-soObj to other meeting modes, whereas shy users preferred the badge.

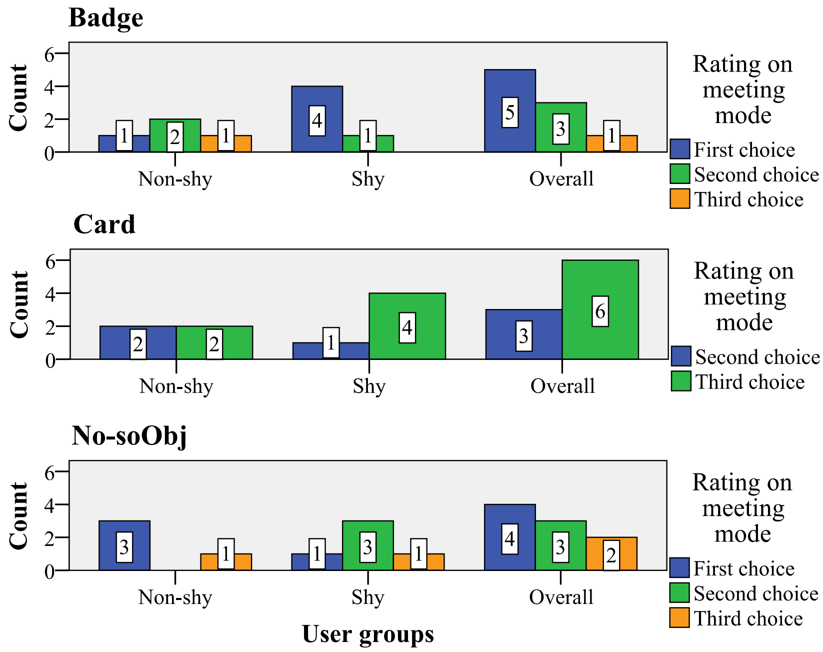


Figure 71: Group-case bar chart showing preferential ranking on three meeting modes, rated by three user groups.

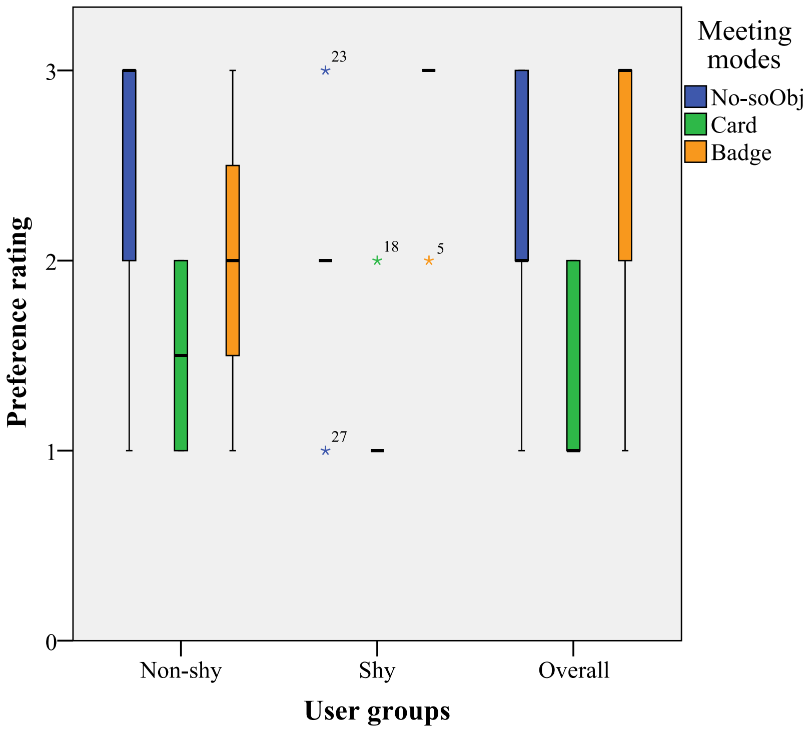


Figure 72: Parallel boxplots comparing preferential ranking of three meeting modes, rated by three user groups.

Brief summary: This observation of the users' ratings of their preferred mode showed that almost all shy users preferred the badge meeting mode, whereas non-shy people preferred no-soObj. Card mode was the least preferred choice for all users. These distinctions were further investigated in a statistical and practical significance test, reported below.

Inferential Statistics

To find out which meeting mode was significantly preferable to the users, the Wilcoxon signed-rank test was chosen as the statistical method for NHST (.05 significance level). Each pair of a user's preferential ratings was compared, basing on the null hypothesis that the medians were equal. As in other tests of difference that required this method, the differences between all paired ratings were assessed for a symmetrical distribution, a critical assumption of the Wilcoxon signed rank method. Histogram charts were used as a visual aid to see whether the paired samples from non-shy (Figure 73), shy (Figure 74) and the overall-user (Figure 75) groups met this assumption. They showed that almost all distributions of the difference in all pairs were relatively symmetrical, except the 'badge vs. card' and 'card vs. no-soObj' pairs from the non-shy, and the 'badge vs. card' of from the shy. The skewness of all samples was therefore assessed using the Shapiro-Wilk test of normality (Table 37). No results exceeded the acceptable limits (±2) for asymmetry(Field, 2013; Gravetter & Wallnau, 2014; Trochim & Donnelly, 2006). Therefore, all samples in these tests of difference were suited to the Wilcoxon signed-rank test.

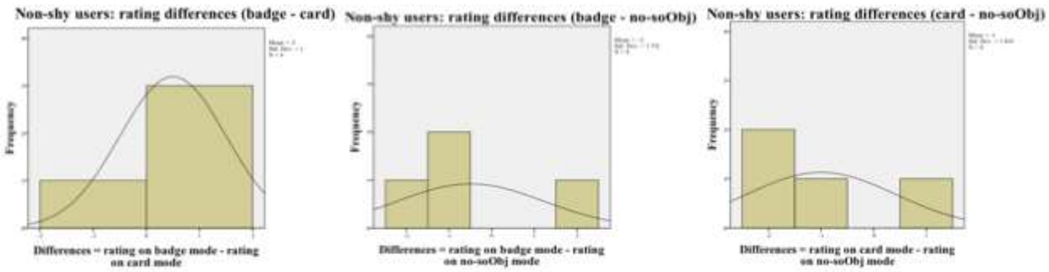


Figure 73: Histograms (with normal curves) showing distributions of difference between preferential rating on three comparative meeting modes (namely, 'badge vs. card' (left), 'badge vs. no-soObj' (middle), and 'card vs. no-soObj' (right)), rated by non-shy group.

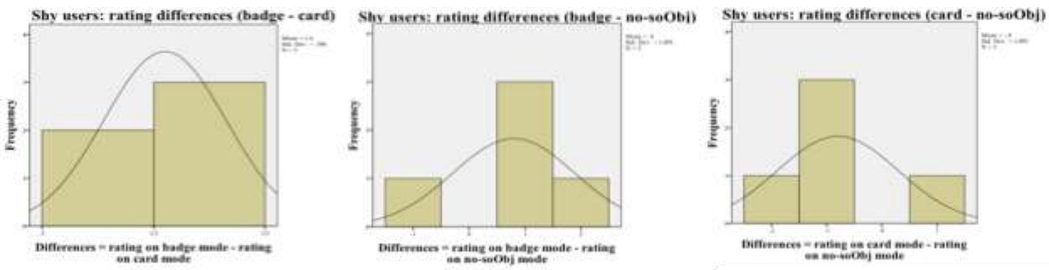


Figure 74: Histograms (with normal curves) showing distributions of difference between preferential rating on three comparative meeting modes (namely, 'badge vs. card' (left), 'badge vs. no-soObj' (middle), and 'card vs. no-soObj' (right)), rated by shy group.

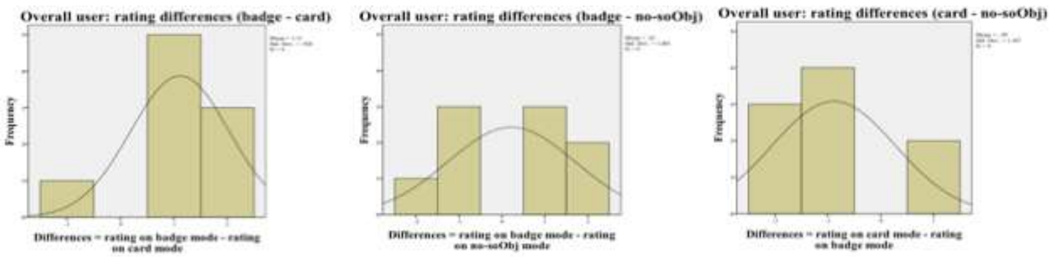


Figure 75: Histograms (with normal curves) showing distributions of difference between preferential rating on three comparative meeting modes (namely, 'badge vs. card' (left), 'badge vs. no-soObj' (middle), and 'card vs. no-soObj' (right)), rated by overall-user group.

Table 37: Results (Sig. values, rectangle marks) of Shapiro-Wilk test of normality of distributions of differences in three comparative meeting modes, rated by three user groups.

		Non-shy	Shy	Overall-user
Badge vs. Card	Statistic	0.63	0.68	0.76
	df	4.00	5.00	9.00
	Sig.	0.00	0.01	0.01
Badge vs. No-soObj	Statistic	0.84	0.83	0.87
	df	4.00	5.00	9.00
	Sig.	0.19	0.14	0.13
Card vs. No-soObj	Statistic	0.83	0.83	0.79
	df	4.00	5.00	9.00
	Sig.	0.16	0.14	0.02

The test results are presented below in three groups. Each test assessed the difference between paired samples (one set as 'control' and another as 'case') by subtracting the preferred rating for 'control' from that of 'case'. When comparing the badge and card modes, badge was set as 'case' and card as 'control'. Similarly, when comparing badge and no-soObj, badge was set as 'case' and card as 'control'. When comparing card and no-soObj, card was set as 'case' and no-soObj as 'control'. Computing the data in this way allowed the researcher to assess whether the rating for 'case' was greater than 'control', for each paired set. Positive differences in a pair would reflect the user's preference for 'case' ('case' minus 'control'), whereas negative differences reflected user preference for 'control' ('control' minus 'case'). For example, a positive difference in a 'badge vs. card' case would determine that the users preferred the badge mode over the card mode, whereas a negative difference would mean the opposite.

For PST, Cohen's *d* estimation with 95% CI range was used to quantify the size and direction of differences between samples. Both NHST and PST outcomes are presented in visual and numerical forms for all test results, shown according to the three user groups.

Non-shy Group

Both NHST[50] (*p* or asymptotic sig. value) and PST (Cohen's *d* and CI) tests resulted in non-significant differences among non-shy users' preferential ratings for all meeting modes (Table 38). These results implied that non-shy users did not find any meeting mode preferable.

[50] See Figure_Apx 17 in Appendix C for graphical outputs of NHST results

Table 38: Numerical results of Wilcoxon signed-rank test (rectangle marks) and Cohen's *d* effect size estimation (oval marks) of differences between preferential rates on three comparative meeting modes, by non-shy group.

		Badge vs. Card	Badge vs. No-soObj	Card vs. No-soObj
Total N		4	4	4
Test Statistic		7.50	3.50	1.50
Standard Error		2.50	2.69	2.69
Asymptotic Sig. (2-sided test)		0.317	0.577	0.194
Cohen's *d*		0.70	-0.55	-1.22
95% CI for Cohen's *d*	Lower	-0.72	-1.96	-2.73
	Upper	2.13	0.86	0.29

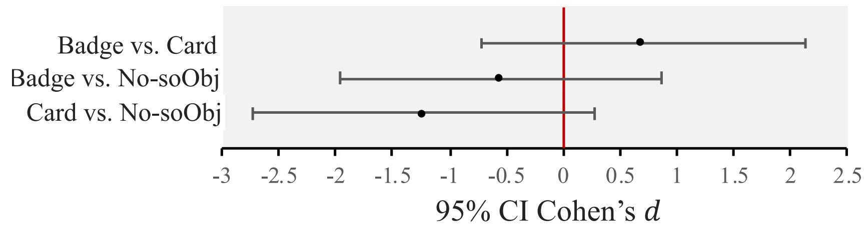


Figure 76: Forest plot showing effect sizes of differences between preferential rates on three comparative meeting modes, rated by non-shy group.

Shy Group

The NHST[51] and PST results (Table 39) of shy users indicated that the difference between ratings for badge versus card modes was statistically and practically significant, with a 'huge' magnitude of difference in favour of badge, according to Cohen's benchmark. This suggests all shy users found the badges more helpful than the card. There were no other significant differences.

Table 39: Numerical results of Wilcoxon signed-rank test (rectangle marks) and Cohen's *d* effect size estimation (oval marks) of differences between preferential rates on three comparative meeting modes, by shy group.

		Badge vs. Card	Badge vs. No-soObj	Card vs. No-soObj
Total N		5	5	5
Test Statistic		15.00	12.50	2.50
Standard Error		3.62	3.54	3.54
Asymptotic Sig. (2-sided test)		0.038	0.157	0.157
Cohen's *d*		3.56	1.35	-1.35
95% CI for Cohen's *d*	Lower	1.56	-0.03	-2.72
	Upper	5.55	2.72	0.03

[51] See Figure_Apx 18 in Appendix C for graphical outputs of NHST results

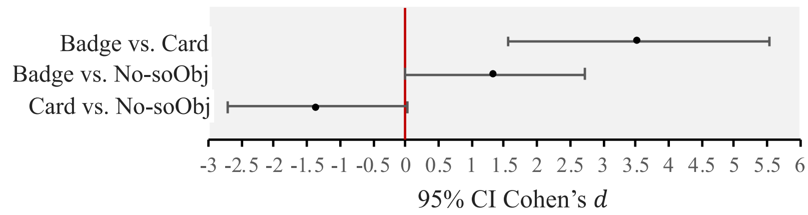


Figure 77: Forest plot showing effect sizes of differences between preferential rates on three comparative meeting modes, rated by shy group.

Overall-user Group

A conflict existed between the NHST[52] and PST outcome for the comparison of preferential ratings for card and no-soObj modes. The NHST indicated that the difference was not statistically significant; the *p*-value was relatively low (p=.057) but was not significant at the .05 confidence level. However, the PST results indicated practical significance of the difference in favour of no-soObj, with a magnitude above 'very large' according to Cohen's *d* effect sizes.

The NHST and PST results for the other paired sets agreed with each other. The difference in user ratings for 'badge vs. no-soObj' was neither statistically nor practically significant. The difference for 'badge vs. card' had a 'very large' effect size according to Cohen's benchmark, in favour of badge mode. The NHST results alone suggested that the overall-user group preferred the badge mode to the card mode. When the PST results were added, this user group seemed to find badge and no-soObj meeting modes preferable to the card mode.

Table 40: Numerical results of Wilcoxon signed-rank test (rectangle marks) and Cohen's *d* effect size estimation (oval marks) of differences between preferential rates on three comparative meeting modes, by overall-user group.

		Badge vs. Card	Badge vs. No-soObj	Card vs. No-soObj
Total N		9	9	9
Test Statistic		41.50	26.50	7.00
Standard Error		8.15	8.15	8.15
Asymptotic Sig. (2-sided test)		0.020	0.623	0.057
Cohen's *d*		1.27	0.28	-1.30
95% CI for Cohen's *d*	Lower	0.26	-0.65	-2.32
	Upper	2.28	1.21	-0.28

[52] See Figure_Apx 19 in Appendix C for graphical outputs of NHST results

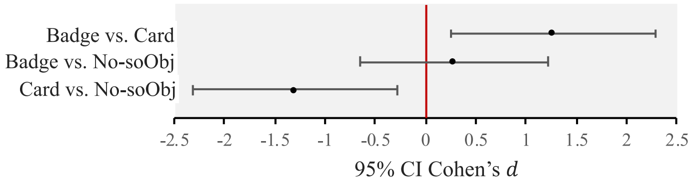


Figure 78: Forest plot showing effect sizes of differences between preferential rates on three comparative meeting modes, rated by overall-user group.

Brief summary: While certain test results supported the hypothesis (namely users preferred badge meeting mode to card meeting mode), other results did not (namely users preferred no-soObj mode to card). When categorising users into smaller groups, shy users appeared to prefer the badges to the cards, whereas non-shy users did not seem to prefer any specific mode.

Tests of Association

Analysis Design and Data Preparation

To see whether the users' preference (for a meeting mode) had any relationship to the degree of their social-interaction anxiety, a test of association was constructed. It measured the correlation between the user's SIAS score and their preferred meeting mode. Therefore, the same data (responses to *post-test* questionnaire QA10) used in the tests of difference above were used again in this test. However, these users' ratings were not broken down into three DV samples (each representing a meeting mode). This was because the interest of this analysis was only on the first choices of meeting mode. These data were used as a single DV sample for this test. The DV sample was paired with the SIAS score sample, which was assigned as IV, as shown in the case summary table (Table_Apx C-18 in Appendix C).

In the preparation of the DV sample, the three meeting modes were arranged in numerical order, mapped onto a 3-point score regarding the visibility of the augmented social cue display in each mode. Badge mode was given the highest score, 3, because its social cues were publicly displayed and could be seen by everyone and all times. The next visibility level was card mode, given a score of 2 because its social cue was privately displayed, available only to the user when she or he chose to look at it. No-soObj mode was given the lowest score, 1, as it was designed without any social cue. Arranging the modes in this way allowed the researcher to systematically differentiate their degrees of display visibility. This ordering was fundamental to understanding the findings but also made the

DV sample an ordinal data of type, practical for the data analysis. The test hypothesis is given as follows.

Test Hypothesis

- There is an association between the degree of a user's social-interaction anxiety and the level of continuous visibility of an augmented social cue. The badge mode has highest visibility, the card has medium, and no-soObj has none. A greater degree of anxiety influences the preference for higher visibility and vice versa.

Descriptive Statistics

The primary observation for DV and IV samples started with pairing users' first choice of meeting mode with their SIAS scores, as seen in the case summary table (Table_Apx C-18 in Appendix C). The users with SIAS score ≥ 41 preferred the badge mode, whereas other participants either preferred the badge or no-soObj. None preferred the card mode. Further details of the paired samples are presented in the key features table (Table_Apx C-19 in Appendix C). Some skewness (to the left) was noted in both samples. This led to a normality assessment of the samples' distributions using the Shapiro-Wilk test for normality. The result showed a significant non-normal distribution of the degree of display visibility (Table 41), which called for a nonparametric statistical method for inferential data analysis.

A further depiction of the relationship between paired samples was made in a scatterplot with 'fit' line R^2 (Figure 79). The scatterplot showed a positive relationship (R^2=.36) between the users' SIAS scores and their preference for degree of visibility of the augmented social cue.

Table 41: Results (Sig. values) of Shapiro-Wilk test of normality of SIAS scores and first choices of meeting mode

	SIAS score	Most preferable meeting mode
Statistic	0.93	0.65
df	9	9
Sig.	0.443	0.000

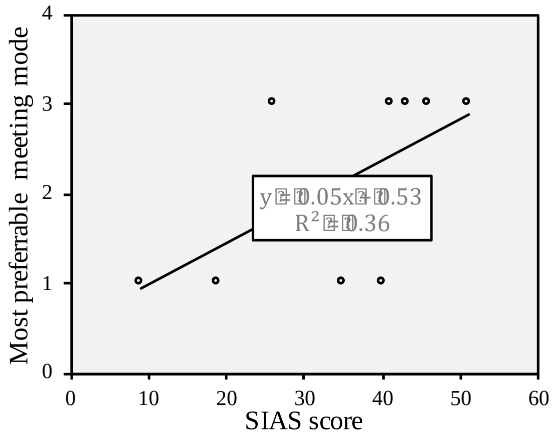


Figure 79: A scatterplot (with 'fit' line value) showing a relationship between SIAS scores and most-preferred meeting mode (namely, 1 = no-soObj; 2 = card; and 3 = badge), rated by overall-user group.

Brief summary: The outcome of this descriptive analysis supported the hypothesis that a relationship existed between SIAS score and user preference for mode. The scatterplot indicated that badge mode was preferable for highly anxious users, and no-soObj mode was preferred by low-anxiety users. However, scatterplots assume the sample on the horizontal axis is predefined (J. H. McDonald, 2014a). This was not true in the current study, as the SIAS scores were measured from partial-randomly selected participants. Hence, further analysis was required to examine whether the SIAS score had any influence on user preference.

Inferential Statistics

The R^2 value of the scatterplot indicated that a relationship existed between users' SIAS scores and their preferences for specific meeting modes. However, the R^2 only determined if a linear relationship between the samples existed (J. H. McDonald, 2014a) and could not show whether one influenced the other. In addition, close inspection of all data points in the scatterplot indicated that the result yielded was positive; the first few data points appeared near the bottom-left corner of the chart, whereas the last few data points appeared near the top-right corner. This suggests that high-SIAS-score users preferred more visible social cues, but did not indicate whether all users' preferences varied according to their SIAS scores.

Spearman's rho (a nonparametric method) was used to answer this question. Used as an NHST method with 0.05 significance level, it tested whether a monotonic relationship (namely, correlation) existed between the two samples (Laerd Statistics, 2013; Spearman, 1904). It determined a correlation coefficient (*r*) that indicated the strength and direction of the relationship of the samples (J. H. McDonald, 2014b). Therefore, an additional effect-size estimation for PST was not needed.

The outcome of this test indicated both statistical and practical significance in the correlation between user SIAS score and preference for visibility of the augmented social cue (Table 42). There was a positive magnitude size above 'very large' according to Cohen's effect-size benchmark. This suggested that users with higher SIAS scores tended to prefer highly visible social cues.

Table 42: Numerical outputs of Spearman's rho test (rectangle marks) and correlation (*r*) estimation (oval marks) on the relationship between SIAS scores (9–51) and preferred degree (1–3) of visibility of social compatibility display, rated by overall-user group.

				SIAS score	Degree of display visibility
SIAS score	Correlation Coefficient			1.00	0.69
	95% CI for Correlation Coeffectient		Lower		0.05
			Upper		0.93
	Sig. (2-tailed)				0.039
	N			9	9
	Bootstrap[c]	Bias		0.00	-0.02
		Std. Error		0.00	0.20
		95% CI	Lower	1.00	0.17
			Upper	1.00	0.90
Degree of display visibility	Correlation Coefficient			0.69	1.00
	95% CI for Correlation Coeffectient		Lower	0.05	
			Upper	0.93	
	Sig. (2-tailed)			0.039	
	N			9	9
	Bootstrap[c]	Bias		-0.02	0.00
		Std. Error		0.20	0.00
		95% CI	Lower	0.17	1.00
			Upper	0.90	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

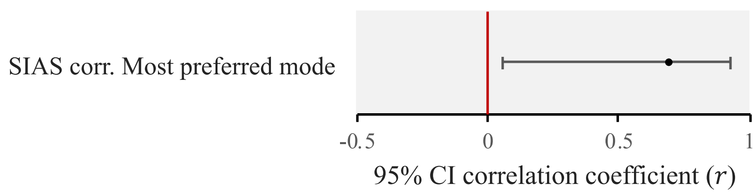


Figure 80: Forest plot showing effect sizes of correlation between SIAS scores preferred degree of visibility of social compatibility display, rated by overall-user group.

Brief summary: This test of association suggested a correlation between social anxiety in users and their preferences for meeting modes. The greater their social anxiety, the more they preferred a higher visibility of the augmented social cues during meetings.

Summary of Analysis

For the three meeting modes, it was hypothesised that the preferred order of users was badge as a first choice, followed by card and no-soObj. To test this hypothesis, three tests of difference was conducted to investigate non-shy, shy and overall users' preferential rankings for the three meeting modes. In addition, the degree of visibility of social cues, with badges providing the most visible cues), was hypothesised to associated with the user's social anxiety – higher anxiety users were likely to prefer greater degree of visibility of the social cues. This required a test of association was required to test this hypothesis. Following are the main findings from these tests.

Tests of Difference:

- For non-shy users' preferences for the three meeting modes, there was no evidence suggesting this user group preferred any specific meeting mode.
- For shy users, there was evidence suggesting that badge mode was preferred to card mode.
- The preferences as rated by the overall-user group provided evidence that the badge and no-soObj modes were preferred to card mode. However, no evidence was found as to whether badge mode was preferred over no-soObj.

Test of association:

- There was evidence supporting the hypothesis that the degree of social anxiety associated with the user's preferences for the type of the display. Users with lower SIAS scores did not like having augmented social cues in the meeting. In contrast, users with higher SIAS scores preferred the meetings to be provided with a peripheral display (Social Badge), despite the information being publicly visible.

6.4.6. Awareness of Cued Content

Overview of Analysis

This last series of analysis was conducted for the responses to EQ6 and EQ11. For EQ6, the degree of user attention to the displayed content of the Social Badge was compared to the Social Card. This was to see whether the card, as a full-attention display, drew more attention than the badge. This required three tests of difference to examine whether any user group (non-shy, shy and overall users) paid more attention to either display modality. For EQ11, a test of association was used to assess the relation between the degree of anxiety and the degree of user attention on each display. This was to find out if the SIAS scores of all users influenced the attention they paid to each display modality.

Tests of Difference

Analysis Design and Data Preparation

These tests of difference examined user feedback given through questions 2, 3 and 6 of the *during-test* questionnaire. The tests were designed as a between-subject study for which two comparative samples (namely attentional ratings for badge and card) were drawn from non-identical sources (similar to the analysis in section 6.4.4). Each sample contained 18 cases, some of which were provided by participants who had had only one opportunity to use the Social Badge or card while others had had more – as is the nature of RTCs. Therefore, all three datasets were treated as obtained from non-identical user groups.

In questions 2 and 3, users were asked to rate the degree of attention they paid to the augmented social cue. Three possible answers were: ‘I was not at all aware of it’ (choice 1), ‘I was aware of it but did not pay attention to its content’ (choice 2), and ‘I paid attention to its content’ (choice 3). For choice 3, they were further asked what social compatibility score they had seen, and whether they could draw the score in an area next to the answer (see during-test QA in Appendix C.2). The accuracy of this detail for choice 3 did not matter if the participant attempted to recall the score. Doing so proved that they had truly paid attention to the social cue content, and that the display had at some point shifted into their focal awareness.

In addition, question 6 asked whether the display or its content were verbally mentioned during the meeting session. This provided a binomial answer choice (‘I discussed its content’ or ‘I did not talk about it’). In the data preparation, this answer was combined with responses to questions 2 and 3. Together they became a rating for the ‘user awareness’ sample (DV), which had four levels, later mapped onto an ordinal scale of 4 attentional scores. A score of 0 meant ‘I was not at all aware of it’; a score of 1 represented ‘I was aware of it but did not pay attention to its content’, a score of 2 meant

‘I paid attention to its content’, and 3 meant ‘I discussed its content’. To investigate whether the user paid more attention to the full-attentional display (Social Card) than the peripheral display (Social Badge), the display modality was set as an IV. It had two factors, assessed with tests of difference that were repeated three times (for the number of user groups: non-shy, shy and overall-user). The test hypothesis is given as follows.

Test Hypotheses

- Users pay more attention to the content of the Social Card than the Social Badge.

Descriptive Statistics

For the sample characteristics, a cluster bar chart (Figure 81) and key features table (Table_Apx C-20 in Appendix C) were generated to compare the card and badge samples of all user groups.

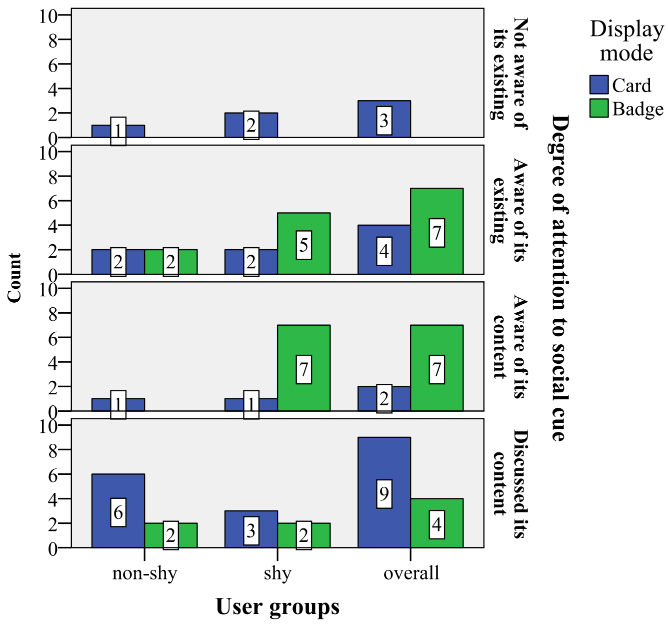


Figure 81: Group-case bar chart showing attentional ratings on two comparative displays, by three user groups.

Together they revealed that the lowest degree of attention (1) the badge display received was greater than the lowest the card received (0). Surprisingly, some users indicated that they were not aware of the card’s existence. Although this seemed odd because while using it, users had to provide their full attention in searching for a specific card that showed information matching the ID of the person they met during each session. This could explain why some users bypassed the process or put the card in a pocket.

Nonetheless, the clustered bar chart also revealed that the greatest attention the card received was greater than the badge received.

In a further observation on these differences, using a parallel boxplot (Figure 82), the average degree of attention shy users paid to the card display was found lower than other groups. In contrast, the average attention given to the badge was almost identical for all user groups. However, the range between the upper and lower degree of attention paid to the card by shy users appeared notably larger than that of other user groups. This suggested that the ratings among shy users were less universal than among users in other groups.

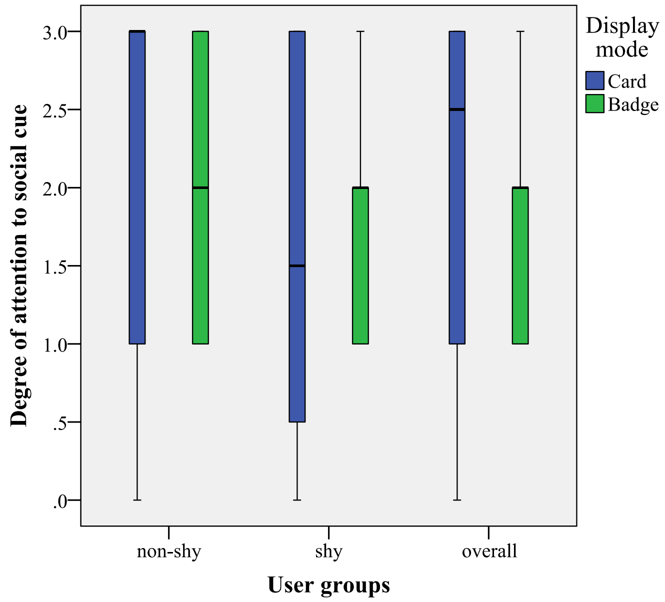


Figure 82: Parallel boxplots comparing attentional ratings on two comparative displays, by three user groups.

Brief summary: A primary investigation of the characteristics of users' attentional ratings suggested that the least attention paid to the card display was lower than that given to the badge, hence disconfirmed the hypothesis. However, on average, the greatest attention that cards received was greater than for the badge; users tended to discuss the card's content more than they did the badge's content.

Inferential Statistics

To determine whether the difference in the degree of user attention paid to both display modalities was significant, Mann-Whitney U test (at .05 significance level) was used for NHST and Cohen's *d* effect size for PST, owing to the characteristics of a between-subject study. A bi-histogram chart was generated to compare the distribution of both samples in each user group (namely non-shy, shy and overall-user) to assess the critical assumption of Mann-Whitney U test. The assumption is that the paired samples are distributed symmetrically (M. Hollander et al., 2014; Wilcox, 1992). The results (Figure 83) showed that none of the comparative-pair distributions met this assumption. Therefore, the comparisons between these comparative samples were made on the basis of mean rank rather than on median – the original approach of Mann-Witney U test (Mann & Whitney, 1947).

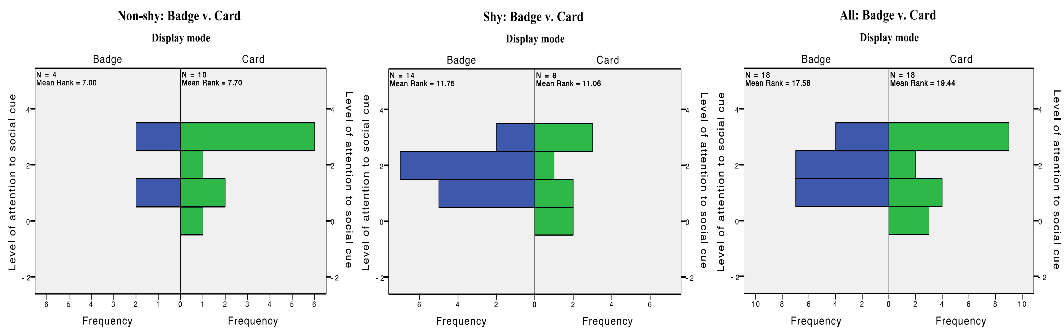


Figure 83: Bi-histograms comparing distribution shapes between attentional ratings on badge and card displays, rated by non-shy (left), shy (middle), and overall-user (right) groups.

The results below are presented in the order of non-shy, shy and overall-user groups. Each set is shown with an NHST and PST output table (Table 43) and a forest plot (Figure 84) illustrating Cohen's *d*, to make the differences explicit. They all indicated non-significant differences between the attentional ratings for the badge and the card, in any user group.

Table 43: Numerical results of Mann-Whitney U test (rectangle marks) and Cohen's *d* effect size estimation (oval marks) of differences between attentional ratings on badge and card displays, by three user groups.

		Non-shy	Shy	Overall-user
Total N		14	22	36
Mann-Whitney U		18.00	59.50	145.00
Std. Error		6.30	13.97	30.13
Std. Test Statistic (Z)		-0.32	0.25	-0.56
Asymptotic Sig.(2-sided test)		0.751	0.802	0.573
Cohen's *d*		-0.18	0.17	-0.11
95% CI for	Lower	-1.34	-0.70	-0.76
Cohen's *d*	Upper	0.99	1.04	0.55

Brief summary: Contrasting with the hypothesis, the degree of user attention paid to the Social Badge and Social Card did not appear different in any user group.

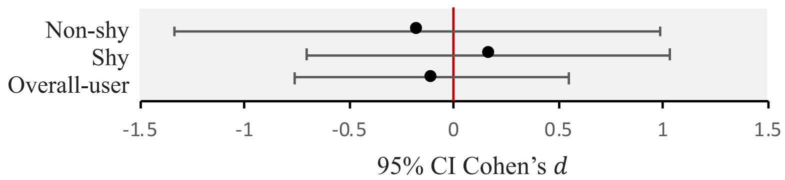


Figure 84: Forest plot showing effect sizes of differences between attention rates on comparative displays (namely users were aware of card more than badge), rated by three user groups.

Tests of Association

Analysis Design and Data Preparation

To examine whether a relationship existed between the users' SIAS scores and the degree of attention they paid to the augmented social cue, two tests of association were conducted. One test examined each attentional rating for the badge, and the other the card display. Like other association tests in this thesis, in which tests are structured as between-subject investigations, the tests of association were only conducted for the overall-user group. There were too few samples to separate them into smaller groups of non-shy and shy for the purpose of analysis. The awareness ratings for card and badge were examined in the overall-user group basis – the same way conducted in the tests of difference, organised by the users' SIAS scores (see the case summary table: Table_Apx C-21 in Appendix C). The test hypothesis is given as follows.

Test Hypothesis

- The higher social anxiety the users have, the more they are aware of the content of both social display modalities and vice versa – the lower social anxiety they have, the less they are aware of the content.

Descriptive Statistics

On a primary observation of all samples, a key features table (Table_Apx 22 in Appendix C) was generated to inspect their characteristics, which revealed some skewness in all samples. Although the skewness values were not statistically significant (namely not exceeding the ±2.00 limit) (Field, 2013; Gravetter & Wallnau, 2014; Trochim & Donnelly, 2006), the data points *(N=18)* were too few. This indicated a nonparametric statistical method for inferential testing was required.

A scatterplot chart with 'fit' line value (R^2) for both related samples (Figure 85) was constructed for the primary observation of the relationship between samples. Both charts showed a relatively weak relationship between SIAS scores and attentional ratings. On inspecting the R^2 values and sample characteristics (in the case summary table and key features table), this indicated that a further examination of the relationships through inferential statistics was not necessary, although the relationship between SIAS score and attentional rating for card (R^2=.01) was non-trivial according to Cohen's benchmark (Becker, 2000). However, previous analyses that employed the same SIAS scores (section 6.4.4 for instance), indicated no correlation between SIAS score and attentional rating for card or badge. Nonetheless, an output table from NHST and from PST for non-statistical results (Table_Apx C-23 and Table_Apx C-24 in Appendix C) was generated for referencing.

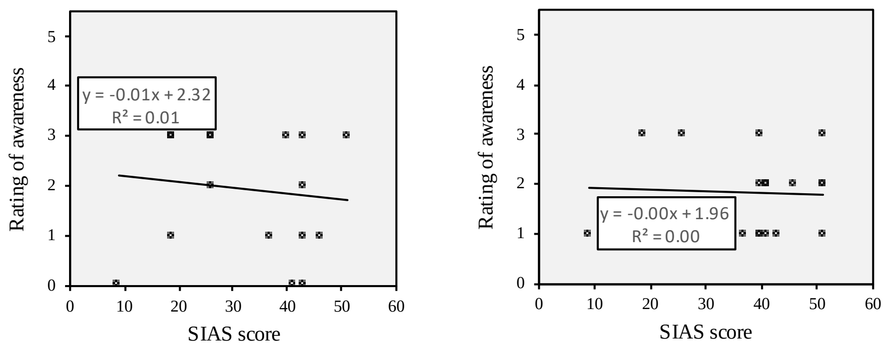


Figure 85: Scatterplots (with 'fit' line values) showing relationships between SIAS scores and attentional ratings on card (left) and badge (right) displays, rated by overall-user group.

Brief summary: A primary observation of sample characteristics and the relationship between SIAS score and attentional rating, for card and badge displays, indicated no notable relationships. Hence the severity of social anxiety seemed not to associate with the attention the user paid to either type of display.

Summary of Analysis

These analyses were conducted to examine two aspects of user awareness of the display content of both display modalities. The first series tested whether the Social Card drew more attention to its content because it demanded full attention. The second tested whether the extent of user awareness varied according to the severity of their social-interaction anxiety – in other words, whether higher social anxiety might be associated with greater awareness of the information shown in the augmented social cues. Previous analysis series had required inferential statistics for both tests of difference and association. In contrast, these series did not require inferential statistics for the test of association, as suggested by the results of descriptive analysis. Accordingly, summarised results are given below.

Tests of Difference:

- Comparison of user awareness of the content displayed on the card and badge yielded no statistical evidence suggesting a difference between the two. This result applied to all user groups.

Tests of Association:

- There was no evidence suggesting a relationship between the degree of a user's social-interaction anxiety and their awareness of the display content of the card or badge.

6.5. Justification on Main Findings

This Final study was conducted to gather evidence for validating the primary assumption that the characteristics (section 3.3.2) of a subtle social object (namely Social Badge) were superior to those of the non-subtle (namely Social Card) in facilitating social interaction for socially anxious people[53]. Although some data analysis results did not agree with the test hypotheses (section 6.4) by being partially influenced by the limited number of samples, the rigorous approach to designing experiment and analytical

[53] The notion of 'socially anxious people' or 'users' in this section (6.5 Justification) refers to the overall participants, who recognised themselves as occasionally and/or most of the time finding interaction with strangers in social situations a challenge. In addition, rather than referring the participants as non-shy or shy, as in the data analysis section that followed Peters' (2000) SIAS cut-off score, here the participants are referred to as users who exhibit a range of anxiety degrees. Due to the randomised control trial approach, the sampling resulted in a great difference in the numbers of high and low social-anxious samples from data collected through *during-test* questionnaire. Thus it was unable to draw conclusions about the correlation between SIAS levels and variables such as the degree of attention paid to social cues' content. Nonetheless, the researcher attempted interpreting the influence of SIAS levels on other variables where the characteristics of required samples allowed.

processes (section 3.4.1) – inferring both NHST and PST approaches – provided several main findings that appeared to support the overall assumption.

This outcome derived mainly from evaluating the capacity of the peripheral display of the subtle SO. By nature, peripheral displays are not compulsory tools for completing a primary task, but for improving user experience in performing it. Hence the evaluation process was central to establishing how the impact of the peripheral display (subtle) differed to that of the focal-attention-demand display in enriching the social routine and interpersonal experience of the user. Such improvement appeared in the socialising phenomena that commonly hinder people with social anxiety, namely making conversation, paying attention to and constructively interpreting social cues, and feeling satisfied with the social outcome. The advantages of using a subtle SO to improve these social routines and experiences are discussed as follows, drawing inferences from the main analysis results together with the qualitative data collected in the previous phases of the research (section 3.1.1).

6.5.1. Usefulness to Conversation Making

Out of the three classifications of helpfulness to making conversation, the meetings provided with the Social Badge were hypothesised to be the most beneficial – given that it provided a social cue unavailable in no-soObj meetings and did not demand as much physical and mental effort as in the card meetings. Users rated the badge mode superior in all helpfulness categories (namely easier to initiate, more topics and longer conversation). They also found using Social Cards not helpful to generate more conversational topics than when not having any augmented social cues present. Drawing on the differences in the displaying characteristics of the two SOs helps to understand why the focal-private-static display of the Social Card was not as much of an assistance to the user as the peripheral-public-dynamic display of the Social Badge. These differences are discussed below.

Focal vs. Peripheral Display

The Social Badge was designed as a peripheral display to present social cues in an ambient environment, without requiring focal attention to operate its system, retrieve relevant pieces of information, or recognise the message. Users could focus on other tasks or central elements in the social situation while perceiving its cues – unlike perceiving the cues on the Social Card that demanded full concentration to operate. Socially anxious users are hindered by attention deficits that impact negatively on their social cognition and mental capacities during social routines (section 2.1.1). Having an additional cue in the environment that requires focus for its operation could compete for their attention in the social performance, particularly in making conversation. These deficiencies explain why users found the card content not so helpful to their overall meeting experience, compared to the efficacy of the same content presented via the badge. Through the badge, the cues could be perceived in a cognitively lightweight manner. User feedback on this characteristic reflects those of Dey and Guzman' (2006) peripheral display embedded in socially assistive furniture installed in a shared space. Without having to pay focal attention to its display, participants reported having been attuned more to the presence of group members and thus attained greater social connectedness.

Static vs. Dynamic Cueing

The interactive features and animated content of the Social Badge make its cueing behaviour dynamic. Responsive to the user handshaking, this system behaviour draws only the information that the users 'need' and at an appropriate moment – unlike the static cueing character of the Social Card that requires users' manual operation to shuffle and search for specific information. While their eyes and hands are occupied, their cognition is 'forced' to focusing on the card. This process restrains the users from direct engagement with one another and could give rise to excessive self-monitoring and assessing habits. As a knock-on effect, it decreases the opportunity to monitor the social event, increases the degree of social anxiety (Kley et al., 2012; Norton & Abbott, 2016), and makes it more challenging for them to break free from the vicious cycle (section 2.1.1). An obvious outcome of this chain of events is an inhibition to initiate a conversation and limitation of conversational resources.

In contrast, the use of the Social Badge frees up the users' eyes, hands and coordinating cognition. This benefit is a by-product of implementing the subdued *active* quality of the SO (sections 2.1.2 and 5.1.1) – a fundamental design consideration that enables the Social Badge to insert itself in the interpersonal space. To counteract the users' excessive self-monitoring, the dynamic cueing behaviour of the Social Badge attract the users' attention and then instantly divert it onto the augmented social cues and the interpretative gap offered as a contextual resource for making conversation.

Private-relational vs. Public-relational Cues

Although the protection of privacy is a common concern for socially anxious people, the consistency in their preference for the open-view of social cues appeared in both the Pilot II and the current studies. Of the latter, this preference was through the comparison between the open access provided by the Social Badge and the individual access by the Social Card. This preference seems to be influenced by the interplay between the badge's *active* and *relational* qualities operating in tandem. Although the set of social compatibility levels presented through the badge and card were comparable, those on the badge had the greater capacity to engage individual users with her/his interaction partners given that they were simultaneously imposed upon by the same *epistemic object* (section 2.1.2) towards the interpretative process of their relationship. This way both users were mutually given the 'licence' to talk and openly made known to one another that they had something in common. Furthermore, their individual 'spaces' become blurred and perceivably less threatening. The researcher posits here that this 'boundary loss' of self (McNeill, 1995) also triggered the loss of self-awareness and allowed the mutual understanding of the 'collective impact' (Di Paolo & Thompson, 2014) of their goals, intentions and co-action to arise.

When relational information between users is made public rather than individually presented, its shareable capacities are expanded into the physical and social environment where mutual awareness and interest are shaped and unfolded. The badge, while holding up this kind of information, reflect Fernaeus el al' (2008) *from-individual-to- sharable* theme, provided under the 'ideal shift' approach to designing social artefacts (section 2.3.2). By prioritising multi-users rather than individuals, the badge positions itself as a shared object (section 2.2.2) users could co-process and negotiate conversation topics, while existing as an embodiment of the 'shared self' – an 'extended self' to which the users can relate (section 3.3.1). Through this process, in a subtle and unobtrusive way, the badge amplified the users' perception of possibilities in the social environment and of their own socialising capacities (section 2.2.1)

6.5.2. Impact on User Awareness and Attitude

Awareness is a peripheral display metric for assessing the extent of information that the user can recognise, hold and comprehend while not attuned to their focal attention. It helps the designer to understand how and what characteristics the information should convey in order for the information to remain useful even when residing in the periphery.

The attentional focus of people with social anxiety during social situations is compromised by fear, apprehension and negative anticipation about the outcome of the social event. This predisposition leads to excessive monitoring of perceived internal (the self) and external (threats) social cues that are interpreted as negative signals (section 2.1.1). These behavioural traits were critical to designing the Social Badge features to accommodate these existing tendencies in a more positive manner. The badge augmented interpersonal information – although in a subtle but encouraging way towards more constructive expectations of social relationships. These positive signals became social affordances that appropriated social cognition and hence afforded joint action (section 2.2.1). Findings that support this argument are discussed as follows.

Awareness of Cueing Content

In the analysis of the attention on the cueing content, the extent of user awareness on Social Badge was compared to that on Social Card. Although they both presented the same information, their display modalities were different hence their interaction models; while the badge required peripheral attention, the card required focal. This contradiction led to a hypothesis that users would pay more attention to the card than to the badge. However, the data analysis yielded the opposite; its results turned out to be the least predictable among all the tests required in this study. The extent of 'awareness' measured on the Social Badge versus the Social Card showed no significant difference at 95% confidence level (CI) across the overall user group. There are four approaches available to justify this unforeseen outcome provided below.

The first is to decrease the confidence level, reasonable when dealing with an extremely small sample. In this case study, reducing it to 72.73% (based on the successful rate of pilot study 2) would increase the power of all statistical methods and the chance for statistical and practical significance in the test results, which would have provided more positive findings to support the hypothesis. However, the NHST analysis in this study followed a standard practice; the 95% CI was applied to all analysis series. The second is to reject the traditional belief in HCI (section 2.1.2) that a full attention-demand display (such as Social Card) requires greater awareness than a peripheral display (Social Badge), specifically when used to provide the same social cues in a subtle manner. The third is to repeat the experiment with more test participants and a less rigorous method for group allocation. Bypassing the randomised-controlled-trial rules (section 5.1.2) for SIAS scores sampling is an example of this approach that may assist to obtain data from a particular subgroup of socially anxious users. Investigating only a particular level of social anxiety (namely mild, medium or high) of the recruits per trial, would allow for more in-depth and varied details of user awareness. The fourth is to examine the characteristics of the dataset more extensively. The data showed a degree of skewness in the sample drawn from highly anxious users ('shy group' in Figure 81). These users reported having far greater awareness ('aware of its content') of the information presented on the badge than the card, namely seven times.

Among these approaches, the last leads to an interpretation aligning with the literature; socially anxious users have preferences for specific types of social technology (section 2.1.2), namely those that facilitate low-cognitive and low social-weight interaction models. Therefore, providing a social cue being subtly available at all times, allowed for the badge to reside and present information for longer periods in the users' visual field, granting easy and intermittent access. In addition, it operated more synchronously with users' preferences compared to its counterpart that only presented information on demand; and required more apparent physical and conscious efforts as well as the interaction with an artefact that was less conventional to the social context.

Degree of Positivity in Social Cue

Regarding secondary purpose of this study to examine the impact of cueing content on users' attitude to their meeting partners, their opinions about higher social compatibility levels (greater positivity) was compared to those about the lower (less positivity). Given that threat vigilance is common among socially anxious people participating in unfamiliar situations, greater positivity was hypothesised to have a greater impact on user attitude than less positivity. Findings appeared to partly support this reasoning; the higher the degree of social anxiety, the greater the impact of the positivity content proved to be, not the vice versa. However, experiencing less positivity in the social cues was not likely to generate any negative feelings, as the qualitative feedback told. The feedback was given in response to the question: how did you feel about being informed of having lower/higher compatibility levels with different meeting partners? Examples of the feedback are given below.

Comments on experiencing lower compatibility levels:

> ***'[I]t's OK as long as it showed something.'***

> ***'[Low is] Still positive as two people can talk [about] something maybe out of curiosity or awkwardness.'***
> ***'[I was] a bit nervous about what to talk about. Felt I had to make more of an effort from the start.'***
> ***'No noticeable effect as they were not immediately at my attention.'***
> ***'It didn't change my approach talking to everyone. I still wanted to know what they studied and wanted to do next.'***
> ***'Not really [matter], but the higher, the better.'***
> ***'Surprising I had a better conversation with less compatible people. Maybe it's because they said they were from Q[ueen] M[ary University] and I felt some sort of sameness.'***
> ***'I think I had fewer conversation topics and talked less.'***

Comments on experiencing higher compatibility levels:

> ***'I felt more at ease and curious to find out about the other person like what we had in common really.'***
> ***'Maybe we had a lot more in common if we could talk longer.'***
> ***'I was more curious to see how the conversation goes and they went pretty much the same as low compatible.'***
> ***'Good fun! I thought I had a lot more in common with them.'***
> ***'I felt comfortable and was able to talk about different topics.'***
> ***'I think I felt more comfortable and talked more.'***

Complementing the quantitative findings with these additional opinions implied that more positive cues tended to improve user behaviour by influencing their desire to converse, but less positive cues did not undermine that or influence negative attitudes.

In addition to hypothesis testing, two distinctive results supported the use of positive information in building the display content of social cues. The display content was designed with two capacities to improve or even reshape the way the user thought about a social situation. The first was its capacity to generate curiosity between two people. This capability was enabled by an abstract form and ambiguous character of the information graphic. Unobtrusively, the cueing content persuaded the user to adopt an active role of communicator, rather than having a passive presence (section 2.1.1) in a challenging situation.

The second was its capacity to make users feel more comfortable in the social situation. It showed in the users' general desire to converse more or for longer, specifically in the last four opinions (of the above 'Comments on experiencing higher compatibility levels'). These opinions belonged to users whose SIAS scores were above the shyness's cut-off score (Peters, 2000). This evidence partly validates the fundamental consideration of designing the *quality of user experience* (Alben, 1996) as implemented in the Social Badge's interaction model. As such, it only requires tasks the user is comfortable to perform and participate in. These two aspects are the driving forces that influenced the users to become more engaged in the central activity of the social situation when they became aware of having mutual interests with one another.

These findings were also consistent with results from the Pilot II study. Despite the augmented social cue appearing less or non-positive, it still encouraged a positive atmosphere and constrained the users' attention within the centre of the social situation. Such studies' outcomes reflect the principle of the *relational* quality of SOs (sections 2.1.2 and 5.1.1), in line with the design principle of subtle SOs (section 3.2.2), to instigate talking between strangers. The relational SO did so by asserting itself as a shared artefact that facilitates coordination of social cognition between the users, and hence augments their sense of *we-agency* (Pacherie, 2013) while simultaneously amplifying the individuals' perception of its own social ability that contributes to the successful joint activity (section 2.2.1). Nonetheless, the degree of user awareness and impact on user attitude alone did not reveal how gratifying it was for the user experience in having these augmented social cues present. Discussed in the following subsection are the findings from examining user satisfaction in social experience and preferences for the cueing modalities.

6.5.3. Satisfaction with Low-Cognitive and Low-Key Interaction

User gratification is a general measure for gauging the capacity of a peripheral display in satisfying the user. Researchers have interpreted it differently, depending on the study theme, as Matthews et al. (2003) argued. Specifically, when the theme is socially related, this criterion should be decoded as the seamless integration of the display into the social context to improve user engagement with the primary social activity. Combining this argument with the low-cognitive themes of user interfaces (section 2.2.1) and psychological concerns for intuitive uses (section 2.3.1), this criterion, therefore, becomes the key component for measuring the cognitive aiding capacity of the social object (Bastick, 1982, p. 133). Concerning users' social experience, it was interpreted as the demand for cognitive effort for social interaction in the case scenario in this study.

As previously mentioned, the prevalence of cognitive overloading in socially anxious people calls for a positive cue to be augmented in ways that are easy to perceive, demands little mental effort while encouraging a puzzle-solving frame of mind to explore the cue and its meaning. Thus, it was initially posited that having these cues in the meeting would be preferred to not having any, and that more visible social cues would be preferred by users who had a higher degree of social anxiety. However, the test results only partially agreed with the hypotheses. An unexpected and two expected findings are discussed as follows.

In regards to the unexpected, users with lower social anxiety (SIAS scores 9–35) preferred not having any additional social cue, if it was augmented via Social Cards. This occurrence appeared to support literature regarding the intrinsic problem of cognitive overload (section 2.1.1) in combination with the intrusive interaction model (2.1.2) of the Social Cards. Having to search for a specific card amongst the set to find content that matched the ID of the interaction partner was awkward; it prevented the user from naturally performing physical and cognitive routines in the social situation. Hence, the users preferred having no additional social cues than having to use Social Card, even if it presented useful information.

The two expected findings were related to users' preferential ranking of the cueing visibility. One indicated a positive correlation between the visibility of the social cue and the degree of users' social anxiety. The higher the degree of their anxiety, the more they became satisfied with using the Social Badge. Another finding was that the users with higher social anxiety (SIAS scores 40-51) preferred having the Social Badge to the Social Card in the meeting, although the badge provided social cues in ways compromising their privacy. Their preferences for low-key and low-cognitive interaction models can explain such satisfactory compromise of their privacy regarding the badge usage. This argument is expanded below drawing on the natural approach to designing tangible and intuitable user interfaces (section 2.2) towards the understanding of how these two characteristics enabled the Social Badge to gain greater user satisfaction.

Tangibility

Social Badge's interface is tangible in the sense that it allows users to directly manipulate digital information in ways natural to their operation of a social routine: the handshake. This user input did not only become a medium for *direct manipulation* to reduce cognitive demand in operating the computational system (section 2.2.2). It also gave a metaphorical meaning to the user interaction with the social technology itself and the context of use. Moreover, it drew on the users' well-established social skills and accurate expectations from the interaction partner who co-manipulated the computation and sensing hardware leading to the update of their social compatibility levels on the display interface. In other words, the Social Badge system adopted user behaviour and anticipation as its own; users manipulating it were thus directly performing the task without having to be concerned about the operating process.

In the broadest sense, both Social Badge and Social Card systems offered direct manipulation through a physical object. In the case of the badge, the handshake takes the two users' hands as a physical medium for updating the social compatibility levels, and with the card, the act of card shuffling reveals the same cueing content. Through the *representational* perspective that focuses purely on the user interface and its materiality (section 2.2.2), the card can be seen as requiring a greater degree of direct manipulation given that its reshuffling action produce a direct change in the paper card display – the same artefact that occupies the user's hands. In contrast, the handshake action produces a change in the badge located in the user's visual field (when making eye contact) – separate away from the hand. However, through the *interactional* perspective that considers relational properties of an artefact to tie the object of manipulation within the user's social context (section 2.2.2), the badge can be seen as superior in facilitating mutual understanding of their joint action and purpose to engage in the social activity. The changes that appear in its system response are responsive not only to the user interaction with the system but also with the social setting. Despite the ease of social understanding, manipulating the badge interface also requires less cognitive demand owing to the 'intuitive use' it offers (discussed in the following).

Intuitiveness

Manipulating the badge's interface not only minimised learning time and apparent mental effort compared to manipulating the card. Operating the badge also led the user to several kinds of *direct knowing*, such as properly operating the artefact, accurately anticipating the system response, and perceiving its meanings. Together these two characteristics form basis for the intuitiveness to the badge use.

Effortlessness (Diefenbach & Ullrich, 2015) is a common component for designing intuitable user interfaces (section 2.3.1). Using the Social Badge can be effortless because its operational input (handshake) is embedded as part of the social interaction routine. Its system response, namely representation of an augmented social cue, is integrated in clothing and, as previously mentioned, positioned in an area within a user's visual field during eye contact and making conversation. This positioning makes it inevitable for the badge users to perceive the change in its cueing content soon after they shake hands. Unlike the cards by which its cueing content diverts attention away from common tasks in the social activity (e.g., cue monitoring, eye contact and talking), the badge can be operated without user attention being distracted away from the social cues and interaction partner. Meanings of its cueing content, thus, occur naturally as the knowledge about its system response is inherent in the user action for operating the system.

Direct knowing (Sinclair & Ashkanasy, 2005) is another aspect that makes the badge interface intuitable. It occurs when the user performs an appropriate action without the need for giving thought to cause and effect (section 2.3.1). The reason for direct knowing developing easily in the badge use, is that its interaction model is implemented with an interface metaphor that 'matches' (Svanæs, 2001) the structure of physical input with that of users' prior interpersonal experience. This metaphorical mapping intensifies direct knowing about the handshake as a co-operative action between the users to simultaneously assess their social compatibility, and leads them to perceive the badge as a 'shared' artefact from which they can establish several senses of connectedness, namely co-manipulation of the system, co-production of the augmented cues, and an exchange of knowledge about their mutual interests. In contrast, card shuffling does not convey such sense of connectivity; it is an self-contained act which creates a private information display. Although it offers some degree of privacy in favour of socially anxious users, its interactional path disengages them from focusing on the face-to-face interaction – the social skill that requires improvement.

Comparing these two characteristics of the Social Badge and the Social Card, the badge model offers greater effortlessness and a non-interrupted route to direct knowledge. With the badge, a tighter coupling in the interaction path (namely between user action, information processing and meaning of the interaction within the social environment) is more likely to happen. This *tight coupling* not only aids the user's cognitive processes by making operation of the technology transparent, but also allows for greater focus on the interaction partner while remaining aware of the badge's information. For the latter, the coupling mechanism operates through users adopting a *we-mode* state (Frith, 2012) as formed through several joint actions, namely mutual understanding of their socialising activity, negotiating their intentions and managing the *we* space (Krueger, 2011) – the interpersonal space that emerges during non-verbal interaction, such as gesture, touch, facial and whole-body expressions (section 2.1.1). This *we* space is severely compromised in the use of Social Card although it can be argued that the card promoted the social value of users' co-presence through its cueing of relational content. However, the Social Badge goes further with its interaction model by restricting the user action and focused attention to the face-to-face interaction.

This model places the Social Badge as an 'extended self' of the co-users, and in turn, it becomes a mediating tool for binding their co-physical and social presences and socialising intentions. Socially anxious people struggle to break free from the *vicious cycle* of anxiety that places their self as a passive object of interaction and causes them to appear reserved (section 2.1.1). With the self(s) extended in the badge display, their social cognition resources expand beyond the own self and their initial intention to socialise are automatically augmented.

In summary, the assumption for RQ2 was validated through these findings; the key advantages of facilitating the socially anxious users' interaction with a subtle technology lie in its three main characteristics: benefits, features, manifestation and functioning behaviour. They provide significant insight into how social technology can be designed to prioritise the nature of the user's needs for a highly persuasive invitation to talk and assurance of a constructive outcome while utilising their existing cognitive-behavioural predispositions without impeding their preferences for social artefacts and interaction models.

Chapter Seven

7. Conclusion

7.1. Overview

This research is central to the challenging demands experienced by shy people in social situations. Adopted as the research problem is their difficulty in initiating and maintaining a conversation with someone they are not familiar with. This exertion causes the shy, or socially anxious people, to 'freeze-up' and appear reserved. Feeling awkward and being overly concerned with self-correction and perceived social cues are common cognitive-behavioural phenomena for this group of people. Cognitive overload is, therefore, an intrinsic factor hindering their performance in social environments.

The shift in Human-computer Interaction (HCI) perspectives on user roles – from independent interactors to social agents – together with the advance in ubiquitous computing provide new ways to naturally minimise the mental and physical demands as well as the social weight of technology. *Calm* computing vision (Weiser & Brown, 1996), in particular, is fundamental to this research to integrate computation into the user background environment. With its system functioning transparently to support and not overwhelm user cognition on the foreground activity, this vision has been an ideal standard for new social technologies compare against traditional intrusive models for user interaction.

Nonetheless, designing merely to *encalm* seems inadequate to influence the shy to foresee constructive outcomes of a social interaction. Hence, it is insufficient to encourage them to take a more active role in face-to-face (F2F) communication. Balancing Weiser's vision with Rogers' (2006) *engage* agenda for third-wave ubiquitous computing is evident in this research to successfully engage the users within the activity they currently find challenging. In that, the technology becomes an unobtrusive aid that puts forward the user's existing abilities to achieve tasks they have thought difficult to undertake. Through the use of a subtle *social object* (SO), this research demonstrates that the interpersonal skills of shy users and their desire to socialise can be advanced, thus leading the users to a more engaging social interaction and satisfying outcome.

This closing chapter begins with the summaries of the main findings from the outcome of three research stages that consecutively led to answering the two central research questions (RQs). Next, each RQ is revisited to reflect on key research contributions, previously outlined as the Icebreaker Cognitive-Behavioural Model (section 3.3.1) and the Design Principle for Subtle Social Objects for Shy Users (section 3.3.2). Before concluding with a closing remark, some limitations encountered during the research activities are presented alongside suggested solutions for further studies.

7.2. Summaries of Main Findings

This part provides the summary of the main findings from the three research phases, responding to the two consecutive research questions (RQs).

7.2.1. *Social Objects* for the Shy

Taking an exploratory mixed method approach to conducting three-phase activities (section 3.1) allowed this research to primarily generate qualitative data from Phase I. This knowledge was subsequently used to form a set of assumptions for the first central research question:

RQ1: How can a social object be used to aid the social interaction of shy users?

To that, a social object would ease the challenges shy user face in social interaction if its features, in subtle ways, augment their relationship through a display of social cues and immediately divert their attention to it. This relational cue needs be deliberately presented with incomplete pieces of information, accommodating the users to enter a joint process of puzzle solving. Although this process requires some degree of mental (social cognition) and/or physical (interpersonal actions) efforts, such efforts are common to the social situation. This process aims to draw user attention to the constructive elements of the social activity. Hence, the knowledge generated through this puzzle solving becomes a resource for conversation making. The social context becomes more familiar to the users with a mutual invitation to start and maintain the conversation with one another. Such assumption led to forming the Icebreaker model that was validated in the next research phase. Two pilot studies were conducted in the research Phase II, each with a user-centred evaluation on usability and experience. Study goal, method and outcome that support the RQ1 assumption are summarised as follows.

Pilot I Study assessed the capacity of a covert vibrotactile interface of the Vibrosign armband. This prototype was designed to convey detailed information about social cues. The results revealed its potential for delivering deictic and letter messages to the user's upper arm, but raised some concerns about the intrusiveness of technology to the physical, mental and the social experience of the user. A questionnaire was used to sample data from expert reviewers. The finding suggested that this display modality was feasible in terms of technical configurations to improve user perception of the cues. Nonetheless, it also yielded some probability to hinder their social performance and experience. This vibrotactile approach to facilitating social interaction with private cues was therefore replaced with a less intrusive modality of display: public visual display, although this new approach could be seen as less supportive of user preference for privacy.

Pilot II Study investigated conceptual and technical feasibilities of presenting a mutual social cue to shy people meeting for the first time in an environment constructed with the Icebreaker model. The Icebreaker T-shirt was used as an instrument for generating samples of user behaviour and experience to be video recorded for analysis afterwards. Its peripheral display on the frontal area acted as a social object showing incomplete information regarding the level of social compatibility to promote curiosity between the users and lead them to initiate and maintain a conversation. They behaved as expected; in a more engaging manner than when the display was not at present. The data also revealed that most users appeared more relaxed and took the active role in conversation making. This group occasionally paid attention to the social display but their primary focus was on the interpersonal engagement with the interlocutor, not the technology. However, some other users seemed to be more occupied with the technology itself due to the unpolished quality of the prototype that sometimes interfered with their social experience. Despite such disruptions, the mutual cues presented through the peripheral display were evident to effectively facilitate social interaction in shy people. Hence, this approach was adopted to develop in the later research stage.

Other than supporting the RQ1 assumption, the outcome of Pilot II, provided greater understanding on the qualities of SOs and their suitability to engage shy users. SOs are known to hold different qualities (namely *personal*, *provocative*, *relational* and *active*), all of which are effective to encourage strangers to talk to one another by reducing their interactional stress (section 2.1.2). However, the psychological tension shy people experience when meeting with strangers is much greater due to their preoccupation with negative cognitive-behavioural attributes. The conceptual analysis prior to implementing the qualities of social objects in the design of technology (section 5.1.1) provided that the *relational* and subdued *active* of SOs were better suited to the social nature of shy people. The two qualities were used in the creation of a dynamic social display of the Icebreaker T-shirt with qualitative data collected from Pilot II study showing that these SO qualities operated well in tandem. The subdued *active* quality is primary to distracting and immediately divert the users' mutual attention onto their relationship. The *relational* quality is crucial to generating ambiguity in the relationship, prompting conversation with its question-generating character. It supplies sufficient clues to construct knowledge for sociality and constrains their performance within a meaningful path of social interaction.

In reply to RQ1, the use of such SO qualities, in an unobtrusive and accommodating manner can become a means to exploit shy users' desire to engage and appropriate their attention into positive channels in the social situation. SOs conceptualised in accordance with these combined qualities can reside in the user periphery and, without being 'noticed', turn the interpersonal environment into an inviting collaborative space for discussion. Such SOs can subsequently be called 'subtle social objects'.

7.2.2. Key Advantages of Subtle Technology

At the beginning of the last research Phase (III), subtlety was hypothesised as being fundamental to the characteristics of social technology that could aid interaction amongst socially anxious users. In order to gauge the extent of such advantages, the research quest was then centred on the second research question:

> *RQ2: What are the key advantages of facilitating social interaction with subtle technology?*

In setting the assumption for this question, a design principle was formulated with three categories of characteristics (i.e., *benefits*, *features*, and *appearance and functioning behaviour*) for designing subtle SOs (section 3.3.2). The design principle was taken as a guideline for improving the subtlety aspects of a new prototype Icebreaker Jacket. With a Social Badge to present social cues (namely social compatibility), the jacket was used as the sample-generating instrument in the Final study. Regarding the disruptive impact video-audio recording had on the user experience (Pilot II study), a during-test questionnaire was used instead as a sampling instrument to accompany a post-test questionnaire. Both drew quantitative-based samples with some complementary qualitative data taken from the participants' opinions on usability and user experience of the technology.

The Final study set out to assess how the three aforementioned characteristics of a subtle SO (Social Badge) were superior to facilitating social interaction of socially anxious users, compared to the Social Card, a comparative non-subtle SO. Findings showed that the subtle SO facilitated social interaction more naturally to the cognitive and behavioural nature of the user. The higher degree of social anxiety in the users, the more they found the badge was helpful to making conversation. They showed a greater preference for the subtle cues given by the badge and expressed more satisfaction with the social experience.

In the process of generalisation of such capacities, each category of subtle SO characteristics is examined below in relation to the user insights outlined in the design principle (section 3.3.2) and the findings specifically from the Pilot II and Final studies.

Benefits

Social-interaction anxiety is a constant challenge for socially anxious people who have the desire to participate in social situations but are hindered, and sometimes even paralysed emotionally and socially, by the fear of rejection. Asserting itself in an environment where the users already find it difficult to manage their own social cognition and interpersonal actions, a novel social aid needs to benefit user behaviour and their experience in an immediate and purposeful manner. The findings from Pilot II and Final studies showed the effectiveness of the subtle display in giving the users an immediate 'ticket' to talk. It did so by making explicit the *isomorphic mapping* (section 2.3.1) between the required operation (handshake) and the update of system output (social cues). This immediate action and consequence, as a result, made it easier to comprehend o the user interaction with the system. Through this process, the users could coordinate with the system and with the other person to further their own understanding of what made them socially compatible, and to take a more active role in the social activity. The latter counteracted the prevalent trait of shy users to process the self as a passive object for socialising. Some participants (section 5.2.2) reflected on their ability to socialise and commented that perhaps they were not shy after all.

These findings agree with the embodied view of cognition in suggesting that tool use amplifies the user's *enactive* perception of own abilities as well as magnifies new possibilities in the user environment. The capacity of the subtle cue, as revealed through the findings, enhanced the user's perception of own social abilities within an unfolding pattern of constructive social activity. Such findings also resonates Dourish's (Dourish, 2004b) embodied view of interaction (section 2.2.2); acting with the other person upon the purposeful technologies, the user action is embodied in the physical as well as social realities. The physical contact and exchange of questions and answers occurred within a specific circumstance that demonstrates a meaningful encounter in the technology-embedded social interaction.

Features

Driven by the balance between Weiser's *calm* and Rogers' *engage* approaches, the feature of a subtle SO was designed to negate the inherent social behaviour of the users and assist them to overcome their common social challenges. Shy people tend be overly sensitive to social cues – an effect of the unrewarding cognitive-behavioural traits of continuous self-monitoring and searching for the negative responses from others). From the perspective of subtle technology, it was important to harness these personality characteristics for the greater good by using them to trigger the processing of the relational self (section 3.3.1). Given that the users are already in a heightened state of awareness of what is happening in the social environment; the relational information augmented in the system display could be recognised effortlessly. From the socially anxious people's perspective, a social environment is commonly 'full' of negative signals owing to the limitations of their social cognitive skills (section 2.1.1). A positive cue symbolised by the social compatibility display was therefore posited to stand out in the social context. Findings from the Pilot II and Final study showed that the users' attention was drawn towards, as well as evolved around, this constructive social resource.

The social compatibility level as a design attribute is not exclusively applied to extend users' information-processing resources beyond the self. However, drawing on the ecological approach to social cognition (section 2.2.1), it stands as a *social affordance* that provides coordinating cues. In that, it guides individual users' attention and action towards the *we-mode* of F2F interaction (section 2.1.1). In addition, the social compatibility display was designed to conform with the immediate result of the handshake input aforementioned and the cultural norm of the deployed social situation. Revealing the compatibility scores soon after the handshake signifies and constrains the meaning of the social exchanges that come afterwards. This mechanism, in one way, provides the platform for both parties to negotiate their intentions. In another way, it influences the users to anticipate a positive outcome of the joint action while the interpersonal action and shared experience are progressing.

Appearance and Functioning Behaviour

Face-to-face interaction is an information-rich situation that demands substantial mental processing. These demands can expose socially anxious people to cognitive overload causing them to appear reserved and avoid proactive behaviour that requires additional mental effort to perform. This explains why shy people prefer minimal cognitive demand, low-key interaction and low social-weight of technology. These aspects, embraced in the physical appearance and system behaviour of the subtle SO (Social Badge), were reported by the users to be more useful to social interaction and contribute to a more satisfying social experience, compared to the non-subtle SO (Social Card). Examining these positive outcomes in terms of subtle SO's user interfaces and its interaction model, make the advantages of using it to facilitate social interaction more apparent.

A subtle SO appears low-key either on its own or when in use, as seen in the case of the Social Badge. Although embedded with computation and electronic components, its user interface exists as a familiar item to both the physical and social contexts of the user. When coupled with the user's physicality and action, it echoes the embodied interaction approach (section 2.2.2) presenting the user-technology participative status as a common occurrence in the everyday world. In addition, its user interfaces facilitate low-social weight of system operation (section 2.3.3); neither the handshake for revealing the display information or the monitoring of the display separate user actions from the social norm. The possibility of these actions becoming the sole object of attention is therefore eliminated. To achieve such low-key aspects of technology was paramount in the approach to designing the Social Badge as a peripheral display. Reinforced with the *ensemble coding* and *pre-attentive* information processing design principles (section 2.3.2), the display becomes a subtle social cue that facilitates a lightweight form of information monitoring. These resulted in the low-cognitive demand interaction model of the technology. Having it present in the environment or using it, hence, does not interfere with the ongoing situation.

As previously discussed, socially anxious users are prone to social cognition deficit and hence cognitive overload (section 2.1.1). These user limitations were adopted as the main design brief to encapsulate the subtle interaction model of Social Badge with a blend of *peripheral-tangible*, *peripheral-subtle* and *implicit* interaction styles (section 2.3.2). Interacting with a computer system intuitively, or on a subconscious level (section 2.3.1), is fundamental to these interaction techniques. They can all be completed instantly to focus user attention on the social-interaction goal, not the system-interaction. Nonetheless, each has a distinctive characteristic contributing to the operation technique of the subtle SO, namely the handshake. In light of the *peripheral-tangible*, the operation is a well-understood and well-practised greeting ritual. Of the *peripheral-subtle*, it is an already executed action and native to the ongoing situation – it does not require additional physical or mental effort to manage a social routine. And of the *implicit*, it resembles the user social pattern, becoming the sole user command that automates the exchange and update of social information. Users operating a subtle SO thus becomes a means for coupling their physical and mental states with the social and computation-mediated environments. The computer system in this sense acts as a ‘transparent’ tool (Clark, 2003; Dourish, 2004b) that fades into the background when operated. Nonetheless, the meanings of user-system and user-environment interactions are not lost. The immediate and apparently discoverable *isomorphic mapping* between the social metaphor (handshaking operation) and the mutual display of social cues brings the meaning into the foreground. This ‘flippability’ of the system behaviour put the subtle SO into the role of a psychological tool that prompts the user thoughts on their relationship and hence meaningful social interaction.

The characteristics of the *benefits*, *features* and *appearance and functioning behaviour* of the subtle social technology as generalised here, in part, form the answer to RQ2. Its key advantages to facilitate socially anxious users’ interaction are primarily in the mutual, immediate and highly persuasive nature of the psychological invitation to start a conversation. It does so by amplifying their perceived social abilities and providing conversational resources to augment the users' social relationships. These benefits are provided by *social affordances*, its features that divert users' attention – from the self and perceived negative signals – to the interpretative gap of the augmented social relationship, hence coordinate their reasoning and social cognition towards the constructive responses by one another. Such features are enabled by the transparency in its user interfaces and interaction model, that when 'coupling' with the users' physical and mental efforts, becomes a psychological tool to manage the demands of social interaction without placing undue demands on their social nature.

7.3.Limitations and Possibilities for Further Exploration

The generalisation of research findings up to this point is subject to certain limitations. Researchers who wish to apply the methods for design and assessment of the subtle artefacts might find it useful to consider the following concerns.

7.3.1. Design and Evaluation of the Comparative Tool

Regardless of the qualities of the computer-mediated tools used in all studies that could be improved mainly on the traditional aesthetic front, the suitability of the comparative tool used in the Final study is a matter for concern. The main reservations for justifying the success of the technical design lie in the choice of user interfaces and interaction model. These limitations were caused by 1) an under-developed design thinking for the Social Card (the non-subtle social object (SO)) used as a comparative tool to the Social Badge (the subtle SO); and 2) the absence of isolated comparisons between their user interfaces and interaction models.

Design and Evaluation of Comparative Tool

The choice of the comparative tool can be redesigned more specifically to particular purposes of the comparison. In the study, the employed Social Card was used as a full-attentional demand SO, implemented with a focal-demanded display modality and static interaction model with no interactivity or computation mediated features. This contrasted sharply with the configuration of the Social Badge, which combined a peripheral-awareness display and a dynamic interaction model. A source of weakness could have originated from this point given that the required physical effort to update information on the Social Card and perceive information from it, were significantly disruptive to the interpersonal performance compared to the Social Badge. All of these could have led users to bias and being in favour of the latter. Although the Social Card offered a private view more favourable to the preferences of socially anxious people, its static operational model was not embedded in any social routine, resulting in its manifestation that was alien to the social context. A more low-key interaction model (e.g., eye-movement or bodily gesture) and a full-attention-demand display native to social environments could reduce the potential for these biases.

Separate Comparisons

There were two potential confounds between, firstly, the physical demand and attentional requirement of both type of SOs; and secondly, the novelty and conventionality of their user interfaces. The first possible confound is related to the unseparated comparisons between the cognitive impacts of the user interfaces and interaction models (of the Social Badge versus the Social Card). The second is potentially caused by user interest in the high-tech or *supernatural* behaviour (Hornecker, 2012, p. 181; Jacob et al., 2008, p. 205) of computer systems – specifically of the Social Badge. Together, these features made it difficult to identify whether the usefulness of technology, user satisfaction in social experience, and preferences for display modalities and interaction models were influenced by the cognitive or implicit physical requirements. Future studies designed to separate these comparisons will undoubtedly gain deeper understanding of the impact of the cognitive demand of technology. A practical approach to this would be to replace the Social Card with two new comparative SOs. One SO could present an equivalent physical demand to that of the Social Badge, while providing social cues through a full-attention display. The other SO could focus on giving social cues through a peripheral display, as the Social Badge did, but with greater effort required to operate the display.

7.3.2. Data Analysis

There are three known shortcomings in the data analysis processes. While the first is common to research involving the development of novel user interfaces, the latter two are unique to the investigation of social behaviour in people with social anxiety.

Small Samples

Although rigorous approaches to designing experiments and data analyses were adopted in the Final study, its test results indicate the small sample sizes as the main limitation.

An essential next step in data analysis would be to conduct larger randomised-controlled trials. This could provide more definitive evidence to support each empirical hypothesis set out for the tests of difference and associations (section 6.4). Two prospective solutions that future studies could adopt would be increase 1) the number of test participants; 2) the number of meeting rounds in each meeting session. Neither approach would require a new design for the testing procedure, but larger samples or more rounds would reduce the data analysis steps and increase the practicality of the test result validation.

The first option may be preferable, because having more test participants is likely to expand the overall range of scores on the social interaction anxiety scale (SIAS) in the recruits. Hence, the degree of skewness in the distribution of this dataset is likely to decrease. This would also give more freedom in selecting and applying parametric statistical methods, known to be more robust than many equivalent nonparametric methods used in this research. In addition to this benefit, researchers could also conduct a power analysis prior to performing inferential statistics. Increasing the referenced alpha level and reducing the referenced effect sizes (that those referred in section 6.4) should also improve the odds of null hypotheses being rejected. Subsequently, the results would yield smaller p-values, which would make the validation of test results more credible.

Apparent Effects of Randomised-Controlled Trial Approach

Randomised-controlled trials might be an indispensable approach to avoid biased distribution of confounders but revealed some significant limitations, particularly in the data analysis of the Final study. By adopting the approach, the testing procedure did not differentiate between degrees of social anxiety among the participants in each meeting pair. The full record of 'who met with whom' is traceable; however, given the right-skewed distribution of SIAS scores, most participants were close to or above the cut-off score. Therefore, the majority of their meeting chances was with high-SIAS people. A few low-SIAS participants met with high-SIAS participants, but this group was too small to generalise a statistical result. Predefining the difference between anxiety levels in each pair (e.g., high meets low, high meets medium, and high meets high) would provide a richer database. This could also give further insight into the association between the severity of social anxiety and the extent of user satisfaction and preferences for each modality of social objects (SOs).

Another drawback posed by the randomised-controlled trial approach was in the limitation of a specific range of social anxiety among the recruits (between 9 and 51 SIAS scores). More fully, the research could have investigated the capacities of the chosen SO qualities in relation to the specific subsets of social-interaction anxiety. The inclusion of more recruits having low, medium (around cut-off) or extremely high (close to maximum) SIAS scores would help to establish a greater degree of accuracy.

Observation of User Behaviour

Due to the ethical constraints (section 3.4.2) and the concern regarding absent recruits encountered in the preliminary study (chapter 5), user behaviour was not recorded with an audio-video device in the Final study. Although the studies employed a *during-test* and *post-test* questionnaires as substitutions, the empirical evidence was still limited, regarding user awareness, attention to SOs, and behaviour (related to memory, sincerity, and comprehensive opinions) among the participants. Future studies might assign some experiment observers in the least possible obtrusive zone of testing area. However, this is not a thorough solution since it can give the test participants a sense of being monitored. A more careful solution could be disguising observers as socially anxious participants. The downside of this approach is the increase of experiment budget and human resources and lower resolution of data records, but should provide more insight into user behaviour and overcome the confounding effects of an electronic recording device.

7.3.3. Setup

Repeatedly mentioned in this thesis, a natural approach is adopted as the fundamental to the designing technology. In that, where possible, it eliminates conceptual, design and technological aspects that have the potential to negatively impact on the psychological, behavioural and social nature of the prospective users. Nonetheless, the setting of social situations employed in the studies are arguably compromising the natural environment of social situations, given that the studies were conducted in a controlled environment. In particular, the test events for Pilot II and Final studies were simulated as a professional speed-dating event in a laboratory. It could have led to more detailed information about how users adjust their behaviour and attitudes in real-world social settings if it had taken place in a real-world environment (e.g. an in-the-wild research or ethnographic study). This could also give a clearer indication of the possibilities and limitations of the technology in serving their needs.

Nonetheless, speed-dating in itself is an unnatural social phenomenon owing to its strict rule-based structure. Without having met before, attendees agree to disclose their information in a collaborative manner. These reasons make speed-dating a substantial testing format that offers various advantages to the studies. In particular, its operative structure that provides intervals for quick assessment of user feedback. Together with the use of *during-test* questionnaire, it worked well for sampling instantaneous responses that tapped user memory and opinion. This helped to overcome some of the challenges inherent to peripheral-display evaluations.

Despite the benefits, speed-dating can also produce confounding effects. As a social environment, it has the potential to cause F2F interactional stress (Goffman, 1967) and create a fearful situation for people prone to social anxiety. Future studies that wish to retain this testing condition may benefit from recruiting test participants who have only mild to medium social-interaction anxiety. Although many participants in the study scored up to 18.8% higher than the SIAS cut-off, they were recruited from the same organisation and location where the experiment took place. Therefore, to some extent they would have felt familiar with the location. This could be a confounding factor that influenced c feelings of comfort and a commitment to participate.

Speed-dating is by its nature a form of an icebreaking event, which means it 'competes' with the functionality of SOs. Work needs to be done to validate the capacity of the technology alone to encourage users to link up or interact in a social situation structured with less or almost no icebreaking pointers; this could include special interest groups and conferences. Settings that present no icebreakers at all include coffee shops and bars. For the latter, where the testing environment becomes more open to the public, researchers may benefit from using Mattick and Clark's (1998) social phobia scale (SPS) screening tool to recruit test participants. The scale could be used in combination with the SIAS, as used in the final study. The SPS was developed to measure specific fears (e.g., drinking, eating and using public spaces) rather than focusing purely on social-interaction anxiety – as the SIAS does. Peters et al. (2012) followed this approach and combined the last six statements of both screening tools; the result is called 'SIAS-6 and SPS-6' and is widely used in clinical and non-clinical screenings.

7.4. Contributions to the field

This research explores novel features and characteristics of computer-embedded tools to aid users with social interaction anxiety. Through the exploratory sequential mixed method design suitable for experimenting with new aspects of non-existing technology, it resulted in some insightful analysis of the HCI natural approach to serving the user needs as well as bringing their social challenges under control. This approach builds on familiar design concepts of the related disciplines (namely ubiquitous computing, interaction design social psychology, sociology) to construct an unobtrusive interaction model and user interfaces, and subsequently to demonstrate new methods for:

- drawing user attention away from excessive self- and threat monitoring onto others and their conversation – the central elements of the social activity;
- augmenting social cues in an abstract form and through a peripheral display perceivable outside attentional focus, to avoid information overload;
- integrating the required user actions into social routines, namely the handshake to avoid additional effort for system operation, and to maintain focus on the interaction partner while perceiving system responses on the periphery; and finally
- reducing F2F attentional stress with the provision of a socially appropriate license to talk, while providing an extended resource for conversational topics.

Such findings, with the Icebreaker model (section 3.3.1) and the design principle for the subtle social object (section 3.3.2) should make important contributions to advance understanding of how the approach can be applied to the psychology of socially anxious users and strengthening their already existing desire to engage in a social situation and abilities to socialise.

Through several design implications, this research extends the vibrotactile (Khaorapapong, Purver, & Cox, 2013) and HCI (Khaorapapong & Purver, 2012b; 2012a; 2012c) literature regarding unobtrusive interaction model and information representation. In addition, the detailed developments of technology in different research stages may be useful for design exploration regarding covert and private information displays. Examples include: a wireless 3-by-3 grid vibrotactile messaging system (chapter 4); soft-circuit visual display for textile embedding (chapter 5); a low-cognitive-demand display and covert user input (chapter 6); and authentication of multi-tags and -readers in a dense RFID network using a *secret handshake* as user command (chapter 6).

The overall success of this research is the result of adopting an exploratory sequential mixed-methods approach (Creswell & Plano Clark, 2017) to designing research strategies and conducting research activities in various research phases (chapter 3). Through its emphasis on the exploring, as the name suggests, this design made possible the problematisation of the nature and challenge of socially anxious people. This emerged the cogent design approach and conceptual tools to extend the understanding of how the existing concepts in HCI and its related fields can be applied to the challenge, and to provide new evidence and perspectives for future research on the same or related issues.

7.5. Closing Remarks

> ***Nothing so much prevents our being natural as the desire to seem so. (François Duc de La Rochefoucauld 1967 cited in Clark & Beck, 2010b, p. 332)***

This research has demonstrated that any tool intended to aid socially anxious people must realistically cater for their psychological nature. Providing tasks that these users feel comfortable with, and which fall within the limited range of their cognitive abilities in social situations, is crucial. Computation and advances in technical tools and materials provide new opportunities to deal with challenges, constantly adding new and dynamic capacities to user interfaces and interaction designs. With this in mind, this research provided indicators to subtly emphasise the desire of shy people to socialise, while not overwhelming them with information load or the social weight of technology. Users who find themselves in a challenging situation may thus adopt a tool that demands little effort, has the potential to enable them to realise their social ambitions and act in more engaging and fulfilling ways with others and the social situation.

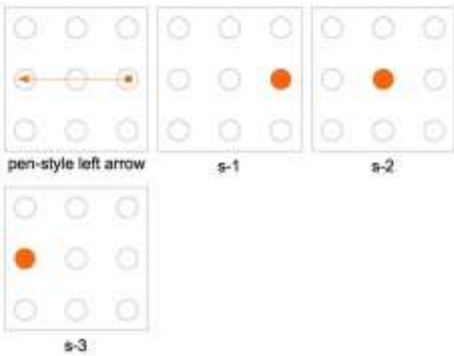
Appendix A

Pilot I Study Material – Vibrosign Armband Test

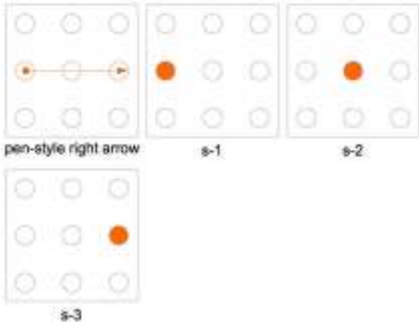
A.1 Tactograms

The following diagrams show each tactogram with required number, position, and sequence of activating tactors, including the total duration for vibration stimulating (set on the default parameters, namely 500 ms pulse duration and 100 ms inter-pulses length).

A.1.1 Deictic Tactogram

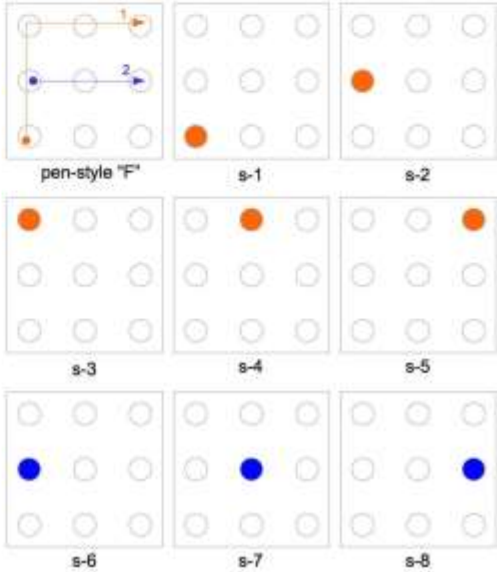


Figure_Apx 1: Left arrow operated in tracing mode of a 3-by-3 tactor array, requiring ~1700 ms duration

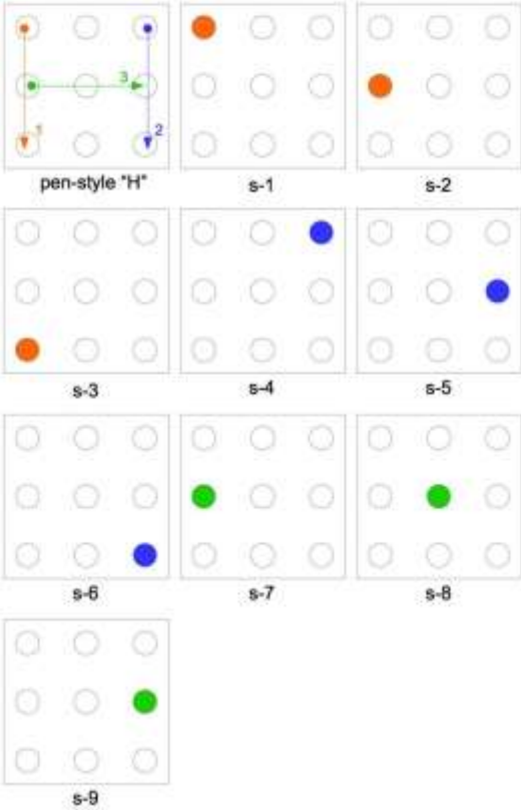


Figure_Apx 2: Right arrow operated in tracing mode of a 3-by-3 tactor array, requiring ~1700 ms duration

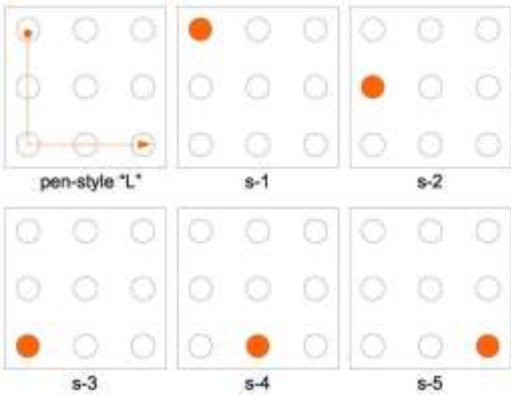
A.1.2 Alphanumeric Tactograms



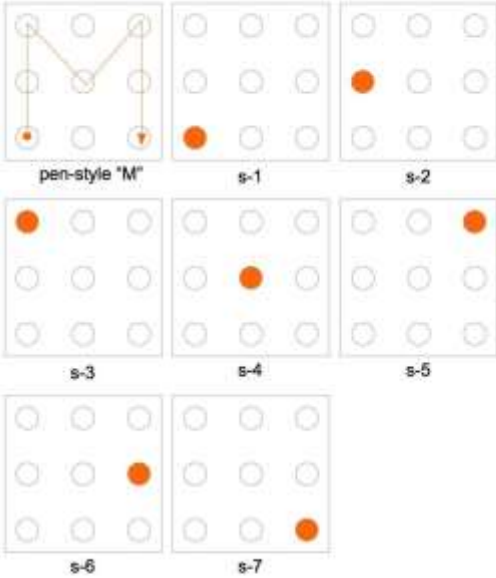
Figure_Apx 3: Letter F operated in tracing mode of a 3-by-3 tactor array, requiring ~4700 ms duration



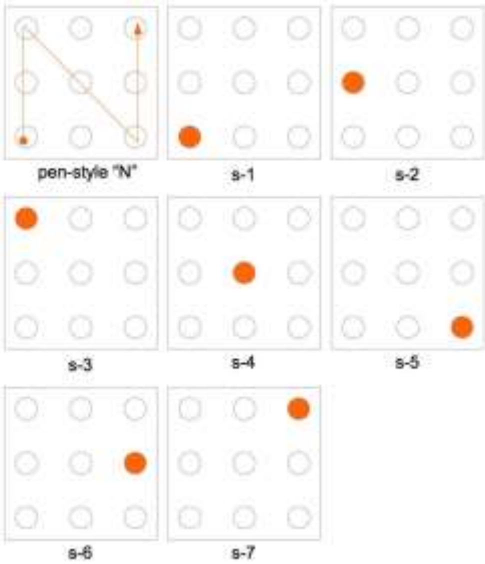
Figure_Apx 4: Letter H operated in tracing mode of a 3-by-3 tactor array, requiring ~5300 ms duration



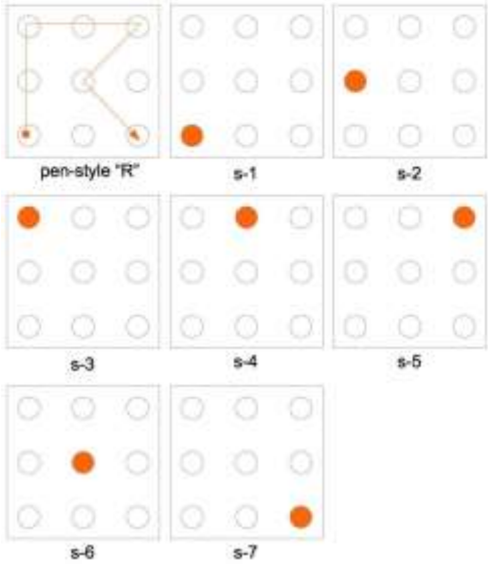
Figure_Apx 5: Letter L operated in tracing mode of a 3-by-3 tactor array, requiring ~2900 ms duration



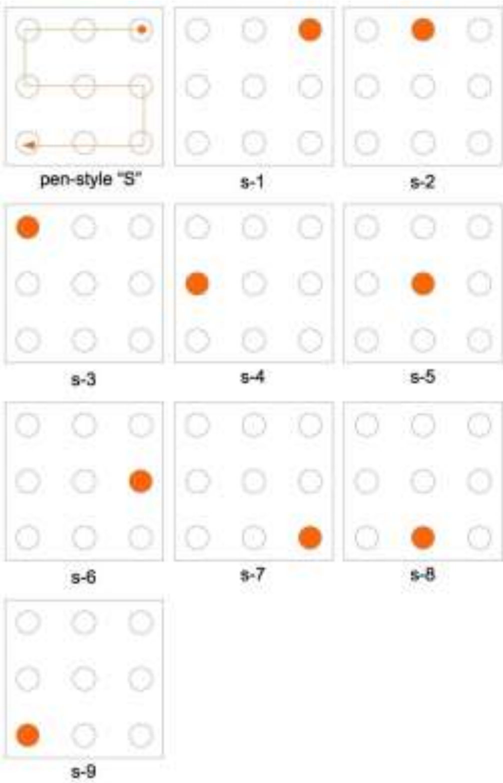
Figure_Apx 6: Letter M operated in tracing mode of a 3-by-3 tactor array, requiring ~4100 ms duration



Figure_Apx 7: Letter N operated in tracing mode of a 3-by-3 tactor array, requiring ~4100 ms duration



Figure_Apx 8: Letter R operated in tracing mode of a 3-by-3 tactor array, requiring ~4100 ms duration



Figure_Apx 9: Letter S operated in tracing mode of a 3-by-3 tactor array, requiring ~5300 ms duration

A.2 *During-test* Questionnaire

Q1 What is your age? ________ years old

Q2 What is your gender?

☐ female ☐ male

Q3 What was your most preferred level of vibration of the central motor?

☐ level 1 ☐ level 2 ☐ level 3

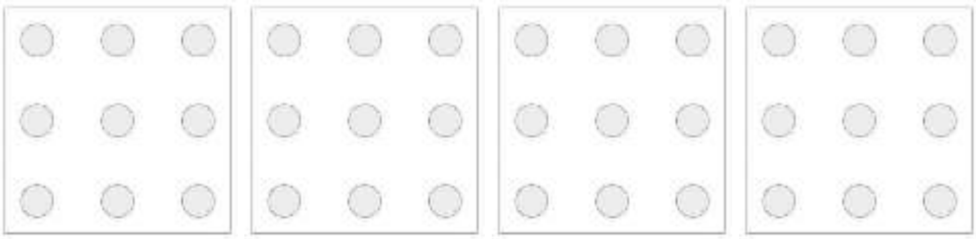
Q4 How long did you like each motor to vibrate for?

☐ length 1 ☐ length 2 ☐ length 3

Q5 How many pulses did you feel the central motor was vibrating? ________ pulses

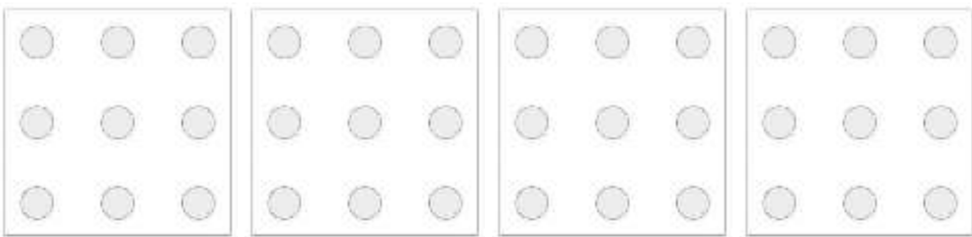
Q6 You have been presented with 4 randomly vibrating *arrows*, please draw them in the order as you felt they were vibrating.

Arrow 1 Arrow 2 Arrow 3 Arrow 4

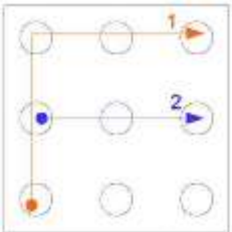


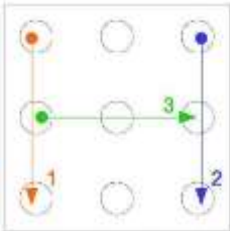
Q7 You have been presented with 4 randomly vibrating *letters* i.e. L and R, please draw them in the order as you felt they were vibrating.

Letter 1 Letter 2 Letter 3 Letter 4



Q8 Which letter did you feel it was vibrating (i.e., F, H, L, M, N, R, S)? Choose one from the following choices.

☐ F


☐ H


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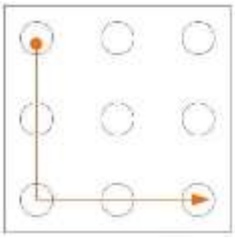
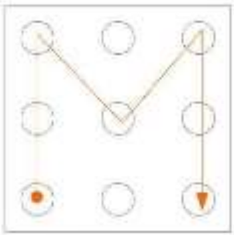
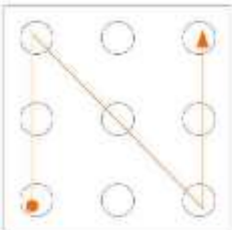
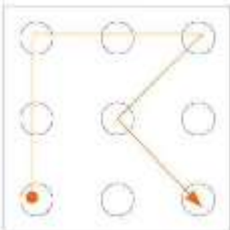
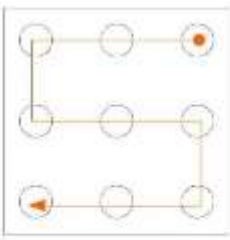


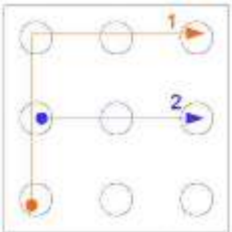
☐ M


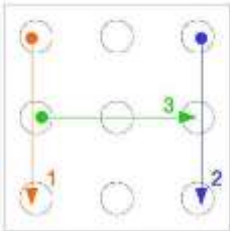
☐ N


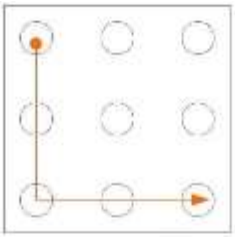
☐ R


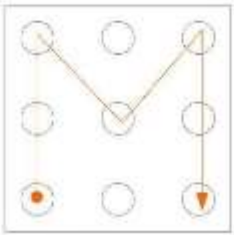
☐ S


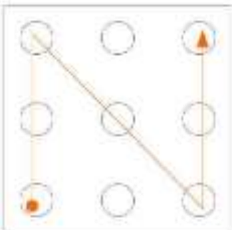
Q9 Which letter did you feel it was vibrating (i.e., F, H, L, M, N, R, S)? Choose one from the following choices.

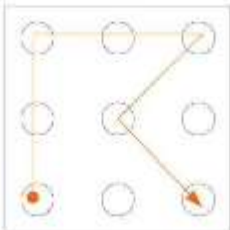
☐ F 

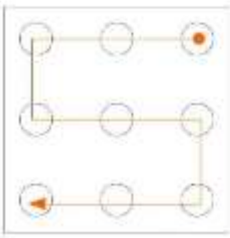
☐ H 

☐ L 

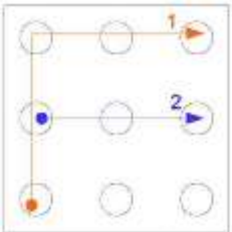
☐ M 

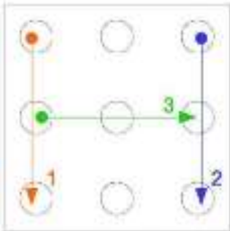
☐ N 

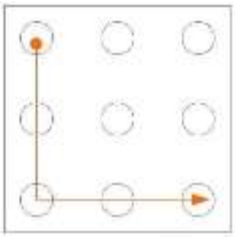
☐ R 

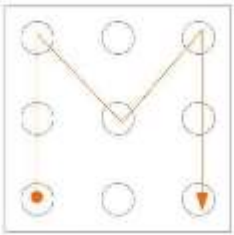
☐ S 

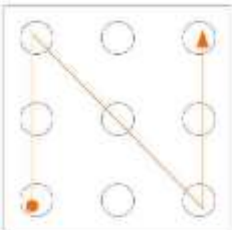
Q10 Which letter did you feel it was vibrating (i.e., F, H, L, M, N, R, S)? Choose one from the following choices.

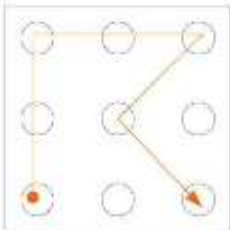
☐ F 

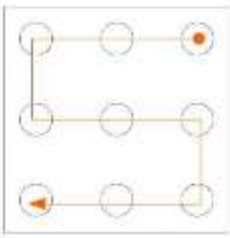
☐ H 

☐ L 

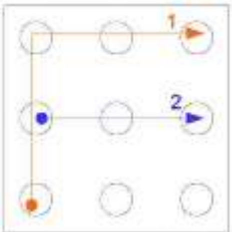
☐ M 

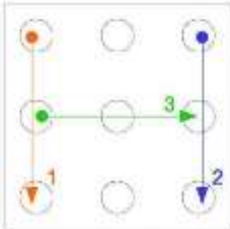
☐ N 

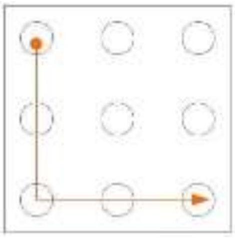
☐ R 

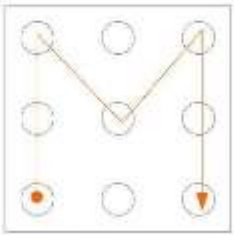
☐ S 

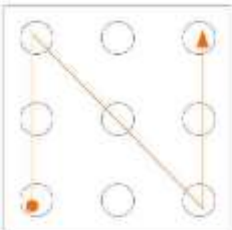
Q11 Which letter did you feel it was vibrating (i.e., F, H, L, M, N, R, S)? Choose one from the following choices.

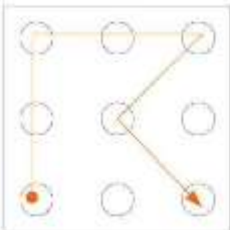
☐ F 

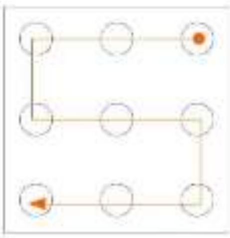
☐ H 

☐ L 

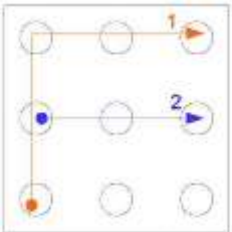
☐ M 

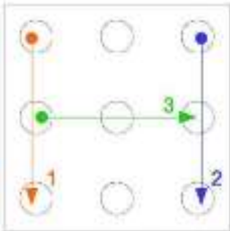
☐ N 

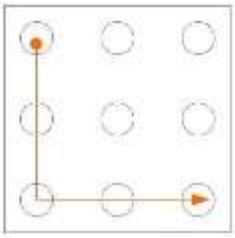
☐ R 

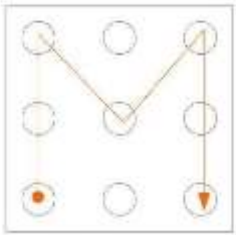
☐ S 

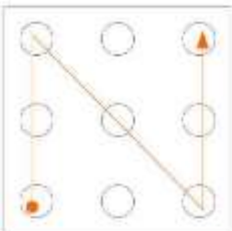
Q12 Which letter did you feel it was vibrating (i.e., F, H, L, M, N, R, S)? Choose one from the following choices.

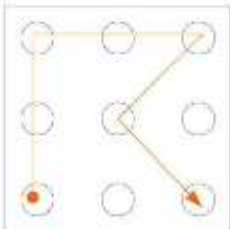
☐ F 

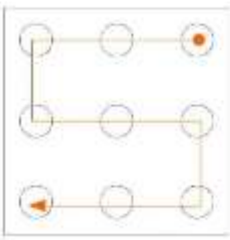
☐ H 

☐ L 

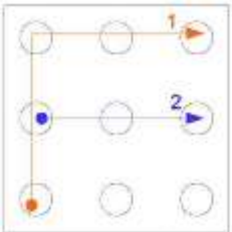
☐ M 

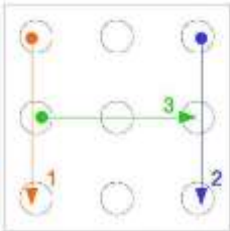
☐ N 

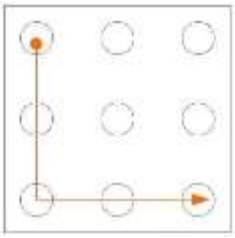
☐ R 

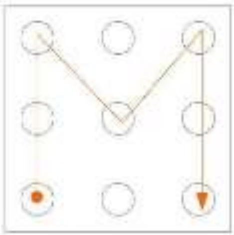
☐ S 

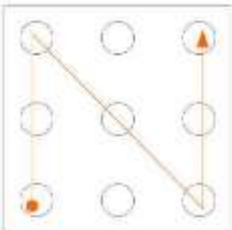
Q13 Which letter did you feel it was vibrating (i.e., F, H, L, M, N, R, S)? Choose one from the following choices.

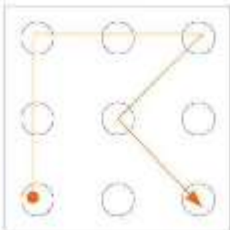
☐ F 

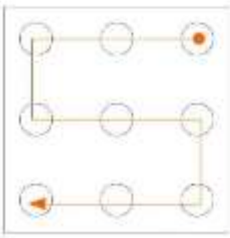
☐ H 

☐ L 

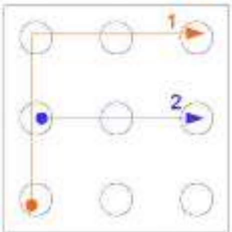
☐ M 

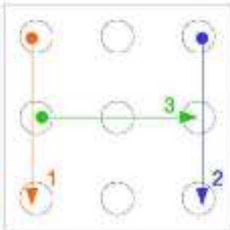
☐ N 

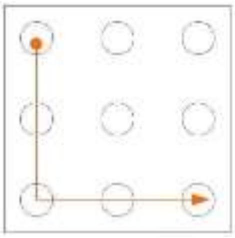
☐ R 

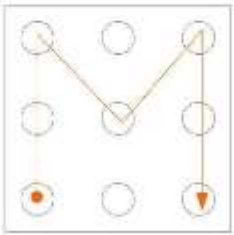
☐ S 

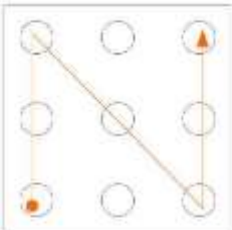
Q14 Which letter did you feel it was vibrating (i.e., F, H, L, M, N, R, S)? Choose one from the following choices.

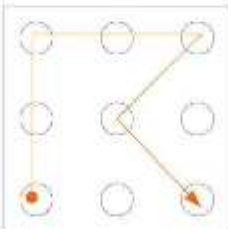
☐ F 

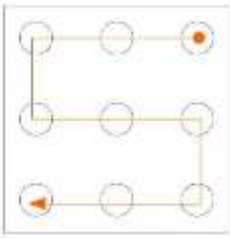
☐ H 

☐ L 

☐ M 

☐ N 

☐ R 

☐ S 

Appendix B

Pilot II Study Material – Icebreaker T-shirt Test

B.1 *Pre-test* Questionnaire

Section A: Demographic information

Q1 Please give your full name ____

Q2 What is your gender?

☐ Female
☐ Male

Q3 Are you a colour-blind person?

☐ No
☐ Yes (please specify all those colours with comma separation) ____________________

____

____

____

Q4 What is your age?

☐ less than 18
☐ 18-24
☐ 25-19
☐ 30-34

☐ 35-39
☐ 40-44
☐ 45-49
☐ 50-54
☐ 55-59
☐ 60-64
☐ 65 or older

Q5 At what email address would you like to be contacted?

____

Q6 At what telephone number would you like to be contacted?

____

Q7 Which of the following best describes your current degree of study/research or work position in your university?

☐ DipHE
☐ PgCert
☐ PgDip
☐ BA
☐ BEng
☐ MEng
☐ MSci
☐ PhD
☐ Researcher
☐ Lecture
☐ Other (please specify) ____

Q8 At which department or school do you study or work?

____

Q9 If possible, please describe your course title and/or subjects of research or teaching.

____

____

Section B: Social Preferences

Q1 Which of the following age of new people do you like to meet? (please specify all this is possible)

☐ less than 18
☐ 18-24
☐ 25-19
☐ 30-34
☐ 35-39
☐ 40-44
☐ 45-49
☐ 50-54
☐ 55-59
☐ 60-64
☐ 65 or older

Q2 Which of the following genders of new people you like to meet? (please specify all this is possible)

☐ Female
☐ Male

Q3 What background of study/research/practice of new people you are interested to meet? (please specify with comma separation)

____

____

____

____

____

____

Q4 Which of the following music genres you most like to listen to? (please specify all that is possible)

☐ Acoustic
☐ Ambient
☐ Blues
☐ Britpop
☐ Classical
☐ Country

☐ Electronic
☐ Emo
☐ Folk
☐ Grime
☐ Hardcore
☐ Hip hop
☐ Indie
☐ Jazz
☐ Metal
☐ New wave
☐ Pop
☐ Punk
☐ RnB
☐ Rock
☐ Soul
☐ World
☐ 60s
☐ 70s
☐ 80s
☐ 90s
☐ Others (please specify) ____

Q5 Which of the following movie genres you most like to watch? (please specify all that is possible)

☐ Anime
☐ Avant-Garde
☐ B Movie
☐ Biker
☐ Breaking the Fourth Wall
☐ Business
☐ Caper
☐ Car Chase
☐ Chick Flick
☐ Coming of Age
☐ Competition
☐ Cult
☐ Cyberpunk
☐ Drama-documentary
☐ Dystopia
☐ Epic
☐ Espionage
☐ Experimental Film
☐ Farce

☐ Fairy Tale
☐ Femme Fatale
☐ Futuristic
☐ Gay / Lesbian
☐ Heist
☐ High School
☐ Kidnapping
☐ Kung Fu
☐ Mockumentary
☐ Monster
☐ Neo-Noir
☐ Parenthood
☐ Parody
☐ Post-Apocalypse
☐ Remake
☐ Road Movie
☐ Robot
☐ Satire
☐ Serial Killer
☐ Shakespeare
☐ Slasher
☐ Spirituality
☐ Spoof
☐ Steampunk
☐ Superhero
☐ Supernatural
☐ Tech-Noir
☐ Time Travel
☐ Vampire
☐ Virtual Reality
☐ Wilhelm Scream
☐ Zombie

Q6 Which of the following literary genres you like reading most? (please specify all that is possible)

☐ Absurdist fiction
☐ Adventure novel
☐ Children's literature
☐ Comic novel
☐ Education fiction
☐ Experimental fiction
☐ Erotic fiction

☐ Historical fiction
☐ Literary fiction
☐ Mathematical fiction
☐ Memoir
☐ Metafiction
☐ Nonfiction novel
☐ Occupational fiction
☐ Philosophical fiction
☐ Political fiction
☐ Pulp fiction
☐ Quantum fiction
☐ Religious fiction
☐ Saga
☐ Speculative science fiction
☐ Speculative horror fiction
☐ Speculative fantasy fiction
☐ Speculative cross-genre fiction
☐ Suspense fiction
☐ Westerns
☐ Women's fiction
☐ Workplace tell-all
☐ Tragedy
☐ Urban fiction
☐ Thriller

Q7 Which of the following hobbies you like doing most? (please specify all that is possible)

☐ Arts and Crafts
☐ Collecting
☐ Food and Drink
☐ Games
☐ Model and Electronics
☐ Music
☐ Performing Arts
☐ Pets
☐ Reading
☐ Sports and Outdoors
☐ Spiritual and Mental
☐ Others (please specify) ____

Section C: Social Interaction Anxiety Information

For each question, please tick the box which indicates the degree to which you feel the statement has been true for you.

Q1 I am afraid of looking foolish in social situations.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q2 I often feel insecure in social situations.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q3 Other people appear to have more fun in social situations than I do.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q4 If someone rejects me I assume that I have done something wrong.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q5 It is hard for me to approach people who are having a conversation.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q6 I feel lonely a good deal of the time.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q7 I tend to be more critical of other people than I appear to be.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q8 It is hard for me to say "no" to unreasonable requests.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q9 I do more than my share on projects because I can't say no.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q10 I find it easy to ask for what I want from other people.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q11 I do not let others know I am frustrated or angry.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q12 I find it hard to ask someone for a date.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q13 It is hard for me to express my real feelings to others.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q14 I tend to be suspicious of other people's intentions toward me.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q15 I am bothered when others make demands on me.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q16 It is easy for me to sit back in a group discussion and observe rather than participate.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q17 I find myself unable to enter new social situations without fearing rejection or not being noticed.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q18 I worry about being a burden on others.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q19 Personal questions from others make me feel anxious.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q20 I let others take advantage of me.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q21 I judge myself negatively when I think others have negative reactions to me.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q22 I try to figure out what is expected in a given situation and then act that way.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q23 I feel embarrassed when I look or seem different from other people.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q24 I am disappointed in myself.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q25 I blame myself when things do not go the way I want them to.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q26 I sometimes feel ashamed after social situations.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q27 I am usually aware of my feelings, even if I do not know what prompted them.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q28 I am frequently concerned about others approval.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q29 I like taking risks in social situations.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q30 If someone is critical of me I am likely to assume that they are having a bad day.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q31 If I let people know too much about me they will gossip about me.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q32 I think it is important to please others.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q33 People feel superior when someone is socially anxious.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q34 I spend a lot of time thinking about my social performance after I spend time with people.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q35 I am satisfied with my level of social support.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

B.2 *Post-test* Questionnaire

My name is ____

My gender is ☐ Female ☐ Male.

I am __________ years old.

Q1 In a general social situation,

☐ I do not normally do handshakes.

☐ I normally do handshakes in situations like ________________________________

____

____

Q2 Being asked to greet other volunteers with a handshake,

☐ somewhat, I felt it was awkward/disruptive, ...
☐ I had no negative experience about it, ...

because ____

____

____

____

Q3 Handshakes are thought to reflect people's personality and influence their first impressions,

☐ I, sometimes/often/usually evaluate people from the strength, consistency of grip, vigour, etc. of their handshakes, ...
☐ I do not judge people from their handshakes, ...

because ____

____

____

____

Q4 If I were told I had something in common with someone,

☐ it could make me feel awkward when I met that person.
☐ it could make me feel more at ease when I met that person.

☐ not sure, it depends on ____

____

____

____

Q5 In the meeting where I wore the Icebreaker T-shirt, its social compatibility display made me feel,

☐ easier to start a conversation with the other person.
☐ difficult to make a conversation. It would be better if ____________________________

____

____

____

B.3 Compatibility levels between test participants

Records of compatibility levels in the Pilot II study: generated from six meeting cases, each between a pair of test participants who met first time while wearing the Icebreaker T-shirt

User ID	Displayed compatibility level on shirt	Displayed compatibility level on shirt	User ID
A	2	3	Z
B	4	5	C
D	4	2	E
F	1	3	G
H	5	4	I
J	3	3	K

Notes:

each row represents a meeting between two participants who wore the Icebreaker T-shirt (IBT). The social compatibility levels shown on their frontal displays conveyed different degrees of social compatibility based on their social profiles and preferences. For example, in the meeting between D and E, the display of D's shirt showed that D was a person whose social profile compatible with some criteria in E's preference, and the compatibility was twice higher than the vice versa.

Appendix C

Final Study Material – Icebreaker Jacket Test

C.1 *Pre-test* Questionnaire

Section A: Demographic information

Q1 Please give your full name ____

Q2 What is your gender?

☐ Female
☐ Male

Q3 Are you a colour-blind person?

☐ No
☐ Yes (please specify all those colours with comma separation) ____________________

____

Q4 What is your age?

☐ 18-24
☐ 25-19
☐ 30-34
☐ 35-39
☐ 40-44
☐ 45-49
☐ 50-54

☐ 55-59
☐ 60-64
☐ 65 or older

Q5 At what email address would you like to be contacted?

___

Q6 At what telephone number would you like to be contacted?

___

Q7 Which of the following best describes your current degree of study/research or work position in QMUL?

☐ DipHE
☐ PgCert
☐ PgDip
☐ BA
☐ BEng
☐ MEng
☐ MSci
☐ PhD
☐ Researcher
☐ Lecture
☐ Other (please specify) ___

Q8 At which department or school do you study or work?

___

Q9 . If possible, please describe your course title and/or subjects of research or teaching.

___

Section B: Preferences

Q1 Which of the following age of new people do you like to meet? (please specify all this is possible)

☐ less than 18
☐ 18-24
☐ 25-19
☐ 30-34
☐ 35-39
☐ 40-44
☐ 45-49
☐ 50-54
☐ 55-59
☐ 60-64
☐ 65 or older

Q2 Which of the following genders of new people you like to meet? (please specify all this is possible)

☐ Female
☐ Male

Q3 Which of the following schools/institutes/departments of new people you are interested to meet? (please specify all this is possible)

☐ School of Business and Management
☐ School of Economics and Finance
☐ School of English and Drama
☐ School of Geography
☐ School of History
☐ School of Languages, Linguistics and Film
☐ School of Law
☐ School of Politics and International Relations
☐ Barts and The London School of Medicine and Dentistry
☐ School of Biological and Chemical Sciences
☐ School of Electronic Engineering and Computer Science
☐ School of Engineering and Materials Science
☐ School of Mathematical Sciences
☐ School of Physics and Astronomy
☐ Materials Research Institute (MRI)
☐ Academic Registry and Council Secretariat
☐ Alumni Relations and Fundraising
☐ Business Development Services
☐ Digital and Photographic Imaging Centre (DPIC)
☐ Estates and Facilities

☐ Finance
☐ Human Resources
☐ IT Services
☐ The Learning Institute
☐ Marketing and Communications
☐ Occupational Health and Safety
☐ Queen Mary Innovation Ltd
☐ Queen Mary Students' Union
☐ The London School of Medicine and Dentistry Students' Association
☐ Student Administration
☐ Student Services
☐ Others (please specify) ____

Q4 Which of the following music genres you most like to listen to? (please specify all that is possible)

☐ Acoustic
☐ Ambient
☐ Blues
☐ Britpop
☐ Classical
☐ Country
☐ Electronic
☐ Emo
☐ Folk
☐ Grime
☐ Hardcore
☐ Hip hop
☐ Indie
☐ Jazz
☐ Metal
☐ New wave
☐ Pop
☐ Punk
☐ RnB
☐ Rock
☐ Soul
☐ World
☐ 60s
☐ 70s
☐ 80s
☐ 90s
☐ Others (please specify) ____

Q5 Which of the following movie genres you most like to watch? (please specify all that is possible)

☐ Anime
☐ Avant-Garde
☐ B Movie
☐ Biker
☐ Breaking the Fourth Wall
☐ Business
☐ Caper
☐ Car Chase
☐ Chick Flick
☐ Coming of Age
☐ Competition
☐ Cult
☐ Cyberpunk
☐ Drama-documentary
☐ Dystopia
☐ Epic
☐ Espionage
☐ Experimental Film
☐ Farce
☐ Fairy Tale
☐ Femme Fatale
☐ Futuristic
☐ Gay / Lesbian
☐ Heist
☐ High School
☐ Kidnapping
☐ Kung Fu
☐ Mockumentary
☐ Monster
☐ Neo-Noir
☐ Parenthood
☐ Parody
☐ Post-Apocalypse
☐ Remake
☐ Road Movie
☐ Robot
☐ Satire
☐ Serial Killer
☐ Shakespeare
☐ Slasher
☐ Spirituality

☐ Spoof
☐ Steampunk
☐ Superhero
☐ Supernatural
☐ Tech-Noir
☐ Time Travel
☐ Vampire
☐ Virtual Reality
☐ Wilhelm Scream
☐ Zombie

Q6 Which of the following literary genres you like reading most? (please specify all that is possible)

☐ Absurdist fiction
☐ Adventure novel
☐ Children's literature
☐ Comic novel
☐ Education fiction
☐ Experimental fiction
☐ Erotic fiction
☐ Historical fiction
☐ Literary fiction
☐ Mathematical fiction
☐ Memoir
☐ Metafiction
☐ Nonfiction novel
☐ Occupational fiction
☐ Philosophical fiction
☐ Political fiction
☐ Pulp fiction
☐ Quantum fiction
☐ Religious fiction
☐ Saga
☐ Speculative science fiction
☐ Speculative horror fiction
☐ Speculative fantasy fiction
☐ Speculative cross-genre fiction
☐ Suspense fiction
☐ Westerns
☐ Women's fiction
☐ Workplace tell-all
☐ Tragedy

☐ Urban fiction
☐ Thriller

Q7 Which of the following hobbies you like doing most? (please specify all that is possible)

☐ Arts and Crafts
☐ Collecting
☐ Food and Drink
☐ Games
☐ Model and Electronics
☐ Music
☐ Performing Arts
☐ Pets
☐ Reading
☐ Sports and Outdoors
☐ Spiritual and Mental
☐ Others (please specify) ____

Section C: Social Interaction Anxiety Information

For each question, please tick the box which indicates the degree to which you feel the statement has been true for you.

Q1 I get nervous if I have to speak with someone in authority (teacher, boss, etc.).

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q2 I have difficulty making eye contact with others.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q3 I become tense if I have to talk about myself or my feelings.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q4 I find it difficult to mix comfortably with the people I work with.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q5 I find it easy to make friends my own age.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q6 I tense up if I meet an acquaintance in the street.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q7 When mixing socially, I am uncomfortable.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q8 I feel tense if I am alone with just one other person.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q9 I am at ease meeting people at parties, etc.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q10 I have difficulty talking with other people.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q11 I find it easy to think of things to talk about.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

Q12 I worry about expressing myself in case I appear awkward.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q13 I find it difficult to disagree with another's point of view.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q14 I have difficulty talking to attractive persons of the opposite sex.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q15 I find myself worrying that I won't know what to say in social situations.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q16 I am nervous mixing with people I don't know well.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q17 I feel I'll say something embarrassing when talking.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q18 When mixing in a group, I find myself worrying I will be ignored.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q19 I am tense mixing in a group.

☐ Not at all ☐ Slightly ☐ Moderately ☐ Very ☐ Extremely

Q20 I am unsure whether to greet someone I know only slightly.

☐	☐	☐	☐	☐
Not at all	Slightly	Moderately	Very	Extremely

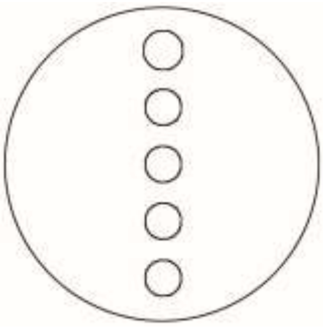
C.2 *During-test* Questionnaire

Q1 In this meeting, which mode of social score notification was used?

☐ None (Go to Q6)
☐ Score cards
☐ Score badge *(Go to Q3)*

Q2 In this meeting, how much attention did you give to the social score cards?

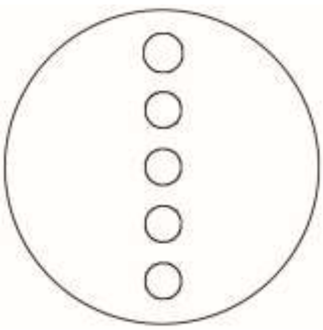
☐ I was not at all aware of it *(Go to Q4)*
☐ I searched through the card set and found the one that matched my meeting partner BUT did not pay attention to the score. *(Go to Q4)*
☐ I searched, found and paid attention to the score, which was ... (please tick in the drawing chart below all the coloured dot(s) you have seen)



(Go to *Q4*)

Q3 In this meeting, how much attention did you give to the social score badge?

☐ I was not at all aware of it.
☐ I was aware of it but did not pay attention to the score.
☐ I paid attention to the social score it presented, the score was ... (please tick in the drawing chart below all the coloured dot(s) you have seen)



Q4 Did the social score have any effect on this meeting or yourself or your feelings about your meeting partner?

☐ No, it did not. *(Go to Q6)*
☐ Yes it did.

Q5 please explain your answer to the previous question

Note: please explain your answer below ...

____

____

____

____

Q6 In this meeting, did you or your meeting partner mention or make reference to the social score? *(More than 1 answer possible)*

☐ No, we did not.
☐ Yes, I did.
☐ Yes, my meeting partner did.

Q7 Which of the following topics was part of your conversation, and in what order? *(For each topic discussed, state whether it came 1st, 2nd, 3rd, etc.)*

_____ Occupation/Position
_____ Area of work/ research/ study
_____On-going work/ research/ study activities
_____Music
_____Movies, videos, TV programs
_____Books
_____Hobbies
_____Other topic, which is _____________________________
_____Other topic, which is _____________________________
_____Other topic, which is _____________________________

Q8 Please rate your overall experience in this meeting.

☐	☐	☐	☐	☐
1	2	3	4	5
Not satisfied at all				Very satisfied

C.3 *Post-test* Questionnaire

Q1 How did you feel about the requirement to shake hands?

☐	☐	☐	☐	☐
1 Not comfortable at all	2	3	4	5 Very comfortable

Note: please explain your answer below ...

____

____

____

____

Q2 In today's experiment, what do you think the score on the cards and badges indicates?

☐ I don't know.
☐ It indicates how socially compatible between me and the person I shook hands with.
☐ Other, (please explain below) ...

____

____

____

____

Q3 Based on your social experience in general, what topics are the most likely for people to discuss when meeting with strangers? *(Please rank the topics in order of likelihood i.e. 1st, 2nd, 3rd , ... etc. where applicable.)*

_____ Study, research or working position of yours or theirs

_____ Area of work/ research/ study/ practice

_____On-going activities in yours or their work/ research/

_____Music

_____Movies, videos, TV programs

______Books

______Hobbies

______Other topic, which is ______________________________

______Other topic, which is ______________________________

______Other topic, which is ______________________________

Q4 Based on your experience using the social score *badge* on the jacket, how helpful was it?

☐	☐	☐	☐	☐
1 Not helpful at all	2	3	4	5 Very helpful

Note: please explain your answer below ...

____

____

____

____

Q5 Based on your experience using the social score *cards*, how helpful were they?

☐	☐	☐	☐	☐
1 Not helpful at all	2	3	4	5 Very helpful

Note: please explain your answer below ...

____

____

____

____

Q6 You have participated in six meetings and seen at least two levels of social compatibility scores. How did you feel when seeing *lower* scores?

☐ Negative
☐ Neutral
☐ Positive

Note: please explain your answer below ...

____

____

____

____

Q7 How did you feel when seeing *higher* scores?

☐ Negative
☐ Neutral
☐ Positive

Note: please explain your answer below ...

____

____

____

____

Q8 In the meetings that used the score *badge*, how did you feel when noticing the difference between the scores on your jacket and on your meeting partner's jacket?

____

____

____

____

Q9 If there had been no social score cards or badge in today's experiment, would your experience have been different?

☐ No, it would have been the same.
☐ Yes, it would have been easier without them.

☐ Yes, it would have been more difficult without them.

Note: please explain your answer below ...

____

____

____

____

Q10 Please rank today's meeting modes in order of your preference. (Please label each mode either 1st, 2nd and 3rd, with 1st being your most preferable).

______ No social score

______ Social score cards

______ Social score badge

Note: please explain your answer below ...

____

____

____

____

Q11 In which meeting mode did you find it easier to ***start*** a conversation?

☐ No social score
☐ Social score cards
☐ Social score badge
☐ Same in all meeting modes
Note: please explain your answer below ...

____

____

____

____

Q12 In which meeting mode did you make ***more*** *conversation*?

☐ No social score

☐ Social score cards
☐ Social score badge
☐ Same in all meeting modes

Note: please explain your answer below ...

____

____

____

____

Q13 In which meeting mode did you make *longer conversation*?

☐ No social score
☐ Social score cards
☐ Social score badge
☐ Same in all meeting modes

Note: please explain your answer below ...

____

____

____

____

Q14 Your opinion is valuable – what features or designs would you like to change or add to improve the jacket that has a score badge on?

☐ Nothing, I like it the way it is.

☐ Some improvement could be ____

____

____

____

____

Q15 How likely would you be to wear this kind of jacket in social networking events i.e. conferences, special interests meet up, speed dating, etc.

☐ No, I don't think I'll wear anything like this in real-world events.

☐ Yes, I’d love to wear it.
☐ I’m not sure, it depends on ____

____

____

____

____

C.4 Data Analysis Material

C.4.1 Helpfulness to Conversation Making (section 6.4.1)

Table_Apx C-1: Case summary of nine users' ratings on three classifications of helpfulness (i.e. 'easier' to initiate conversations, 'more' conversation topics, and 'longer' conversations) of badge, card and no-soObj meeting modes. '0' indicates 'not helpful'. '1' indicates 'helpful'

					Meeting mode		
Case	User	SIAS score	Shyness	Help class	Badge	Card	No-soObj
1	R	9	Non-shy	1 – easier	1	0	1
2	Y	19	Non-shy	1 – easier	1	0	1
3	Z	26	Non-shy	1 – easier	1	1	0
4	U	35	Non-shy	1 – easier	0	0	0
5	F	40	Shy	1 – easier	1	0	1
6	O	41	Shy	1 – easier	0	0	0
7	K	43	Shy	1 – easier	1	0	1
8	N	46	Shy	1 – easier	1	0	0
9	B	51	Shy	1 – easier	1	0	0
10	R	9	Non-shy	2 – more	0	0	0
11	Y	19	Non-shy	2 – more	1	0	1
12	Z	26	Non-shy	2 – more	1	1	0
13	U	35	Non-shy	2 – more	0	0	0
14	F	40	Shy	2 – more	1	1	1
15	O	41	Shy	2 – more	1	0	0
16	K	43	Shy	2 – more	0	0	0
17	N	46	Shy	2 – more	0	0	0
18	B	51	Shy	2 – more	1	1	0
19	R	9	Non-shy	3 – longer	0	0	0
20	Y	19	Non-shy	3 – longer	1	0	1
21	Z	26	Non-shy	3 – longer	1	1	0
22	U	35	Non-shy	3 – longer	0	0	0
23	F	40	Shy	3 – longer	1	1	1
24	O	41	Shy	3 – longer	1	0	0
25	K	43	Shy	3 – longer	0	0	0
26	N	46	Shy	3 – longer	1	0	1
27	B	51	Shy	3 – longer	1	1	1

Table_Apx C-2: Nine 2 x 2 contingency tables arranged in three columns showing the overall-user group's categorical ratings on three classifications of helpfulness of three comparative parried meeting modes (i.e. ‘badge vs. card’, ‘badge vs. no-soObj’, and ‘card vs. no-soObj’.

All users' response on helpfulness rating of meeting modes arranged in three classifications, each covers three comparative cases between paired modes

Class 1: help *ease* initiating conversation

Pair 1: Badge v. Card

		Badge ('case' mode)		
		Not easier	Easier	Total
Card ('control' mode)	Not easier	2	6	8
	% of Total	22.2%	66.7%	88.9%
	Easier	0	1	1
	% of Total	0.0%	11.1%	11.1%
	Total	2	7	9
	% of Total	22.2%	77.8%	100.0%

Pair 2: Badge v. No-soObj

		Badge ('case' mode)		
		Not easier	Easier	Total
No-soObj ('control' mode)	Not easier	2	3	5
	% of Total	22.2%	33.3%	55.6%
	Easier	0	4	4
	% of Total	0.0%	44.4%	44.4%
	Total	2	7	9
	% of Total	22.2%	77.8%	100.0%

Pair 3: Card v. No-soObj

		Card ('case' mode)		
		Not easier	Easier	Total
No-soObj ('control' mode)	Not easier	4	1	5
	% of Total	44.4%	11.1%	55.6%
	Easier	4	0	4
	% of Total	44.4%	0.0%	44.4%
	Total	8	1	9
	% of Total	88.9%	11.1%	100.0%

Class 2: help generate *more* conversation topics

Pair 1: Badge v. Card

		Badge ('case' mode)		
		Not more	More	Total
Card ('control' mode)	Not more	4	2	6
	% of Total	44.4%	22.2%	66.7%
	More	0	3	3
	% of Total	0.0%	33.3%	33.3%
	Total	4	5	9
	% of Total	44.4%	55.6%	100.0%

Pair 2: Badge v. No-soObj

		Badge ('case' mode)		
		Not more	More	Total
No-soObj ('control' mode)	Not more	4	3	7
	% of Total	44.4%	33.3%	77.8%
	More	0	2	2
	% of Total	0.0%	22.2%	22.2%
	Total	4	5	9
	% of Total	44.4%	55.6%	100.0%

Pair 3: Card v. No-soObj

		Card ('case' mode)		
		Not more	More	Total
No-soObj ('control' mode)	Not more	5	2	7
	% of Total	55.6%	22.2%	77.8%
	More	1	1	2
	% of Total	11.1%	11.1%	22.2%
	Total	6	3	9
	% of Total	66.7%	33.3%	100.0%

Class 3: help make *longer* conversation

Pair 1: Badge v. Card

		Badge ('case' mode)		
		Not longer	Longer	Total
Card ('control' mode)	Not longer	3	3	6
	% of Total	33.3%	33.3%	66.7%
	Longer	0	3	3
	% of Total	0.0%	33.3%	33.3%
	Total	3	6	9
	% of Total	33.3%	66.7%	100.0%

Pair 2: Badge v. No-soObj

		Badge ('case' mode)		
		Not longer	Longer	Total
No-soObj ('control' mode)	Not longer	3	2	5
	% of Total	33.3%	22.2%	55.6%
	Longer	0	4	4
	% of Total	0.0%	44.4%	44.4%
	Total	3	6	9
	% of Total	33.3%	66.7%	100.0%

Pair 3: Card v. No-soObj

		Card ('case' mode)		
		Not longer	Longer	Total
No-soObj ('control' mode)	Not longer	4	1	5
	% of Total	44.4%	11.1%	55.6%
	Longer	2	2	4
	% of Total	22.2%	22.2%	44.4%
	Total	6	3	9
	% of Total	66.7%	33.3%	100.0%

Table_Apx C-3: Six 2 x 2 contingency tables arranged in two columns. The left column presents non-shy users' categorical ratings ('helpful'/'not helpful') on the 'overall' helpfulness of three comparative paired meeting modes (i.e. 'badge vs. card', 'badge vs. no-soObj', and 'card vs. no-soObj'). The right column presents shy users' ratings.

Non-shy users' response on overall helpfulness of meeting modes with three comparative cases between paired modes

Pair 1: Badge v. Card

		Badge ('case' mode)		
		Not helpful	Helpful	Total
Card ('control' mode)	Not helpful	5	4	9
	% of Total	41.7%	33.3%	75.0%
	Helpful	0	3	3
	% of Total	0.0%	25.0%	25.0%
	Total	5	7	12
	% of Total	41.7%	58.3%	100.0%

Pair 2: Badge v. No-soObj

		Badge ('case' mode)		
		Not helpful	Helpful	Total
No-soObj ('control' mode)	Not helpful	5	3	8
	% of Total	41.7%	25.0%	66.7%
	Helpful	0	4	4
	% of Total	0.0%	33.3%	33.3%
	Total	5	7	12
	% of Total	41.7%	58.3%	100.0%

Pair 3: Card v. No-soObj

		Card ('case' mode)		
		Not helpful	Helpful	Total
No-soObj ('control' mode)	Not helpful	5	3	8
	% of Total	41.7%	25.0%	66.7%
	Helpful	4	0	4
	% of Total	33.3%	0.0%	33.3%
	Total	9	3	12
	% of Total	75.0%	25.0%	100.0%

Shy users' response on overall helpfulness of meeting modes with three comparative cases between paired modes

Pair 1: Badge v. Card

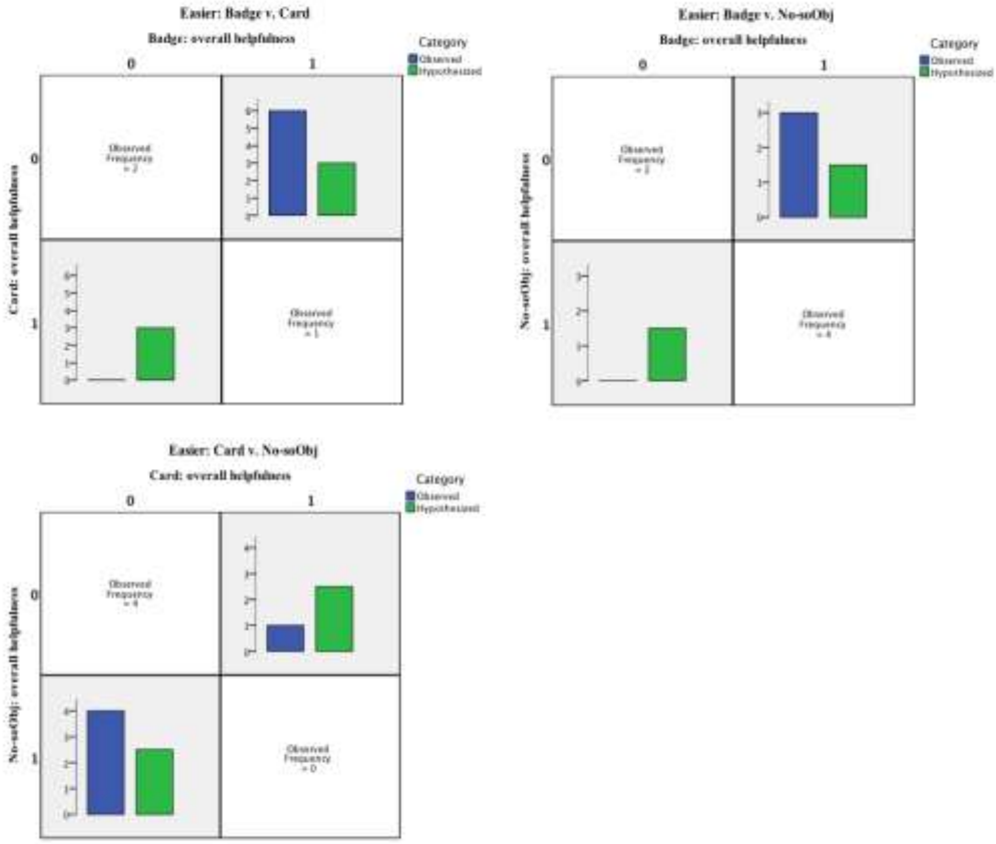
		Badge ('case' mode)		
		Not helpful	Helpful	Total
Card ('control' mode)	Not helpful	4	7	11
	% of Total	26.7%	46.7%	73.3%
	Helpful	0	4	4
	% of Total	0.0%	26.7%	26.7%
	Total	4	11	15
	% of Total	26.7%	73.3%	100.0%

Pair 2: Badge v. No-soObj

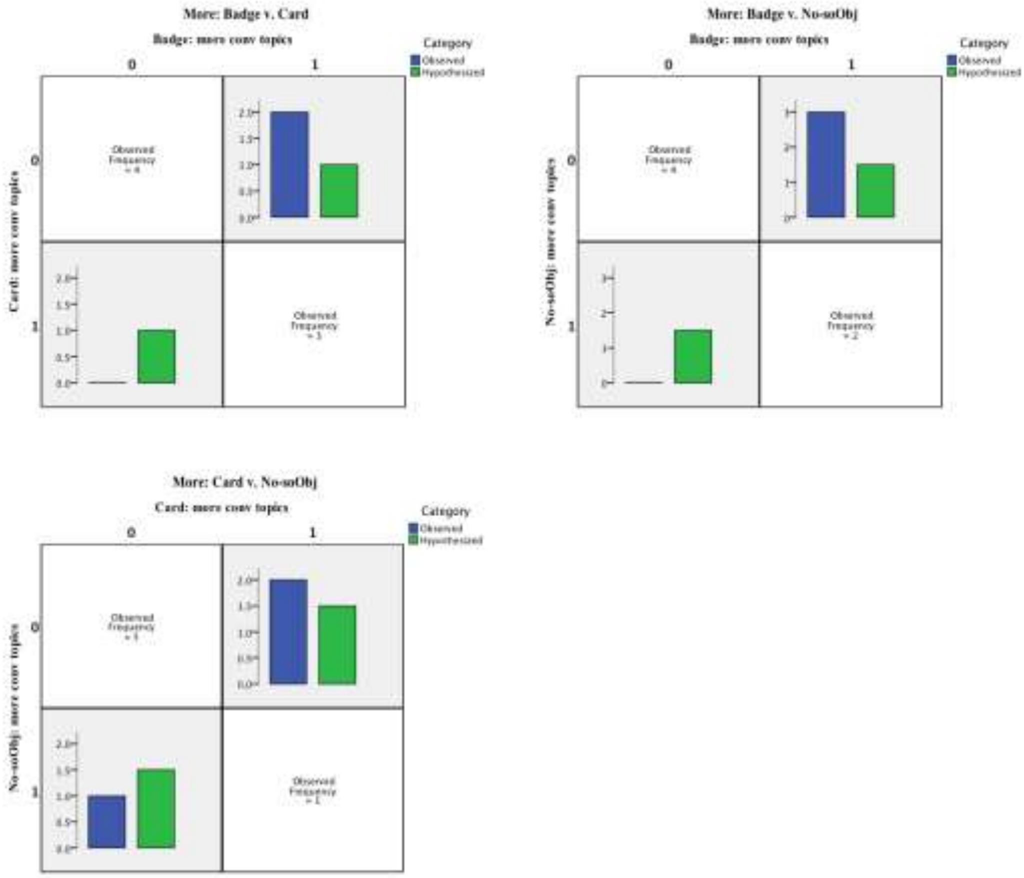
		Badge ('case' mode)		
		Not helpful	Helpful	Total
No-soObj ('control' mode)	Not helpful	4	5	9
	% of Total	26.7%	33.3%	60.0%
	Helpful	0	6	6
	% of Total	0.0%	40.0%	40.0%
	Total	4	11	15
	% of Total	26.7%	73.3%	100.0%

Pair 3: Card v. No-soObj

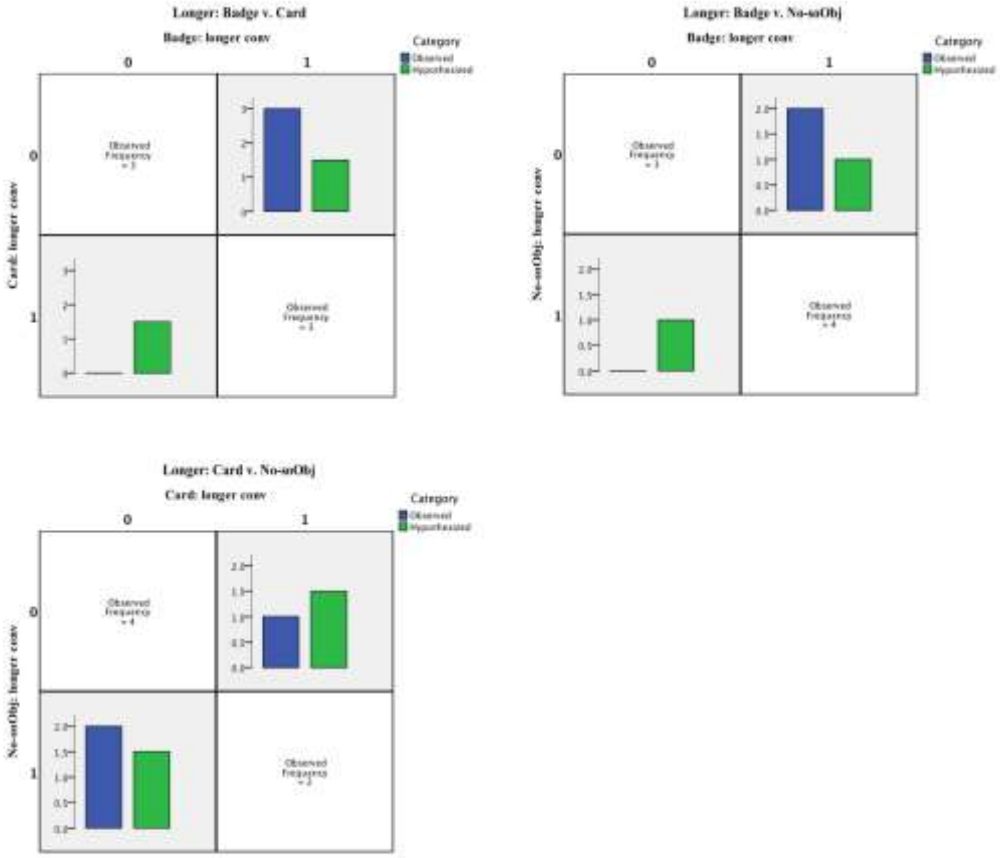
		Card ('case' mode)		
		Not helpful	Helpful	Total
No-soObj ('control' mode)	Not helpful	8	1	9
	% of Total	53.3%	6.7%	60.0%
	Helpful	3	3	6
	% of Total	20.0%	20.0%	40.0%
	Total	11	4	15
	% of Total	73.3%	26.7%	100.0%



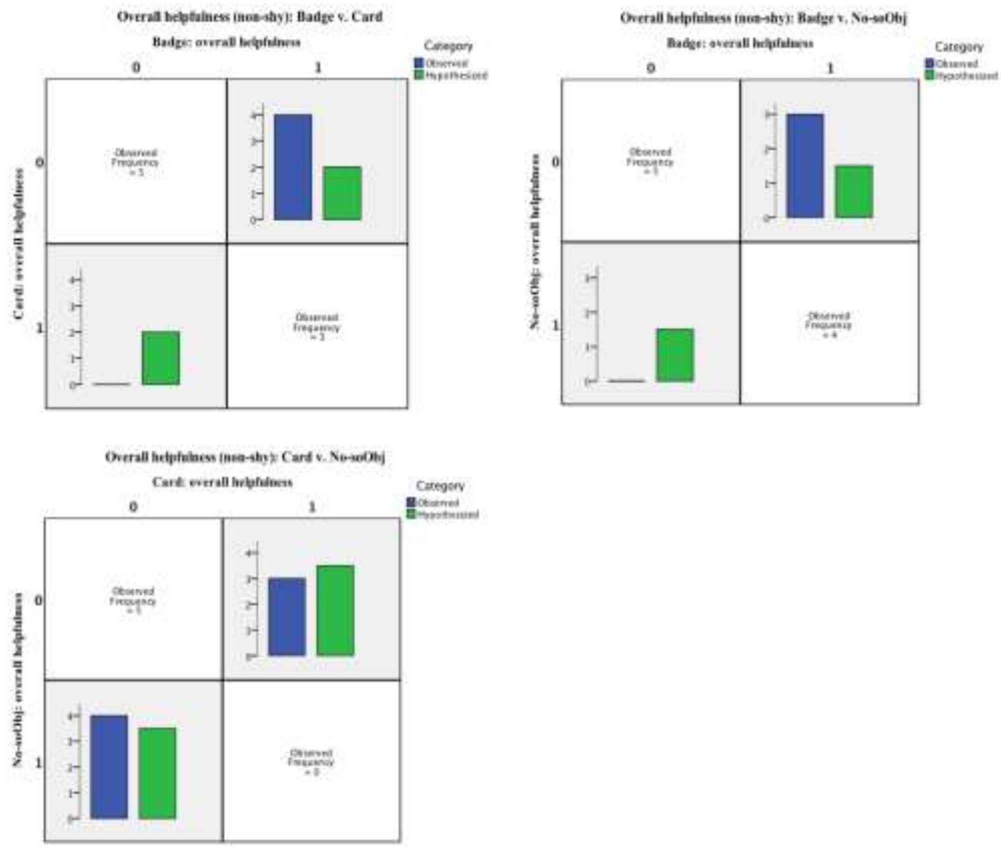
Figure_Apx 10: Graphical outputs of McNemar test of proportion changes in helpfulness class 1 (i.e. from 'easier' to 'not easier') in three comparative meeting modes (i.e. 'badge vs. card' (top-left), 'badge vs. no-soObj' (top-right), and 'card vs. no-soObj' (bottom-left)), rated by overall-user group.



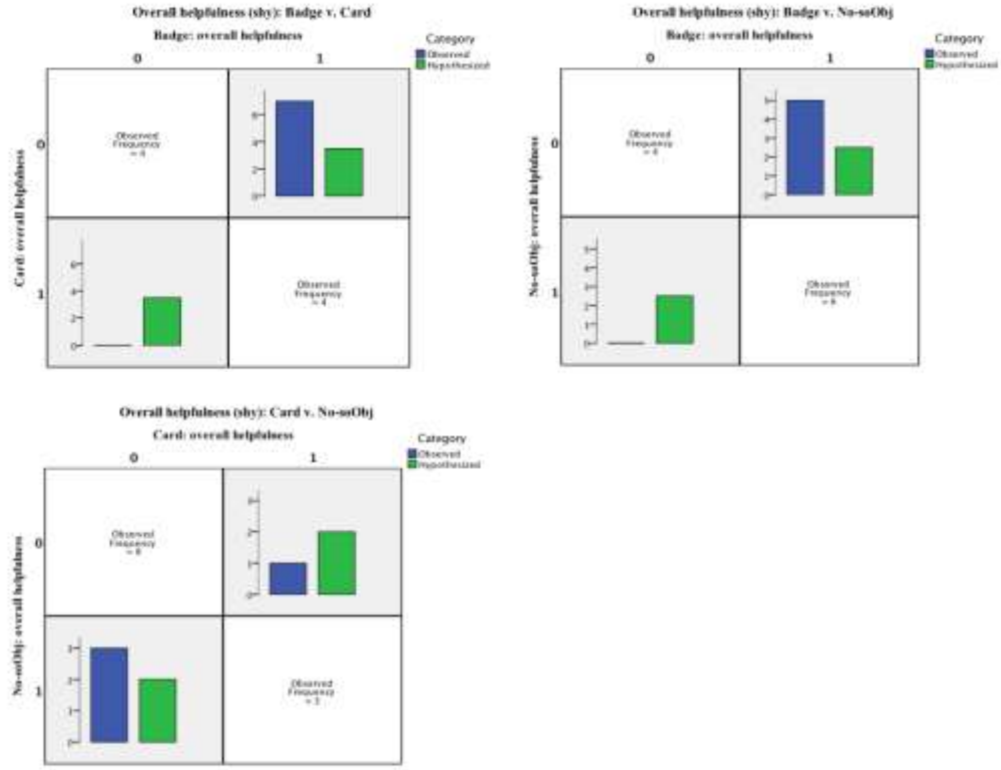
Figure_Apx 11: Graphical outputs of McNemar test of proportion changes in helpfulness class 2 (i.e. from 'more' to 'not more') in three comparative meeting modes (i.e. 'badge vs. card' (top-left), 'badge vs. no-soObj' (top-right), and 'card vs. no-soObj' (bottom-left)), rated by overall-user group.



Figure_Apx 12: Graphical outputs of McNemar test of proportion changes in helpfulness class 3 (i.e. from ‘longer’ to ‘not longer’) in three comparative meeting modes (i.e. ‘badge vs. card’ (top-left), ‘badge vs. no-soObj’ (top-right), and ‘card vs. no-soObj’ (bottom-left)), rated by overall-user group.



Figure_Apx 13: Graphical outputs of McNemar test of proportion changes in the overall helpfulness (i.e. ‘helpful’ to ‘not helpful’) in three comparative meeting modes (i.e. ‘badge vs. card’ (top-left), ‘badge vs. no-soObj’ (top-right), and ‘card vs. no-soObj’ (bottom-left)), rated by non-shy group.



Figure_Apx 14: Graphical outputs of McNemar test of proportion changes in the overall helpfulness (i.e. ‘helpful’ to ‘not helpful’) in three comparative meeting modes (i.e. ‘badge vs. card’ (top-left), ‘badge vs. no-soObj’ (top-right), and ‘card vs. no-soObj’ (bottom-left)), rated by shy group.

C.4.2 Helpfulness to Meeting Experience (section 6.4.2)

Table_Apx C-4: Key features of helpfulness ratings on comparative displays of social cues

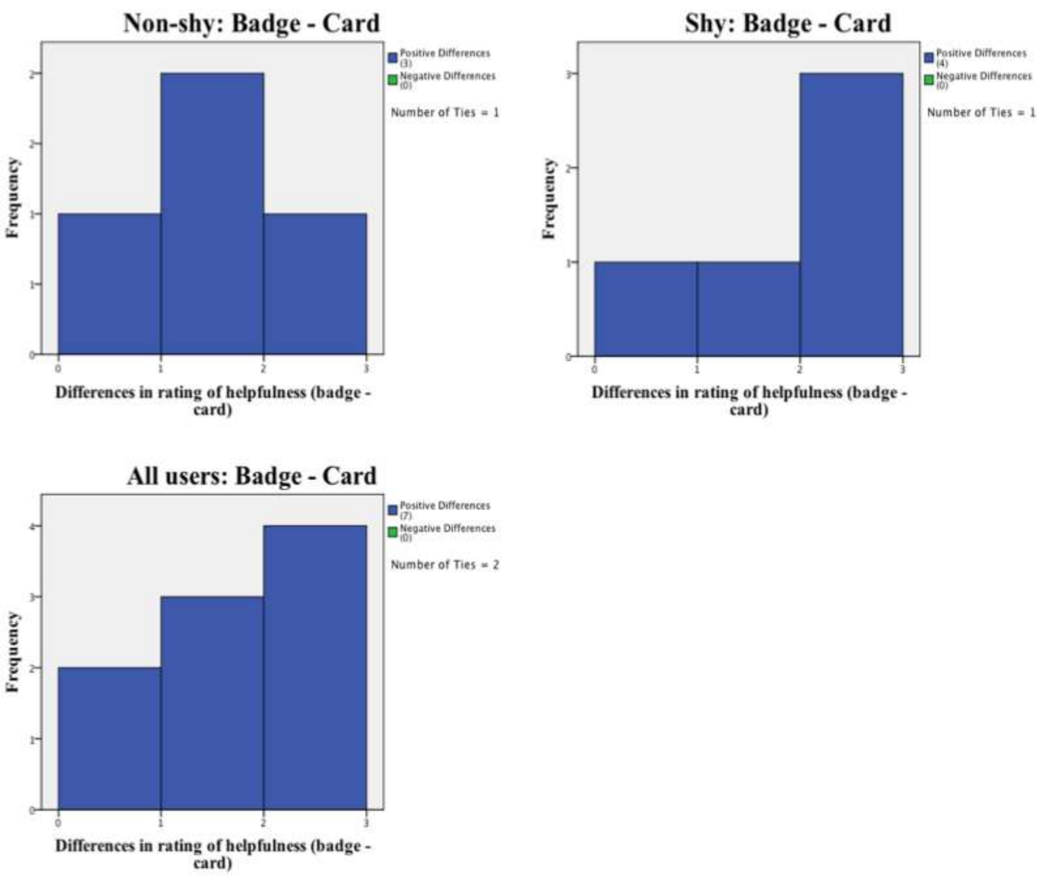
		Group 1 – Non-shy		Group 2 – Shy		Group 3 – Overall	
		Badge	Card	Badge	Card	Badge	Card
Total		4	4	5	5	9	9
Mean		3.00	2.00	3.80	2.40	3.44	2.22
S.E Mean		0.71	0.71	0.58	0.40	0.44	0.36
95% CI for	Lower	0.75	-0.25	2.18	1.29	2.42	1.38
Mean	Upper	0.75	4.25	5.42	3.51	4.47	3.06
Median		2.50	1.50	4.00	3.00	3.00	2.00
Variance		2.00	2.00	1.70	0.80	1.78	1.19
Std. Deviation		1.41	1.41	1.30	0.89	1.33	1.09
Minimum		2	1	2	1	2	1
Maximum		5	4	5	3	5	4
Range		3	3	3	2	3	3
Interquartile Range		3	3	3	2	3	2
Skewness		1.41	1.41	-0.54	-1.26	0.15	0.19
S.E Skewness		1.01	1.01	0.91	0.91	0.72	0.72
Kurtosis		1.50	1.50	-1.49	0.31	-1.96	-1.23
S.E Kurtosis		2.62	2.62	2.00	2.00	1.40	1.40

Table_Apx C-5: Case summary of nine users' SIAS scores matching with their helpfulness ratings on displays.

		Rating of helpfulness	
Case	SIAS	Badge display	Card display
1	9	Unhelpful (2)	Very unhelpful (1)
2	19	Neutral (3)	Very unhelpful (1)
3	26	Very helpful (5)	Helpful (4)
4	35	Unhelpful (2)	Unhelpful (2)
5	40	Unhelpful (2)	Very unhelpful (1)
6	41	Neutral (3)	Neutral (3)
7	43	Very helpful (5)	Neutral (3)
8	46	Helpful (4)	Unhelpful (2)
9	51	Very helpful (5)	Neutral (3)
Total N	9	9	9

Table_Apx C-6: Key features of nine users' SIAS score sample, matched with 'overall helpfulness' ratings on badge and card display samples

		SIAS score	Helpfulness rating on badge	Helpfulness rating on card
Mean		34.44	3.44	2.22
S.E. Mean		4.58	0.44	0.36
95% CI for Mean	Lower	23.88	2.42	1.38
	Upper	45.01	4.47	3.06
Median		40.00	3.00	2.00
Variance		189.03	1.78	1.19
Std. Deviation		13.75	1.33	1.09
Minimum		9	2	1
Maximum		51	5	4
Range		42	3	3
Interquartile Range		22	3	2
Skewness		-0.84	0.15	0.19
S.E. Skewness		0.72	0.72	0.72
Kurtosis		-0.21	-1.96	-1.23
S.E. Kurtosis		1.40	1.40	1.40



Figure_Apx 15: Graphical output of Wilcoxon signed-rank test of differences between helpfulness ratings on badge and card displays, rated by non-shy (top-left), shy (top-right) and overall (bottom-left).

C.4.3 Impact of Cued Content (section 6.4.3)

Table_Apx C-7: Key features of degrees of impact of higher and lower social scores, rated by three user groups

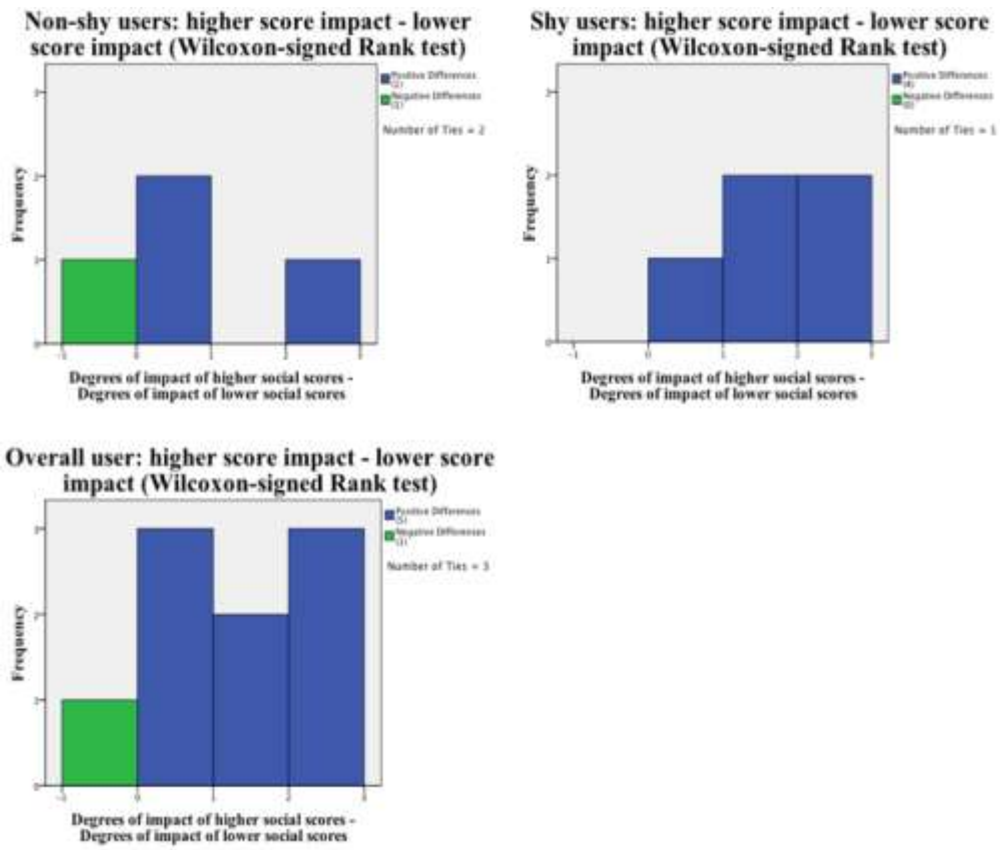
		Group 1 – Non-shy		Group 2 – Shy		Group 3 – Overall	
		Lower	Higher	Lower score	Higher	Lower score	Higher
Total		4	4	5	5	9	9
Mean		0.00	0.25	-0.20	1.00	-0.11	0.67
S.E Mean		0.41	0.25	0.37	0.00	0.26	0.17
95% CI for Mean	Lower	-1.30	-0.55	-1.24	a	-0.71	0.28
	Upper	1.30	1.05	0.84	a	0.49	1.05
Median		0.00	0.00	0.00	1.00	0.00	1.00
Variance		0.67	0.25	0.70	0.00	0.61	0.25
Std. Deviation		0.82	0.50	0.84	0.00	0.78	0.50
Minimum		-1	0	-1	1	-1	0
Maximum		1	1	1	1	1	1
Range		2	1	2	0	2	1
Interquartile Range		2	1	2	1	2	1
Skewness		0.00	2.00	0.51	a	0.22	-0.86
S.E Skewness		1.01	1.01	0.91	a	0.72	0.72
Kurtosis		1.50	4.00	-0.61	a	-1.04	-1.71
S.E Kurtosis		2.62	2.62	2.00	a	1.40	1.40

Table_Apx C-8: Case summary of nine users' SIAS scores matching with their ratings of degree of impact of social score levels on their attitudes towards meeting partners

		Rating of impact of social score level	
Case	SIAS	Impact of lower scores	Impact of higher scores
1	9	Neutral (0)	Neutral (0)
2	19	Possitive impact (+1)	Neutral (0)
3	26	Negative impact (-1)	Possitive impact (+1)
4	35	Neutral (0)	Neutral (0)
5	40	Neutral (0)	Possitive impact (+1)
6	41	Possitive impact (+1)	Possitive impact (+1)
7	43	Negative impact (-1)	Possitive impact (+1)
8	46	Neutral (0)	Possitive impact (+1)
9	51	Negative impact (-1)	Possitive impact (+1)
Total N	9	9	9

Table_Apx C-9: Key features of SIAS score sample and impact degrees of lower social score and higher social score samples, rated by all nine users

		SIAS score	Impact of lower social scores	Impact of higher social
Mean		34.44	-0.11	0.67
S.E. Mean		4.58	0.26	0.17
95% CI for	Lower	23.88	-0.71	0.28
Mean	Upper	45.01	0.49	1.05
Median		40.00	0.00	1.00
Variance		189.03	0.61	0.25
Std. Deviation		13.75	0.78	0.50
Minimum		9	-1	0
Maximum		51	1	1
Range		42	2	1
Interquartile Range		22	2	1
Skewness		-0.84	0.22	-0.86
S.E. Skewness		0.72	0.72	0.72
Kurtosis		-0.21	-1.04	-1.71
S.E. Kurtosis		1.40	1.40	1.40



Figure_Apx 16: Graphical output of Wilcoxon signed-rank test of differences between impact rates of higher and lower social-compatibility scores, rated by non-shy (top-left), shy (top-right) and overall (bottom-left).

C.4.4 Satisfaction with Meeting Experience (section 6.4.4)

Table_Apx C-10: Case summary of all users' satisfactory ratings on three meeting modes

	No-soObj mode				Card mode				Badge mode			
Case	User ID	Shyness	SIAS score	Badge mode	User ID	Shyness	SIAS score	Card mode	User ID	Shyness	SIAS score	No-soObj
1	R	Non-shy	9	5	R	Non-shy	9	2	R	Non-shy	9	5
2	R	Non-shy	9	5	Y	Non-shy	19	3	Y	Non-shy	19	4
3	R	Non-shy	9	4	Y	Non-shy	19	3	Z	Non-shy	26	5
4	R	Non-shy	9	5	Y	Non-shy	19	4	U	Non-shy	35	4
5	Y	Non-shy	19	5	Y	Non-shy	19	2	F	Shy	40	4
6	Z	Non-shy	26	2	Z	Non-shy	26	4	F	Shy	40	4
7	U	Non-shy	35	4	Z	Non-shy	26	3	F	Shy	40	4
8	U	Non-shy	35	5	Z	Non-shy	26	4	F	Shy	40	4
9	U	Non-shy	35	5	Z	Non-shy	26	4	O	Shy	41	4
10	U	Non-shy	35	4	U	Non-shy	35	3	O	Shy	41	3
11	F	Shy	40	4	F	Shy	40	5	O	Shy	41	4
12	O	Shy	41	4	O	Shy	41	3	O	Shy	41	5
13	K	Shy	43	4	K	Shy	43	4	K	Shy	43	5
14	N	Shy	46	5	K	Shy	43	5	N	Shy	46	5
15	N	Shy	46	4	K	Shy	43	4	B	Shy	51	5
16	N	Shy	46	5	K	Shy	43	4	B	Shy	51	5
17	N	Shy	46	4	N	Shy	46	5	B	Shy	51	5
18	B	Shy	51	3	B	Shy	51	5	B	Shy	51	5
Total N				18				18				18

Table_Apx C-11: Key features of comparative paired samples (i.e., satisfactory ratings on badge and card meeting modes), rated by three user groups

		Case 1 – Non-shy		Case 2 – Shy		Case 3 – Overall	
		Card	Badge	Card	Badge	Card	Badge
Total N		10	4	8	14	18	18
Mean		3.20	4.50	4.38	4.43	3.72	4.44
S.E. Mean		0.25	0.29	0.26	0.17	0.23	0.15
95% CI for Mean	Lower	2.64	3.58	3.75	4.06	3.25	4.14
	Upper	3.76	5.42	5.00	4.80	4.20	4.75
Median		3.00	4.50	4.50	4.50	4.00	4.50
Variance		0.62	0.33	0.55	0.42	0.92	0.38
Std. Deviation		0.79	0.58	0.74	0.65	0.96	0.62
Minimum		2	4	3	3	2	3
Maximum		4	5	5	5	5	5
Range		2	1	2	2	3	2
Interquartile Range		1	1	1	1	1	1
Skewness		-0.41	0.00	-0.82	-0.69	-0.27	-0.62
S.E.		0.69	1.01	0.75	0.60	0.54	0.54
Kurtosis		-1.07	-6.00	-0.15	-0.25	-0.66	-0.39
S. E. Kurtosis		1.33	2.62	1.48	1.15	1.04	1.04

Table_Apx C-12: Key features of comparative samples (i.e., satisfactory ratings on badge and no-soObj meeting modes), rated by three user groups

		Case 1 – Non-shy		Case 2 – Shy		Case 3 – Overall	
		no-soObj	Badge	no-soObj	Badge	no-soObj	Badge
Total N		10	4	8	14	18	18
Mean		4.40	4.50	4.13	4.43	4.28	4.44
S.E. Mean		0.31	0.29	0.23	0.17	0.19	0.15
95% CI for	Lower	3.71	3.58	3.59	4.06	3.87	4.14
Mean	Upper	5.09	5.42	4.66	4.80	4.69	4.75
Median		5.00	4.50	4.00	4.50	4.00	4.50
Variance		0.93	0.33	0.41	0.42	0.68	0.38
Std. Deviation		0.97	0.58	0.64	0.65	0.83	0.62
Minimum		2	4	3	3	2	3
Maximum		5	5	5	5	5	5
Range		3	1	2	2	3	2
Interquartile Range		1	1	1	1	1	1
Skewness		-1.96	0.00	-0.07	-0.69	-1.30	-0.62
S.E.		0.69	1.01	0.75	0.60	0.54	0.54
Kurtosis		4.19	-6.00	0.74	-0.25	2.10	-0.39
S. E. Kurtosis		1.33	2.62	1.48	1.15	1.04	1.04

Table_Apx C-13: Key features of comparative samples (i.e., satisfactory ratings on card and no-soObj meeting modes), rated by three user groups

		Case 1 – Non-shy		Case 2 – Shy		Case 3 – Overall	
		no-soObj	Card	no-soObj	Card	no-soObj	Card
Total N		10	10	8	8	18	18
Mean		4.40	3.20	4.13	4.38	4.28	3.72
S.E. Mean		0.31	0.25	0.23	0.26	0.19	0.23
95% CI for	Lower	3.71	2.64	3.59	3.75	3.87	3.25
Mean	Upper	5.09	3.76	4.66	5.00	4.69	4.20
Median		5.00	3.00	4.00	4.50	4.00	4.00
Variance		0.93	0.62	0.41	0.55	0.68	0.92
Std. Deviation		0.97	0.79	0.64	0.74	0.83	0.96
Minimum		2	2	3	3	2	2
Maximum		5	4	5	5	5	5
Range		3	2	2	2	3	3
Interquartile Range		1	1	1	1	1	1
Skewness		-1.96	-0.41	-0.07	-0.82	-1.30	-0.27
S.E.		0.69	0.69	0.75	0.75	0.54	0.54
Kurtosis		4.19	-1.07	0.74	-0.15	2.10	-0.66
S. E. Kurtosis		1.33	1.33	1.48	1.48	1.04	1.04

Table_Apx C-14: Key features of comparative samples (i.e., satisfactory ratings on meeting experience in with-social-cue and without-social-cue meeting modes), rated by three user groups

		Case 1 – Non-shy		Case 2 – Shy		Case 3 – Overall	
		w/o clue	w/ clue	w/o clue	w/ clue	w/o clue	w/ clue
Total N		10	14	8	22	18	36
Mean		4.40	3.57	4.13	4.41	4.28	4.08
S.E. Mean		0.31	0.25	0.23	0.14	0.19	0.15
95% CI for	Lower	3.71	3.03	3.59	4.11	3.87	3.79
Mean	Upper	5.09	4.11	4.66	4.70	4.69	4.38
Median		5.00	4.00	4.00	4.50	4.00	4.00
Variance		0.93	0.88	0.41	0.44	0.68	0.76
Std. Deviation		0.97	0.94	0.64	0.67	0.83	0.87
Minimum		2.00	2.00	3.00	3.00	2.00	2.00
Maximum		5.00	5.00	5.00	5.00	5.00	5.00
Range		3.00	3.00	2.00	2.00	3.00	3.00
Interquartile Range		1.00	1.00	0.75	1.00	1.00	1.00
Skewness		-1.96	-0.24	-0.07	-0.70	-1.30	-0.71
S.E.		0.69	0.60	0.75	0.49	0.54	0.39
Kurtosis		4.19	-0.49	0.74	-0.43	2.10	-0.07
S. E. Kurtosis		1.33	1.15	1.48	0.95	1.04	0.77

Table_Apx C-15: Key features of related samples (i.e., between users' SIAS scores and their satisfactory ratings on badge, card and no-soObj meeting experiences), rated by overall-user group

		Case 1 Badge mode		Case 2 Card mode		Case 3 No-soObj mode	
		SIAS score	Rating of satisfaction	SIAS score	Rating of satisfaction	SIAS score	Rating of satisfaction
Mean		39.22	4.44	31.89	3.72	32.22	4.28
S.E. Mean		2.65	0.15	2.88	0.23	3.51	0.19
95% CI for	Lower	33.64	4.14	25.81	3.25	24.82	3.87
Mean	Upper	44.81	4.75	37.97	4.20	39.62	4.69
Median		41.00	4.50	30.50	4.00	35.00	4.00
Variance		126.18	0.38	149.63	0.92	221.60	0.68
Std. Deviation		11.23	0.62	12.23	0.96	14.89	0.83
Minimum		9	3	9	2	9	2
Maximum		51	5	51	5	51	5
Range		42	2	42	3	42	3
Interquartile Range		9	1	24	1	30	1
Skewness		-1.46	-0.62	-0.17	-0.27	-0.66	-1.30
S.E.		0.54	0.54	0.54	0.54	0.54	0.54
Kurtosis		2.24	-0.39	-1.24	-0.66	-1.07	2.10
S. E. Kurtosis		1.04	1.04	1.04	-0.66	1.04	1.04

Table_Apx C-16: Key features of related samples (i.e., between users' SIAS scores and their satisfactory ratings on experience in with-social-cue and without-social-cue meeting conditions), rated by overall-user group.

		Case 4 With-social-clue condition		Case 5 Without-social-clue condition	
		SIAS score	Rating of satisfaction	SIAS score	Rating of satisfaction
Total N		36	36	18	18
Mean		35.56	4.08	32.22	4.28
S.E. Mean		2.03	0.15	3.51	0.19
95% CI for Mean	Lower	31.44	3.79	24.82	3.87
	Upper	39.67	4.38	39.62	4.69
Median		40.00	4.00	35.00	4.00
Variance		147.80	0.76	221.59	0.68
Std. Deviation		12.16	0.87	14.89	0.83
Minimum		9	2	9	2
Maximum		51	5	51	5
Range		42	3	42	3
Interquartile Range		17	1	30	1
Skewness		-0.68	-0.71	-0.66	-1.30
S.E.		0.39	0.39	0.54	0.54
Kurtosis		-0.57	-0.07	-1.07	2.10
S. E. Kurtosis		0.77	0.77	1.04	1.04

C.4.5 Preferred Meeting Mode (section 6.4.5)

Table_Apx C-17: Key features of preferential ratings on three meeting modes, by all user groups

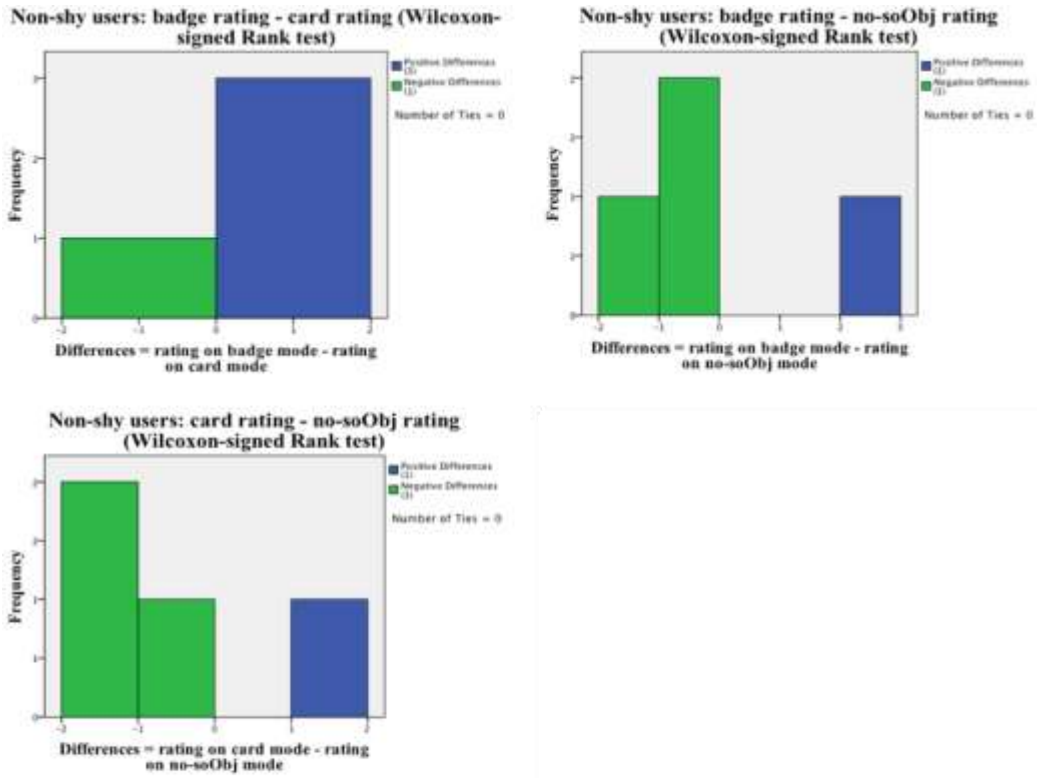
		Non-shy users			Shy users			Overall user		
		Badge	Card	No-soObj	Badge	Card	No-soObj	Badge	Card	No-soObj
Total N		4	4	4	5	5	5	9	9	9
Mean		2.00	1.50	2.50	2.80	1.20	2.00	2.44	1.33	2.22
S.E. Mean		0.41	0.29	0.50	0.20	0.20	0.32	0.24	0.17	0.28
95% CI	Lower	0.70	0.58	0.91	2.24	0.64	1.12	1.89	0.95	1.58
for Mean	Upper	3.30	2.42	4.09	3.36	1.76	2.88	3.00	1.72	2.86
Median		2.00	1.50	3.00	3.00	1.00	2.00	3.00	1.00	2.00
Variance		0.67	0.33	1.00	0.20	0.20	0.50	0.53	0.25	0.69
Std. Deviation		0.82	0.58	1.00	0.45	0.45	0.71	0.73	0.50	0.83
Minimum		1	1	1	2	1	1	1	1	1
Maximum		3	2	3	3	2	3	3	2	3
Range		2	1	2	1	1	2	2	1	2
Interquartile Range		2	1	2	1	1	1	1	1	2
Skewness		0.00	0.00	-2.00	-2.24	2.24	0.00	-1.01	0.86	-0.50
S.E. Skewness		1.01	1.01	1.01	0.91	0.91	0.91	0.72	0.72	0.72
Kurtosis		1.50	-6.00	4.00	5.00	5.00	2.00	0.19	-1.71	-1.28
S. E. Kurtosis		2.62	2.62	2.62	2.00	2.00	2.00	1.40	1.40	1.40

Table_Apx C-18: Case summary of nine users' SIAS scores, matched with their most preferable meeting modes (from lowest degree of display visibility: no-soObj (1) to highest: badge (3))

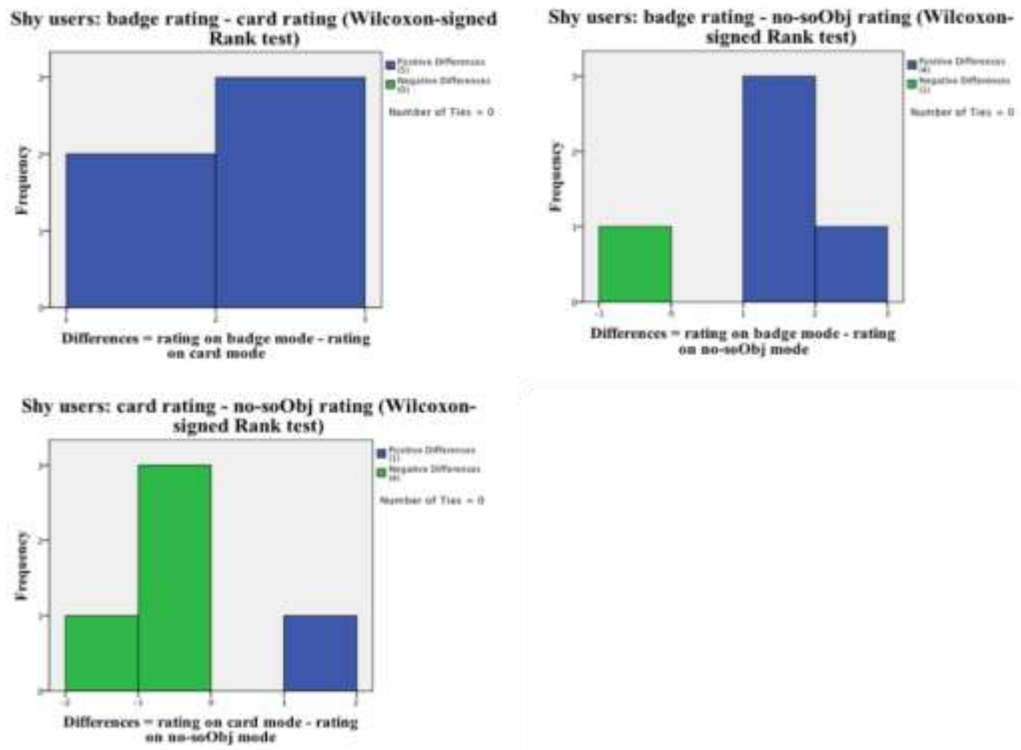
		SIAS score	Most preferable meeting mode
1		9	no-soObj (1)
2		19	no-soObj (1)
3		26	badge (3)
4		35	no-soObj (1)
5		40	no-soObj (1)
6		41	badge (3)
7		43	badge (3)
8		46	badge (3)
9		51	badge (3)
Total	N	9	9

Table_Apx C-19: Key features of users' SIAS scores and their 1st choice of meeting modes

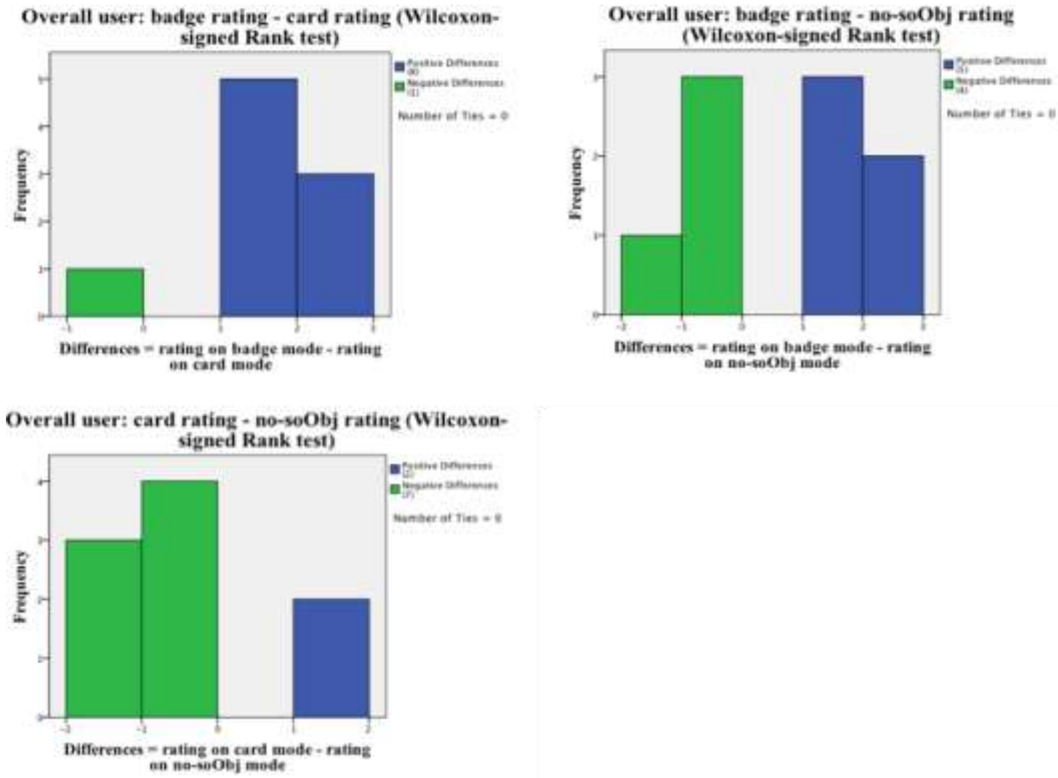
		SIAS score	Most preferable meeting mode
Total		9	9
Mean		34.44	2.11
S.E Mean		4.583	0.351
95% CI for Mean	Lower	23.88	1.30
	Upper	45.01	2.92
Median		40.00	3.00
Variance		189.028	1.111
Std. Deviation		13.749	1.054
Minimum		9	1
Maximum		51	3
Range		42	2
Interquartile Range		22	2
Skewness		-0.841	-0.271
S.E Skewness		0.717	0.717
Kurtosis		-0.207	-2.571
S.E Kurtosis		1.400	1.400



Figure_Apx 17: Graphical output of Wilcoxon signed-rank test of differences between preferential ratings on three comparative meeting modes (i.e. ‘badge vs. card’ (top-left), ‘badge vs. no-soObj’ (top-right), and ‘card vs. no-soObj’ (bottom-left)), rated by non-shy group.



Figure_Apx 18: Graphical output of Wilcoxon signed-rank test of differences between preferential ratings on three comparative meeting modes (i.e. ‘badge vs. card’ (top-left), ‘badge vs. no-soObj’ (top-right), and ‘card vs. no-soObj’ (bottom-left)), rated by shy group.



Figure_Apx 19: Graphical output of Wilcoxon signed-rank test of differences between preferential ratings on three comparative meeting modes (i.e. ‘badge vs. card’ (top-left), ‘badge vs. no-soObj’ (top-right), and ‘card vs. no-soObj’ (bottom-left)), rated by overall-user group.

C.4.6 Awareness of Cued Content (section 6.4.6)

Table_Apx C-20: Key features of comparative samples i.e., attentional ratings on displays, rated by three user groups

		Case 1 Non-shy		Case 2 Shy		Case 3 Overall	
		Card	Badge	Card	Badge	Card	Badge
Total N		10	4	8	14	18	18
Mean		2.20	2.00	1.63	1.79	1.94	1.83
S.E. Mean		0.36	0.58	0.46	0.19	0.29	0.19
95% CI for Mean	Lower	1.39	0.16	0.54	1.38	1.34	1.44
	Upper	3.01	3.84	2.71	2.19	2.55	2.22
Median		3.00	2.00	1.50	2.00	2.50	2.00
Variance		1.29	1.33	1.70	0.49	1.47	0.62
Std. Deviation		1.14	1.15	1.30	0.70	1.21	0.79
Minimum		0	1	0	1	0	1
Maximum		3	3	3	3	3	3
Range		3	2	3	2	3	2
Interquartile Range		2	2	3	1	2	1
Skewness		-1.05	0.00	-0.11	0.32	-0.55	0.32
S.E.		0.69	1.01	0.75	0.60	0.54	0.54
Kurtosis		-0.39	-6.00	-1.92	-0.63	-1.38	-1.24
S. E. Kurtosis		1.33	2.62	1.48	1.15	1.04	1.04

Table_Apx C-21: Case summary of all users' attentional ratings on displays

	Card			Badge		
	User ID	SIAS score	Attentional rating	User ID	SIAS score	Attentional rating
1	R	9	I was not at all aware of it (0)	R	9	I was aware of it but not paid attention to its content (1)
2	Y	19	I was aware of it but not paid attention to its content (1)	Y	19	I discussed its content' (3)
3	Y	19	I discussed its content' (3)	Z	26	I discussed its content' (3)
4	Y	19	I discussed its content' (3)	U	37	I was aware of it but not paid attention to its content (1)
5	Y	19	I discussed its content' (3)	F	40	I was aware of it but not paid attention to its content (1)
6	Z	26	I discussed its content' (3)	F	40	I discussed its content' (3)
7	Z	26	I paid attention to its content (2)	F	40	I paid attention to its content (2)
8	Z	26	I discussed its content' (3)	F	40	I was aware of it but not paid attention to its content (1)
9	Z	26	I discussed its content' (3)	O	41	I paid attention to its content (2)
10	U	37	I was aware of it but not paid attention to its content (1)	O	41	I was aware of it but not paid attention to its content (1)
11	F	40	I discussed its content' (3)	O	41	I paid attention to its content (2)
12	O	41	I was not at all aware of it (0)	O	41	I paid attention to its content (2)
13	K	43	I was aware of it but not paid attention to its content (1)	K	43	I was aware of it but not paid attention to its content (1)
14	K	43	I paid attention to its content (2)	N	46	I paid attention to its content (2)
15	K	43	I discussed its content' (3)	B	51	I was aware of it but not paid attention to its content (1)
16	K	43	I was not at all aware of it (0)	B	51	I paid attention to its content (2)
17	N	46	I was aware of it but not paid attention to its content (1)	B	51	I paid attention to its content (2)
18	B	51	I discussed its content' (3)	B	51	I discussed its content' (3)
Total N		18	18		18	18

Table_Apx 22: Key features of matched samples i.e., SIAS score and their attentional rating on three meeting modes

		Case 1 Card		Case 2 Badge	
		SIAS score	Rating of awareness	SIAS score	Rating of awareness
Total N		18	18	18	18
Mean		31.89	1.94	39.22	2.65
S.E. Mean		2.88	0.29	39.22	2.65
95% CI for Mean	Lower	25.81	1.34	33.64	1.44
	Upper	37.97	2.55	44.81	2.22
Median		30.50	2.50	41.00	2.00
Variance		149.63	1.47	126.18	0.62
Std. Deviation		12.23	1.21	11.23	0.79
Minimum		9	0	9	1
Maximum		51	3	51	3
Range		42	3	42	2
Interquartile Range		24	2	9	1
Skewness		-0.17	-0.55	-1.46	0.32
S.E.		0.54	0.54	0.54	0.54
Kurtosis		-1.24	-1.38	2.24	-1.24
S. E. Kurtosis		1.04	1.04	1.04	1.04

Table_Apx C-23: Numerical outputs of Spearman's rho test (retangle marks) and correlation (*r*) estimation (oval marks) on the relationship between SIAS scores (9–51) and attentional rating (0–3) on card display, rated by overall-user group.

				SIAS	Attention
SIAS	Correlation Coefficient			1.00	-0.15
	95% CI for Correlation Coeffectient		Lower		0.57
			Upper		0.35
	Sig. (2-tailed)				0.567
	N			18.00	18.00
	Bootstrap[c]	Bias		0.00	0.01
		Std. Error		0.00	0.26
		95% Confidence Interval	Lower	1.00	-0.61
			Upper	1.00	0.39
Attention	Correlation Coefficient			-0.15	1.00
	95% CI for Correlation Coeffectient		Lower	0.57	
			Upper	0.35	
	Sig. (2-tailed)			0.567	
	N			18.00	18.00
	Bootstrap[c]	Bias		0.01	0.00
		Std. Error		0.26	0.00
		95% Confidence Interval	Lower	-0.61	1.00
			Upper	0.39	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Table_Apx C-24: Numerical outputs of Spearman's rho test (retangle marks) and correlation (r) estimation (oval marks) on the relationship between SIAS scores (9–51) and attentional rating (0–3) on badge display, rated by overall-user group

				SIAS	Attention
SIAS	Correlation Coefficient			1.00	0.01
	95% CI for Correlation Coeffectient		Lower		-0.46
			Upper		0.47
	Sig. (2-tailed)				0.968
	N			18.00	18.00
	Bootstrap[c]	Bias		0.00	0.02
		Std. Error		0.00	0.28
		95% Confidence Interval	Lower	1.00	-0.53
			Upper	1.00	0.59
Attention	Correlation Coefficient			-0.15	1.00
	95% CI for Correlation Coeffectient		Lower	-0.57	
			Upper	0.35	
	Sig. (2-tailed)			0.968	
	N			18.00	18.00
	Bootstrap[c]	Bias		0.02	0.00
		Std. Error		0.28	0.00
		95% Confidence Interval	Lower	-0.53	1.00
			Upper	0.59	1.00

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

C.5 Compatibility levels between test participants

Records of compatibility levels in the Final study: generated from nine meeting cases, each between a pair of test participants who met first time while wearing the Icebreaker Jacket with a clip-on Social Badge

User ID	Displayed compatibility level on badge	Displayed compatibility level on badge	User ID
R	3	4	F
Y	2	3	O
Z	3	5	F
U	2	3	O
F	3	2	R
F	4	3	Z
F	4	2	O
F	5	4	B
O	3	1	Y
O	2	3	U
O	1	4	F
O	5	4	B
K	4	2	B
N	1	2	B
B	3	4	F
B	3	5	O
B	4	5	K
B	3	5	N

Notes:
each row represents a meeting between two participants who wore the Icebreaker Jacket with a clip-on Social Badge. The social compatibility levels shown on their badge displays conveyed different degrees of social compatibility based on their social profiles and preferences. For example, in the meeting between O and F, the display of O's badge showed that O was a person whose social profile compatible with some criteria in F's preference, and the compatibility was four times lower than the vice

Reference

Abouzied, A., & Chen, J. (2014). CommonTies: A Context-Aware Nudge towards Social Interaction (pp. 1–4). Presented at the Conference on Computer Supported Cooperative Work and Social Computing, New York, New York, USA: ACM Press. http://doi.org/10.1145/2556420.2556783

Abowd, G. D., & Mynatt, E. D. (2000). Charting past, present, and future research in ubiquitous computing. *ACM Transactions on Computer-Human Interaction (TOCHI) – Special Issue on the Theory and Practice of Embodied Interaction in HCI and Interaction Design*, 29–58.

Aderka, I. M., McLean, C. P., Huppert, J. D., Davidson, J. R. T., & Foa, E. B. (2013). Fear, avoidance and physiological symptoms during cognitive-behavioral therapy for social anxiety disorder. *Behaviour Research and Therapy*, *51*(7), 352–358. http://doi.org/10.1016/j.brat.2013.03.007

Agresti, A. (2002). Categorical Data Analysis. John Wiley & Sons.

Ahn, J.-K., & Kwon, J.-H. (2018). Modifying Negative Self-Imagery Increases the Effectiveness of Cognitive Behavior Therapy for Social Anxiety Disorder: A Benchmarking Study. *Cognitive Therapy and Research*, *37*(8), 715–14. http://doi.org/10.1007/s10608-018-9918-5

Alben, L. (1996). Quality of experience - defining the criteria for effective interaction design. *Interactions*, *3*(3), 11–15. http://doi.org/10.1145/235008.235010

Albrecht, A. R., & Scholl, B. J. (2010). Perceptually averaging in a continuous visual world extracting statistical summary representations over time. *Psychological Science*, *21*(4), 560–567. http://doi.org/10.1177/0956797610363543

Ali, El, A. (2011). Studying and Designing for Mobile Social Awareness Cues in Urban Interactions. *Proceeding of the 11th International Conference on Human Computer Interaction with Mobile Devices and Services*, 1–4.

Allmark, P. (2004). Should research samples reflect the diversity of the population? *Journal of Medical Ethics*, *30*(2), 185–189. http://doi.org/10.1136/jme.2003.004374

Alvarez, G. A. (2011). Representing multiple objects as an ensemble enhances visual cognition. *Trends in Cognitive Sciences*, *15*(3), 122–131. http://doi.org/10.1016/j.tics.2011.01.003

Alvarez, G. A., & Oliva, A. (2008). The representation of simple ensemble visual features outside the focus of attention. *Psychological Science*, *19*(4), 392–398. http://doi.org/10.1111/j.1467-9280.2008.02098.x

Alvarez, G. A., & Oliva, A. (2009). Spatial ensemble statistics are efficient codes that can be represented with reduced attention. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(18), 7345–7350. http://doi.org/10.1073/pnas.0808981106

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5) – 5th ed* (pp. 1–970). Arlington, VA: American Psychiatric Publishing.

Anderson, F., Grossman, T., & Wigdor, D. (2015). Supporting Subtlety with Deceptive Devices and Illusory Interactions. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*, 1489–1498.

Andersson, G., Cuijpers, P., Carlbring, P., Riper, H., & Hedman, E. (2014). Guided Internet-based vs. face-to-face cognitive behavior therapy for psychiatric and somatic disorders: a systematic review and meta-analysis. *World Psychiatry: Official Journal of the World Psychiatric Association (WPA)*, *13*(3), 288–295. http://doi.org/10.1002/wps.20151

Antle, A. N. (2007). The CTI framework - Informing the design of tangible systems for children. *Proceeding of the 6th International Conference on Tangible, Embedded and Embodied Interaction*, 195.

Antle, A. N., Corness, G., & Droumeva, M. (2009a). Human-computer-intuition? Exploring the cognitive basis for intuition in embodied interaction. *International Journal of Arts and Technology*, *2*(3), 235–254.

Antle, A. N., Corness, G., & Droumeva, M. (2009b). What the body knows: Exploring the benefits of embodied metaphors in hybrid physical digital environments. *Interacting with Computers*, *21*(1-2), 66–75. http://doi.org/10.1016/j.intcom.2008.10.005

Antle, A. N., Corness, G., Bakker, S., Droumeva, M., Van Den Hoven, E., & Bevans, A. (2009c). Designing to support reasoned imagination through embodied metaphor. *Creativity & Cognition*, 275–284. http://doi.org/10.1145/1640233.1640275

Aoki, P. M., & Woodruff, A. (2005). Making space for stories: ambiguity in the design of personal communication systems. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 181–190. http://doi.org/10.1145/1054972.1054998

Ariely, D. (2001). Seeing Sets: Representation by Statistical Properties. *Psychological Science*, *12*(2), 157–162. http://doi.org/10.1111/1467-9280.00327

Arnau, E., Estany, A., Rafael González del Solar, & Sturm, T. (2013). The extended cognition thesis: Its significance for the philosophy of (cognitive) science. *Philosophical Psychology*, *27*(1), 1–1. http://doi.org/10.1080/09515089.2013.836081

Asikhia, O. K., Setchi, R., Hicks, Y., & Walter, A. (2015). Conceptual Framework for Evaluating Intuitive Interaction Based on Image Schemas. *Interacting with Computers*, 287–310. http://doi.org/10.1112/iwcomp/iwu050

Ateniese, G., Kirsch, J., & Blanton, M. (2007). Secret Handshakes with Dynamic and Fuzzy Matching. *Ndss*.

Atterer, R., Wnuk, M., & Schmidt, A. (2006). Knowing the user's every move: user activity tracking for website usability evaluation and implicit interaction (pp. 203–212). New York, New York, USA: ACM. http://doi.org/10.1145/1135777.1135811

Augimeri, A., Fortino, G., Rege, M. R., Handziski, V., & Wolisz, A. (2010). A cooperative approach for handshake detection based on body sensor networks. *2010 IEEE International Conference on Systems, Man and Cybernetics*, 281–288.

Australian Psychological Society. (2010). The social and psychological impact of online social networking. The Australian Psychological Society Ltd. Retrieved from https://www.psychology.org.au/publications/inpsych/2010/december/social/

Baber, C. (2018). Designing Smart Objects to Support Affording Situations: Exploiting Affordance through an Understanding of Forms of Engagement. *Frontiers in Psychology*, *9*, 723–8. http://doi.org/10.3389/fpsyg.2018.00292

Baber, C., Parekh, M., & Cengiz, T. G. (2014). Tool use as distributed cognition: how tools help, hinder and define manual skill. *Frontiers in Psychology*, *5*, 116. http://doi.org/10.3389/fpsyg.2014.00116
Bacchetti, P. (2013). Small sample size is not the real problem. *Nature Reviews Neuroscience*, *14*(8), 585–585. http://doi.org/10.1038/nrn3475-c3
Bacchetti, P., Deeks, S. G., & McCune, J. M. (2011). Breaking Free of Sample Size Dogma to Perform Innovative Translational Research. *Science Translational Medicine*, *3*(87), 87ps24. http://doi.org/10.1126/scitranslmed.3001628
Backhaus, A., Agha, Z., Maglione, M. L., Repp, A., Ross, B., Zuest, D., et al. (2012). Videoconferencing psychotherapy: A systematic review. *Psychological Services*, *9*(2), 111–131. http://doi.org/10.1037/a0027924
Baker, K., Greenberg, S., & Gutwin, C. (2002). Empirical development of a heuristic evaluation methodology for shared workspace groupware. *Proceeding of the 2002 ACM Conference on Computer Supported Cooperative Work*, 96–105. http://doi.org/10.1145/587078.587093
Bakker, S., & Niemantsverdriet, K. (2016). The interaction-attention continuum: Considering various levels of human attention in interaction design. *International Journal of Design*, *10*(2).
Bakker, S., Van Den Hoven, E., & Eggen, B. (2015). Peripheral interaction: characteristics and considerations. *Personal and Ubiquitous Computing*, *19*(1), 239–254. http://doi.org/10.1007/s00779-014-0775-2
Bakker, S., Van Den Hoven, E., Eggen, B., & Overbeeke, K. (2012). Exploring peripheral interaction design for primary school teachers. *Proceeding of the 6th International Conference on Tangible, Embedded and Embodied Interaction*, 245–252. http://doi.org/10.1145/2148131.2148184
Balfanz, D., Durfee, G., Shankar, N., Smetters, D., Staddon, J., & Hao-Chi Wong. (2003). Secret handshakes from pairing-based key agreements (pp. 180–196). Presented at the 2003 Symposium on Security and Privacy, IEEE Comput. Soc. http://doi.org/10.1109/SECPRI.2003.1199336
Bandelow, B., Reitt, M., Röver, C., Michaelis, S., Görlich, Y., & Wedekind, D. (2015). Efficacy of treatments for anxiety disorders. *International Clinical Psychopharmacology*, *30*(4), 183–192. http://doi.org/10.1097/YIC.0000000000000078
Barkowski, S., Schwartze, D., Strauss, B., Burlingame, G. M., Barth, J., & Rosendahl, J. (2016). Efficacy of group psychotherapy for social anxiety disorder: A meta-analysis of randomized-controlled trials. *Journal of Anxiety Disorders*, *39*, 44–64. http://doi.org/10.1016/j.janxdis.2016.02.005
Barley, W. C., Leonardi, P. M., & Bailey, D. E. (2012). Engineering Objects for Collaboration: Strategies of Ambiguity and Clarity at Knowledge Boundaries. *Human Communication Research*, *38*(3), 280–308. http://doi.org/10.1111/j.1468-2958.2012.01430.x
Bastick, T. (1982). Intuition: How We Think and Act. Chichester, UK: John Wiley & Sons Inc.
Batson, C. D., Lishner, D. A., & Cook, J. (2005). Similarity and nurturance: Two possible sources of empathy for strangers. *Basic and Applied Social Psychology*, *27*(1), 15–25. http://doi.org/10.1207/s15324834basp2701_2
Bauer, B. (2009). Does Stevens's power law for brightness extend to perceptual brightness averaging? *The Psychological Record*, *59*, 171–186. http://doi.org/10.1016/b978-0-12-391926-7.50005-9
Baumeister, R. F., & Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, 497–529.

Beaudouin-Lafon, M. (2004). Designing interaction, not interfaces (pp. 15–22). New York, USA: ACM. http://doi.org/10.1145/989863.989865
Becker, L. A. (2000). Effect Size (ES). Retrieved November 16, 2016, from http://www.uccs.edu/lbecker/effect-size.html
Beidel, D. C., & Turner, S. M. (1999). The natural course of shyness and related syndromes. (L. A. Schmidt & J. Schulkin, Eds.) (pp. 203–223). Oxford University Press. http://doi.org/10.1093/acprof:oso/9780195118872.003.0012
Beidel, D. C., & Turner, S. M. (2007a). Behavioral and Cognitive-Behavioral Treatment of Social Anxiety Disorder in Adults. In D. C. Beidel & S. M. Turner (Eds.), *Shy children, phobic adults: Nature and treatment of social anxiety disorders* (2nd ed., pp. 201–260). DC, USA: American Psychological Association. http://doi.org/10.1037/11533-008
Beidel, D. C., & Turner, S. M. (2007b). Behavioral and Cognitive-Behavioral Treatment of Social Anxiety Disorder in Children and Adolescents. In *Shy children, phobic adults: Nature and treatment of social anxiety disorders* (pp. 261–313). DC, USA: American Psychological Association. http://doi.org/10.1037/11533-009
Beidel, D. C., Turner, S. M., & Morris, T. L. (2000). Behavioral treatment of childhood social phobia. *Journal of Consulting and Clinical Psychology*, *68*(6), 1072–1080. http://doi.org/10.1037/0022-006X.68.6.1072
Bennington, G. (2008). Handshake. *Derrida Today*, *1*(2), 167–184. http://doi.org/10.3366/e1754850008000213
Berggren, N., Richards, A., Taylor, J., & Derakshan, N. (2013). Affective attention under cognitive load: reduced emotional biases but emergent anxiety-related costs to inhibitory control. *Frontiers in Human Neuroscience*, *7*(188), 1–7. http://doi.org/10.3389/fnhum.2013.00188/abstract
Bernieri, F. J., & Petty, K. N. (2011). The influence of handshakes on first impression accuracy. *Social Influence*, *6*(2), 78–87. http://doi.org/10.1080/15534510.2011.566706
Bertin, J. (1983). Semiology of graphics: diagram, networks, and maps. (W. J. Berg, Trans.). University of Wisconsin Press.
Bevan, N. (2009). What is the difference between the purpose of usability and user experience evaluation methods. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*.
Bhatt, H., & Glover, B. (2006). RFID Essentials. O'Reilly Media Inc.
Blackler, A. L., Popovic, V., & Mahar, D. P. (2006). Towards a Design Methodology for Applying Intuitive Interaction. *Proceeding of Wonder Ground Design Research Society International Conference*, 1–21.
Blackler, A., & Popovic, V. (2015). Towards Intuitive Interaction Theory. *Interacting with Computers*, *27*(3), 203–209. http://doi.org/10.1112/iwcomp/iwv011
Blackler, A., Popovic, V., & Mahar, D. (2003). The nature of intuitive use of products: an experimental approach. *Design Studies*, *24*(6), 491–506. http://doi.org/10.1016/S0142-694X(03)00038-3
Blackler, A., Popovic, V., & Mahar, D. (2010). Investigating users • intuitive interaction with complex artefacts. *Applied Ergonomics*, *41*(1), 72–92. http://doi.org/10.1016/j.apergo.2009.04.010
Blackwell, A. F. (2006). The Reification of Metaphor as a Design Tool. *ACM Transactions on Computer-Human Interaction (TOCHI) – Special Issue on the Theory and Practice of Embodied Interaction in HCI and Interaction Design*, *13*(4), 490–530.

Blair, K. S., Otero, M., Teng, C., Geraci, M., Lewis, E., Hollon, N., et al. (2016). Learning from other people's fear: amygdala-based social reference learning in social anxiety disorder. *Psychological Medicine*, *46*(14), 2943–2953. http://doi.org/10.1017/S0033291716001537

Blasco, R., Marco, Á., Casas, R., Cirujano, D., & Picking, R. (2014). A Smart Kitchen for Ambient Assisted Living. *Sensors*, *14*(1), 1629–1653. http://doi.org/10.3390/s140101629

Bloomberg, L. D., & Volpe, M. (2012). Presenting Methodology and Research Approach. In *Completing Your Qualitative Dissertation: A Roadmap from Beginning to End* (pp. 65–93). CA.

Boettcher, J., Andersson, G., Carlbring, P., on behalf of the SOFIE-13 research group. (2013). Combining attention training with cognitive-behavior therapy in Internet-based self-help for social anxiety: study protocol for a randomized controlled trial. *Trials*, *14*(1), 68. http://doi.org/10.1186/1745-6215-14-68

Boettcher, J., Berger, T., & Renneberg, B. (2011). Internet-Based Attention Training for Social Anxiety: A Randomized Controlled Trial. *Cognitive Therapy and Research*, *36*(5), 522–536. http://doi.org/10.1007/s10608-011-9374-y

Borovoy, R., Martin, F., Vemuri, S., Resnick, M., Silverman, B., & Hancock, C. (1998). Meme tags and community mirrors: moving from conferences to collaboration. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*, 159–168. http://doi.org/10.1145/289444.289490

Bortnik, K., Henderson, L., & Zimbardo, P. (2002). The ShyQ, a Measure of Chronic Shyness: Associations with Interpersonal Motives, Interpersonal Values and Self-Conceptualizations (pp. 1–9). Presented at the Poster session at 36th annual conference of the Association for the Advancement of Behavior Therapy.

Bourriaud, N. (2002). Relational Aesthetics (English version Excerpt). (S. Pleasance, F. Woods, & M. Copeland, Trans.). Dijon, France: Les Presses du Réel.

Böckler, A., Knoblich, G., & Sebanz, N. (2012). Effects of a coactor's focus of attention on task performance. *Journal of Experimental Psychology: Human Perception and Performance*, *38*(6), 1404–1415. http://doi.org/10.1037/a0027523

Brahnam, S. (2014). HCI Prototyping and Modeling of Future Psychotherapy Technologies in Second Life. In A. Marcus (Ed.), *Design, User Experience, and Usability. Theory, Methods, Tools and Practice* (Vol. 8510, pp. 273–284). Cham: Springer International Publishing. http://doi.org/10.1007/978-3-319-07233-3_26

Brahnam, S., & Brooks, A. L. (2014). Two innovative healthcare technologies at the intersection of serious games, alternative realities, and play therapy. *Innovation in Medicine and Healthcare*, 153–162. http://doi.org/10.3233/978-1-61499-474-9-153

Bramel, D., & Friend, R. (1981). Hawthorne, the Myth of the Docile Worker, and Class Bias in Psychology. *American Psychologist*, *36*, 867–878.

Brennan, S. E., Chen, X., Dickinson, C. A., Neider, M. B., & Zelinsky, G. J. (2008). Coordinating cognition: The costs and benefits of shared gaze during collaborative search. *Cognition*, *106*(3), 1465–1477. http://doi.org/10.1016/j.cognition.2007.05.012

Brewster, S. A., Lumsden, J., Bell, M., Hall, M., & Tasker, S. (2003). Multimodal “eyes-free” interaction techniques for wearable devices. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 473–480. http://doi.org/10.1145/642611.642694

Brewster, S., & Brown, L. M. (2004). Tactons: structured tactile messages for non-visual information display, 15–23.

Britton, A., Setchi, R., & Marsh, A. (2013). Intuitive interaction with multifunctional mobile interfaces. *Journal of King Saud University - Computer and Information Sciences*, *25*(2), 187–196. http://doi.org/10.1016/j.jksuci.2012.11.002
Brown, L. M., Brewster, S. A., & Purchase, H. C. (2006). Multidimensional tactons for non-visual information presentation in mobile devices. *Mobile HCI*, 231.
Brown, P. J., Bovey, J. D., & Chen, X. (1997). Context-aware applications - from the laboratory to the marketplace. *IEEE Personal Commun.*, *4*(5), 58–64. http://doi.org/10.1109/98.626984
Bryant, B., & Trower, P. E. (1974). Social difficulty in a student sample. *The British Journal of Educational Psychology*, *44*(1), 13–21. http://doi.org/10.1111/(ISSN)2044-8279
Bryman, A. (2007). Barriers to Integrating Quantitative and Qualitative Research. *Journal of Mixed Methods Research*, *1*(1), 8–22. http://doi.org/10.1177/2345678906290531
Buchenau, M., & Suri, J. F. (2000). Experience Prototyping. *Symposium on Designing Interactive Systems*, 424–433. http://doi.org/10.1145/347642.347802
Burr, D., & Ross, J. (2008). A visual sense of number. *Current Biology*, *18*(6), 425–428. http://doi.org/10.1016/j.cub.2008.02.052
Buss, A. H. (2013). Two Kinds of Shyness. In R. Schwarzer (Ed.), *Self-related Cognitions in Anxiety and Motivation* (pp. 65–76). New York, USA.
Buxton, B. (2007). Sketching User Experiences: Getting the Design Right and the Right Design. San Francisco, CA: Morgan Kaufmann.
Bærentsen, K. B., & Trettvik, J. (2002). An activity theory approach to affordance. *Proceeding of the 5th Nordic Conference on Human-Computer Interaction: Building Bridges*, 51–60.
Cain, S. (2012). Quiet: The power of introverts in a world that can't stop talking. New York, USA: Crown Publishers.
Caplan, S., Williams, D., & Yee, N. (2009). Problematic Internet use and psychosocial well-being among MMO players. *Computers in Human Behavior*, *25*(6), 1312–1319. http://doi.org/10.1016/j.chb.2009.06.006
Card, S. K., Mackinlay, J. D., & Ben Shneiderman. (1999a). Readings in Information Visualization, 686.
Card, S. K., Mackinlay, J. D., & Shneiderman, B. (1999b). Information Visualization. In *Readings in information visualization using vision to think* (pp. 1–35). San Francisco, USA.
Carducci, B. J. (2000). Shyness: The new solution. *Psychology Today*, *33*(1), 38.
Carducci, B. J., & Klaphaak, K. W. (1999). Shyness, Internet Usage, and Electronic Extroversion: Patterns and Consequences. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*.
Carlbring, P., Andersson, G., Cuijpers, P., Riper, H., & Hedman-Lagerlöf, E. (2017). Internet-based vs. face-to-face cognitive behavior therapy for psychiatric and somatic disorders: an updated systematic review and meta-analysis. *Cognitive Behaviour Therapy*, 1–21. http://doi.org/10.1080/16506073.2017.1401115
Carroll, J. M. (2003). HCI Models, Theories, and Frameworks: Toward a Multidisciplinary Science, 1–579.
Carroll, J. M. (2012). Human Computer Interaction - brief intro. In A. Zahirovic, J. Lowgren, J. M. Carroll, M. Hassenzahl, T. Erickson, A. Blackwell, & K. Overbeek (Eds.), *The Encyclopedia of Human-Computer Interaction, 2nd Ed.* (pp. 1–26). Interaction-Design.org.

Carter, S., Mankoff, J., Klemmer, S. R., & Matthews, T. (2008). Exiting the Cleanroom: On Ecological Validity and Ubiquitous Computing. *Human–Computer Interaction*, *23*(1), 47–99. http://doi.org/10.1080/07370020701851086

Carus, P. (1916). Croce's Use of the Word 'Intuition.'. *The Monist*, *26*(2), 312–315.

Celentano, A., & Dubois, E. (2014). Metaphors, Analogies, Symbols: In Search of Naturalness in Tangible User Interfaces. *Procedia - Procedia Computer Science*, *39*, 99–106. http://doi.org/10.1016/j.procs.2014.11.015

Chalmers, D., Fitzpatrick, G., Scott, S., & Wakeman, I. (2008). *Supporting Shy Users in Pervasive Computing (Full Proposal)*.

Chan, M. (2011). Shyness, sociability, and the role of media synchronicity in the use of computer-mediated communication for interpersonal communication. *Asian Journal of Social Psychology*, 84–90. http://doi.org/10.1111/j.1467-839X.2010.01335.x

Chaplin, W. F., Phillips, J. B., Brown, J. D., Clanton, N. R., & Stein, J. L. (2000). Handshaking, gender, personality, and first impressions. *Journal of Personality and Social Psychology*, *79*(1), 110–117. http://doi.org/10.1037/10022·3514.79.1.110

Chavira, D. A., Stein, M. B., & Malcarne, V. L. (2002). Scrutinizing the relationship between shyness and social phobia. *Journal of Anxiety Disorders*, 585–598.

Cheek, J. M., Melchior, L. A., & Carpentieri, A. M. (1986). Shyness and Self-Concept. In L. M. Hartman & K. R. Blankstein (Eds.), *Perception of Self in Emotional Disorder and Psychotherapy* (pp. 113–131). Boston, MA: Springer US. http://doi.org/https://doi.org/10.1007/978-1-4613-1793-7_5

Chemero, A. (2003). An outline of a theory of affordances. *Ecological Psychology*, *15*(2), 181–195. http://doi.org/10.1207/s15326969eco1502_5

Chemero, A. (2009). Radical Embodied Cognitive Science (pp. 1–269). Cambridge, MA: MIT Press.

Chen, F., Deng, J., Pang, Z., Baghaei Nejad, M., Yang, H., & Yang, G. (2018). Finger Angle-Based Hand Gesture Recognition for Smart Infrastructure Using Wearable Wrist-Worn Camera. *Applied Sciences*, *8*(3), 369–19. http://doi.org/10.3390/app8030369

Chen, Jay, & Abouzied, A. (2016). One LED is Enough: Catalyzing Face-to-face Interactions at Conferences with a Gentle Nudge (pp. 172–182). Presented at the Computer-Supported Cooperative Work and Social Computing, New York, USA: ACM Press. http://doi.org/10.1145/2818048.2819969

Chiesa, M., & Hobbs, S. (2008). Making sense of social research: how useful is the Hawthorne Effect? *European Journal of Social Psychology*, *38*(1), 67–74. http://doi.org/10.1002/ejsp.401

Choi, S., & Kuchenbecker, K. J. (2012). Vibrotactile display: Perception, technology, and applications. *Proceeding of the IEEE*, *10*(9), 2093–2104. http://doi.org/10.1109/JPROC.2012.2221071

Cholewiak, R. W., & Collins, A. A. (2003). Vibrotactile localization on the arm: effects of place, space, and age. *Perception & Psychophysics*, *65*(7), 1058–1077.

Cholewiak, R. W., Brill, J. C., & Schwab, A. (2004). Vibrotactile localization on the abdomen: effects of place and space. *Perception & Psychophysics*, *66*(6), 970–987.

Clark, A. (1998). Being There: Putting Brain, Body, and World Together Again (pp. 1–277). Cambridge, MA: MIT Press.

Clark, A. (1999a). An embodied cognitive science? *Trends in Cognitive Sciences*, *3*(9), 345–351.

Clark, A. (2003). Natural-Born Cyborgs. Oxford University Press.

Clark, A. (2008). Supersizing the Mind. Oxford University Press. http://doi.org/10.1093/acprof:oso/9780195333213.001.0001

Clark, A., & Chalmers, D. (1998). The Extended Mind. *Analysis*, *58*(1), 7–19.

Clark, D. A., & Beck, A. T. (2010a). Cognitive therapy of anxiety disorders. London: Guildford Press.

Clark, D. A., & Beck, A. T. (2010b). Cognitive Therapy of Social Phobia. In D. A. Clark & A. T. Beck (Eds.), *Cognitive therapy of anxiety disorders* (pp. 332–387). London: Guildford Press.

Clark, D. M. (1999b). Anxiety disorders: Why they persist and how to treat them. *Behaviour Research and Therapy*, *37*(SUPPL. 1), S5–S27. http://doi.org/10.1016/s0005-7967(99)00048-0

Clark, D. M. (2001). A Cognitive Perspective on Social Phobia. In W. R. Crozier & L. E. Alden (Eds.), *International Handbook of Social Anxiety* (pp. 405–430).

Clark, D. M. (2005). A Cognitive Perspective on Social Phobia. In W. R. Crozier & L. E. Alden (Eds.), *The Essential Handbook of Social Anxiety for Clinicians* (pp. 193–220). Chichester, UK.

Clark, D. M., & Wells, A. (1995). A Cognitive Model of Social Phobia. In R. G. Heimberg, M. R. Liebowitz, D. A. Hope, & F. R. Schneier (Eds.), (pp. 69–93). New York: Gilford Press.

Coe, R. (2002). It's the Effect Size, Stupid (pp. 1–16). Presented at the Annual Conference of the British Educational Research Association.

Cohen, J. (1994). The earth is round (p<.05). *American Psychologist*, *49*(12), 997–1003. http://doi.org/10.1037/0003-066x.49.12.997

Colle, L., Pellecchia, G., Moroni, F., Carcione, A., Nicolò, G., Semerari, A., & Procacci, M. (2017). Levels of Social Sharing and Clinical Implications for Severe Social Withdrawal in Patients with Personality Disorders. *Frontiers in Psychiatry*, *8*, 675–11. http://doi.org/10.3389/fpsyt.2017.00263

Costanza, E., Inverso, S. A., Allen, R., & Maes, P. (2007). Intimate interfaces in action: Assessing the usability and subtlety of EMG-based motionless gestures. Presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.

Costanza, E., Inverso, S. A., Pavlov, E., Allen, R., & Maes, P. (2006). Eye-q: Eyeglass Peripheral Display for Subtle Intimate notifications. *Proceeding of the 2006 Conference on Human-Computer Interaction with Mobile Devices and Services*, 211–218. http://doi.org/10.1145/1152215.1152261

Crabtree, A., Hemmings, T., & Rodden, T. (2003). The Social Construction of Displays: Coordinate Displays and Ecologically Distributed Networks. In K. O'Hara, M. Perry, E. Churchill, & D. Russell (Eds.), *Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies* (pp. 170–190). Dordrecht, Netherlands: Springer, Dordrecht. http://doi.org/10.1007/978-94-017-2813-3_7

Cramér, H. (1962). Mathematical Methods of Statistics (First Indian Edition, pp. 1–590). Asia Publishing House, Bombay.

Cranor, D., Peyton, A., Persaud, A., Bhatia, R., Kim, S., & Bove, V. M. (2011). ShakeOnit: an exploration into leveraging social rituals for information access. *Proceeding of 5th International Conference on Tangible, Embedded and Embodied Interaction*, 277–278. http://doi.org/10.1145/1935701.1935761

Creswell, J. W. (2014). A Concise Introduction to Mixed Methods Research. London, UK: Sage.

Creswell, J. W., & Plano Clark, V. L. (2017). Designing and Conducting Mixed Methods Research (3rd ed.). London, UK: Sage Publications.

Creswell, J. W., Fetters, M. D., & Ivankova, N. V. (2004). Designing A Mixed Methods Study in Primary Care. *The Annals of Family Medicine*, *2*(1), 7–12. http://doi.org/10.1370/afm.104

Crozier, W. R. (2002). Shyness. *The Psychologist: the Magazine of the British Psychological Society*, 460–463.
Dalrymple, K. L., & Zimmerman, M. (2013). When does benign shyness become social anxiety, a treatable disorder? *Current Psychiatry*, *12*(11), 21–38.
Dalsgård, P. (2008). Designing for inquisitive use. *Conference on Designing Interactive Systems*, 21–30. http://doi.org/10.1145/1394445.1394448
Dangeti, S., Chen, Y. V., & Zheng, C. (2016). Comparing bare-hand-in-air Gesture and Object-in-hand Tangible User Interaction for Navigation of 3D Objects in Modeling. *Proceeding of the Tenth International Conference on Tangible, Embedded, and Embodied Interaction*, 417–421. http://doi.org/10.1145/2839462.2856555
Day, D., & Wagner, J. (2014). Objects as tools for talk. In M. R. Nevile, P. Haddington, T. Heinemann, & M. Rauniomaa (Eds.), *Interacting with objects Language, materiality, and social activity* (pp. 101–124). Amsterdam: John Benjamins Publishing Company. http://doi.org/10.1075/z.186.05day
De Voogd, E. L., Wiers, R. W., Prins, P. J. M., & Salemink, E. (2014). Visual search attentional bias modification reduced social phobia in adolescents. *Journal of Behavior Therapy and Experimental Psychiatry*, *45*(2), 252–259. http://doi.org/10.1016/j.jbtep.2013.11.006
DeLucia, P. R., Harold, S. A., & Tang, Y.-Y. (2013). Innovation in Technology-Aided Psychotherapy through Human Factors/Ergonomics: Toward a Collaborative Approach. *Journal of Contemporary Psychotherapy*, *43*(4), 253–260. http://doi.org/10.1007/s10879-013-9238-8
Dey, A. K., & de Guzman, E. (2006). From awareness to connectedness: the design and deployment of presence displays. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 899–908.
Di Paolo, E., & Thompson, E. (2014). The Enactive Approach. In L. Shapiro (Ed.), *The Routledge Handbook of Embodied Cognition* (pp. 68–78). New York, USA.
Dickie, C., Vertegaal, R., Sohn, C., & Cheng, D. (2005). eyeLook: Using attention to facilitate mobile media consumption (pp. 103–5). Presented at the 18th annual ACM symposium, New York, USA: ACM Press. http://doi.org/10.1145/1095034.1095050
Diefenbach, S., & Ullrich, D. (2015). An experience perspective on intuitive interaction: central components and the special effect of domain transfer distance. *Interacting with Computers*. http://doi.org/10.1112/iwcomp/iwv001
Donald, J., Abbott, M. J., & Smith, E. (2012). Comparison of Attention Training and Cognitive Therapy in the Treatment of Social Phobia: A Preliminary Investigation. *Behavioural and Cognitive Psychotherapy*, *42*(01), 74–91. http://doi.org/10.1017/S1352465812001051
Donkin, L., & Glozier, N. (2012). Motivators and Motivations to Persist With Online Psychological Interventions: A Qualitative Study of Treatment Completers. *Journal of Medical Internet Research*, *14*(3), e91–12. http://doi.org/10.2196/jmir.2100
Dourish, P. (2001). Seeking a Foundation for Context-Aware Computing. *Human–Computer Interaction*, *16*(2), 229–241. http://doi.org/10.1207/S15327051HCI16234_07
Dourish, P. (2004a). What we talk about when we talk about context. *Personal and Ubiquitous Computing*, *8*(1), 19–30. http://doi.org/10.1007/s00779-003-0253-8
Dourish, P. (2004b). Where the Action Is: the Foundations of Embodied Interaction. Cambridge, Massachusetts, USA: The MIT Press.
Dunne, L. E., Profita, H., Zeagler, C., Clawson, J., Gilliland, S., Do, E. Y.-L., & Budd, J. (2014). The social comfort of wearable technology and gestural interaction (pp. 4159–4162). Presented at the 2014 36th Annual International Conference of the

IEEE Engineering in Medicine and Biology Society (EMBC), IEEE. http://doi.org/10.1109/EMBC.2014.6944540
Ebeling-Witte, S., Frank, M. L., & Lester, D. (2007). Shyness, Internet Use, and Personality. *Cyber Psychology & Behavior*, *10*(5), 713–716. http://doi.org/10.1089/cpb.2007.9964
Edge, D. (2008). *Tangible user interfaces for peripheral interaction*. … of Cambridge Computer Laboratory Technical Report.
Edge, D., & Blackwell, A. F. (2009). Peripheral tangible interaction by analytic design (pp. 69–8). Presented at the 3rd International Conference, New York, USA: ACM Press. http://doi.org/10.1145/1517664.1517687
Edge, D., & Blackwell, A. F. (2016). Peripheral Tangible Interaction. *Peripheral Interaction*.
Edwards, A. L. (1948). Note on the "correction for continuity" in testing the significance of the difference between correlated proportions. *Psychometrika*, *13*(3), 185–187. http://doi.org/10.1007/BF02289261
Elliot, A. J. (2015). Color and psychological functioning: a review of theoretical and empirical work. *Frontiers in Psychology*, *6*, 1–8. http://doi.org/10.3389/fpsyg.2015.00368
Engeström, J. (2005, April). Why some social network services work and others don't – Or: the case for object-centered sociality. Retrieved June 12, 2013, from http://www.zengestrom.com/blog/2005/04/why-some-social-network-services-work-and-others-dont-or-the-case-for-object-centered-sociality.html
Engeström, Y., & Blackler, F. (2005). On the Life of the Object. *Organization*, *12*(3), 307–330. http://doi.org/10.1177/1350508405051268
Erbe, D., Eichert, H.-C., Riper, H., & Ebert, D. D. (2017). Blending Face-to-Face and Internet-Based Interventions for the Treatment of Mental Disorders in Adults: Systematic Review. *Journal of Medical Internet Research*, *19*(9), e306–14. http://doi.org/10.2196/jmir.6588
Erickson, T. (2002). Some Problems with the Notion of Context-Aware Computing. *Communications of the ACM*, *45*(2), 102–104.
Falk, J., & Björk, S. (1999). The BubbleBadge: a wearable public display. *Extended Abstracts on 2000 Human Factors in Computing Systems*, 318–319. http://doi.org/10.1145/632716.632909
Falk, J., & Björk, S. (2003). Crossbreeding Wearable and Ubiquitous
Computing: A Design Experience. In J. E. Katz (Ed.), *Machines that Become Us: The Social Context of Personal Communication Technology* (pp. 233–243). London, UK.
Fang, A., Sawyer, A. T., Asnaani, A., & Hofmann, S. G. (2013). Social Mishap Exposures for Social Anxiety Disorder: An Important Treatment Ingredient. *Cognitive and Behavioral Practice*, *20*(2), 213–220. http://doi.org/10.1016/j.cbpra.2012.05.003
Faraj, S., & Azad, B. (2012). The Materiality of Technology: An Affordance Perspective. In P. M. Leonardi, B. A. Nardi, & J. Kallinikos (Eds.), *Materiality and Organizing Social Interaction in a Technological World* (pp. 1–12). Oxford University Press. http://doi.org/10.1093/acprof:oso/9780199664054.001.0001
Farr, W., Price, S., & Jewitt, C. (2012). *An introduction to embodiment and digital technology research: interdisciplinary themes and perspectives* (pp. 1–18). National Centre for Research Methods.
Favotto, L., Michaelson, V., & Davison, C. (2017). Perceptions of the influence of computer-mediated communication on the health and well-being of early adolescents. *International Journal of Qualitative Studies on Health and Well-Being*, *12*(1), 1–12. http://doi.org/10.1080/17482631.2017.1335575

Feigenson, L., Dehaene, S., & Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences*, *8*(7), 307–314. http://doi.org/10.1016/j.tics.2004.05.002
Ferguson, C. J. (2009). An Effect Size Primer: A Guide for Clinicians and Researchers. *Professional Psychology: Research and Practice*, *40*(5), 532–538. http://doi.org/10.1037/a0015808
Fernaeus, Y., Tholander, J., & Jonsson, M. (2008). Towards a new set of ideals - consequences of the practice turn in tangible interaction. *Proceeding of the 6th International Conference on Tangible, Embedded and Embodied Interaction*, 223–280.
Fetters, M. D., Curry, L. A., & Creswell, J. W. (2013). Achieving Integration in Mixed Methods Designs-Principles and Practices. *Health Services Research*, *48*(6pt2), 2134–2156. http://doi.org/10.1111/1475-6773.12117
Field, A. (2013). Discovering Statistics Using IBM SPSS Statistics (4 ed.). SAGE.
Findlay, J. M., & Gilchrist, L. D. (1998). Eye Guidance and Visual Search. In G. Underwood (Ed.), *Eye Guidance and Visual Information Processing* (pp. 295–312). Elsevier. http://doi.org/10.1016/b978-008043361-5/50002-x
Finkel, E. J., Eastwick, P. W., & Matthews, J. (2007). Speed-dating as an invaluable tool for studying romantic attraction: A methodological primer. *Personal Relationships*, *14*(1), 149–166. http://doi.org/10.1111/j.1475-6811.2006.00146.x
Finkel, E. J., Eastwick, P. W., Karney, B. R., Reis, H. T., & Sprecher, S. (2012). Online Dating: A Critical Analysis from the Perspective of Psychological Science. *Psychological Science in the Public Interest*, *13*(1), 3–66. http://doi.org/10.1177/1529100612436522
Finkel, E. J., Norton, M. I., Reis, H. T., Ariely, D., Caprariello, P. A., Eastwick, P. W., et al. (2015). When Does Familiarity Promote Versus Undermine Interpersonal Attraction? A Proposed Integrative Model from Erstwhile Adversaries. *Perspectives on Psychological Science*, *10*(1), 3–19. http://doi.org/10.1177/1745691614561682
Fischer, S., Itoh, M., & Inagaki, T. (2015). Screening Prototype Features in Terms of Intuitive Use - Design Considerations and Proof of Concept. *Interacting with Computers*. http://doi.org/10.1112/iwcomp/iwv002
Fishkin, K. (2004). A taxonomy for and analysis of tangible interfaces. *Personal and Ubiquitous Computing*, *8*(5), 1–12. http://doi.org/10.1007/s00779-004-0297-4
Fistikci, N., Saatcioglu, O., Keyvan, A., & Topcuoglu, V. (2015). Attentional Bias and Training in Social Anxiety Disorder. *Noro Psikiyatri Arsivi*, *52*(1), 4–7. http://doi.org/10.5152/npa.2015.8777
Fitzmaurice, G. W., Ishii, H., & Buxton, W. A. S. (1995). Bricks: laying the foundations for graspable user interfaces. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 442–449. http://doi.org/10.1145/223904.223964
Flach, S., Margulies, D., & Soffner, J. (2010). Introduction. In *Habitus in Habitat I-Emotion and Motion* (pp. 7–22). Bern, Germany.
Floden, R. E. (2009). Empirical research without certainty. *Educational Theory*, *59*(4), 485–498. http://doi.org/10.1111/j.1741-5446.2009.00332.x
Foa, E. B., & Kozak, M. J. (1986). Emotional processing of fear: Exposure to corrective information. *Psychological Bulletin*, *99*(1), 20–35. http://doi.org/10.1037/0033-2909.99.1.20
Fredrickson, B. L. (2001). The role of positive emotions in positive psychology. *American Psychologist*, *56*(3), 218–226.
Frith, C. D. (2008). Social cognition. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1499), 2033–2039. http://doi.org/10.1098/rstb.2008.0005

Frith, C. D. (2012). The role of metacognition in human social interactions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1599), 2213–2223. http://doi.org/10.1098/rstb.2012.0123

Fulkerson, M. (2014). The First Sense: A Philosophical Study of Human Touch (pp. ix–219). Cambridge, MA: The MIT Press.

García-Herranz, M., Olivera, F., Haya, P., & Alaman, X. (2012). Harnessing the Interaction Continuum for Subtle Assisted Living. *Sensors*, *12*(12), 9829–9846. http://doi.org/10.3390/s120709829

Gaver, W. W., Beaver, J., & Benford, S. (2003). Ambiguity as a Resource for Design. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 233–240.

Geller, S. M., & Greenberg, L. S. (2012). Therapeutic presence: A mindful approach to effective therapy. Washington DC, USA: American Psychological Association. http://doi.org/10.1037/13485-000

Gemperle, F., Hirsch, T., Goode, A., Pearce, J., Siewiorek, D., & Smailigic, A. (2003). *Wearable Vibro-tactile Display* (pp. 1–32). Wearable Group, Carnegie Mellon University.

Gerhards, S. A. H., Abma, T. A., Arntz, A., de Graaf, L. E., Evers, S. M. A. A., Huibers, M. J. H., & Widdershoven, G. A. M. (2011). Improving adherence and effectiveness of computerised cognitive behavioural therapy without support for depression: A qualitative study on patient experiences. *Journal of Affective Disorders*, *129*(1-3), 117–125. http://doi.org/10.1016/j.jad.2010.09.012

Ghosh, S., Shruthi, C. S., Bansal, H., & Sethia, A. (2017). What is User's Perception of Naturalness? An Exploration of Natural User Experience. In A. Marcus (Ed.), *Design, User Experience, and Usability. Theory, Methods, Tools and Practice* (Vol. 10514, pp. 224–242). Cham: Springer International Publishing. http://doi.org/10.1007/978-3-319-67684-5_14

Giannopoulos, E., Eslava, V., Oyarzabal, M., Hierro, T., González, L., Ferre, M., & Slater, M. (2008). The Effect of Haptic Feedback on Basic Social Interaction within Shared Virtual Environments. In *Haptics: Perception, Devices and Scenarios* (Vol. 5024, pp. 301–307). Berlin, Heidelberg: Springer, Berlin, Heidelberg. http://doi.org/10.1007/978-3-540-69057-3_36

Gibson, J. J. (2015). The Ecological Approach to Visual Perception. Psychology Press.

Gil, M., Giner, P., & Pelechano, V. (2011). Personalization for unobtrusive service interaction. *Personal and Ubiquitous Computing*, *16*(5), 543–561. http://doi.org/10.1007/s00779-011-0414-0

Gillespie, R. B., & O'Modhrain, M. S. (2011). Embodied cognition as a motivating perspective for haptic interaction design - A position paper. *World Haptics*, 481–486. http://doi.org/10.1109/WHC.2011.5945533&orderBeanReset=true&startPage=481&endPage=486&proceedingName=World+Haptics+Conference+%28WHC%29%2C+2011+IEEE","displayPublicationTitle“:”World

Giner-Sorolla, R. (2012). Science or Art? How Aesthetic Standards Grease the Way Through the Publication Bottleneck but Undermine Science. *Perspectives on Psychological Science*, *7*(6), 562–571. http://doi.org/10.1177/1745691612457576

Gkika, S., Wittkowski, A., & Wells, A. (2017). Social cognition and metacognition in social anxiety: A systematic review. *Clinical Psychology & Psychotherapy*, *25*(1), 10–30. http://doi.org/10.1002/cpp.2127

Goffman, E. (1967). Interaction Ritual: Essay on Face-to-Face Behaviour. New York, USA: Pantheon Books.

Gonzales, A. L., & Hancock, J. T. (2011). Mirror, Mirror on my Facebook Wall: Effects of Exposure to Facebook on Self-Esteem. *Cyberpsychology, Behavior, and Social Networking*, *14*(1-2), 79–83. http://doi.org/10.1089/cyber.2009.0411

Goodman, F. R., Doorley, J. D., & Kashdan, T. B. (2018). Well-being and psychopathology: A deep exploration into positive emotions, meaning and purpose in life, and social relationships. In E. Diener, S. Oishi, & L. Tay (Eds.), *Handbook of well-being*. Salt Lake City, UT: nobascholar.com.

Grandhi, S. A., Joue, G., & Mittelberg, I. (2011). Understanding naturalness and intuitiveness in gesture production: insights for touchless gestural interfaces. *Proceeding of the 11th SIGCHI Conference on Human Factors in Computing Systems*, 821–824. http://doi.org/10.1145/1978942.1979061

Gravetter, F. J., & Wallnau, L. B. (2014). Statistics for the Behavioral Sciences (9 ed.). Belmont, CA, USA: Cengage Learning.

Greenberg, S., Marquardt, N., Ballendat, T., Diaz-Marino, R., & Wang, M. (2011). Proxemic interactions - the new ubicomp? *Interactions*, 42–50.

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a Conceptual Framework for Mixed-Method Evaluation Designs. *Educational Evaluation and Policy Analysis*, *11*(3), 255–274. http://doi.org/10.3102/01623737011003255

Greenfield, A. (2006). Everyware: the dawning age of ubiquitous computing. New Riders.

Gregory, B., & Peters, L. (2017). Changes in the self during cognitive behavioural therapy for social anxiety disorder: A systematic review. *Clinical Psychology Review*, *52*(C), 1–18. http://doi.org/10.1016/j.cpr.2016.11.008

Grudin, J. (1990). Interface. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*, 269–278.

Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Leibenluft, E., et al. (2010). Attention Bias Modification Treatment: A Meta-Analysis toward the Establishment of Novel Treatment for Anxiety. *Biological Psychiatry*, *68*(11), 982–990. http://doi.org/10.1016/j.biopsych.2010.07.021

Hall, E. T. (1990). The Hidden Dimension (pp. 1–126). Random House, Inc.

Hallnäs, L., & Redström, J. (2001). Slow Technology–Designing for Reflection. *Personal and Ubiquitous Computing*, 201–212.

Hambrick, J. P., Weeks, J. W., Harb, G. C., & Heimberg, R. G. (2003). Cognitive-Behavioral Therapy for Social Anxiety Disorder: Supporting Evidence and Future Directions. *CNS Spectrums*, *8*(5), 373–381. http://doi.org/10.1017/S1092852900018630

Hansson, R., & Ljungstrand, P. (2000). The reminder bracelet: subtle notification cues for mobile devices. *Extended Abstracts on 2000 Human Factors in Computing Systems*, 323–324.

Hartson, R. (2003). Cognitive, physical, sensory, and functional affordances in interaction design. *Behaviour and Information Technology*, *22*(5), 315–338. http://doi.org/10.1080/01449290310001592587

Harwood, J., Dooley, J. J., Scott, A. J., & Joiner, R. (2014). Constantly connected – The effects of smart-devices on mental health. *Computers in Human Behavior*, *34*(C), 267–272. http://doi.org/10.1016/j.chb.2014.02.006

Haug, T. T., Hellstrøm, K., Blomhoff, S., Humble, M., Madsbu, H. P., & Wold, J. E. (2000). The treatment of social phobia in general practice. Is exposure therapy feasible? *Family Practice*, *17*(2), 114–118.

Hausen, D. (2012). Reducing Cognitive Load by Using the Periphery of our Attention (pp. 1–4). Presented at the Workshop Designing for Cognitive Limitations. In

Conjunction with DIS. Retrieved from https://www.medien.ifi.lmu.de/pubdb/publications/pub/hausen2012dis_ws/hausen2012dis_ws.pdf
Hausen, D., Boring, S., & Greenberg, S. (2013). The Unadorned Desk - Exploiting the Physical Space around a Display as an Input Canvas. *Interact*, *8117*(Chapter 10), 140–158.
Hausen, D., Boring, S., Lueling, C., Rodestock, S., & Butz, A. (2012). StaTube: facilitating state management in instant messaging systems. *Proceeding of the 6th International Conference on Tangible, Embedded and Embodied Interaction*, 283–290.
Hausen, D., Tabard, A., Thermann, von, A., Holzner, K., & Butz, A. (2014). Evaluating peripheral interaction. Presented at the International Conference on Tangible, Embedded and Embodied Interaction. http://doi.org/10.1145/2540930.2540941
Healey, C. G., & Enns, J. T. (2012). Attention and Visual Memory in Visualization and Computer Graphics, *18*(7), 1170–1188. http://doi.org/10.1109/TVCG.2011.127
Heeren, A., Reese, H. E., McNally, R. J., & Philippot, P. (2012). Attention training toward and away from threat in social phobia: Effects on subjective, behavioral, and physiological measures of anxiety. *Behaviour Research and Therapy*, *50*(1), 30–39. http://doi.org/10.1016/j.brat.2011.10.005
Hegarty, M., & Stull, A. T. (2012). Visuospatial Thinking. In K. J. Holyoak & R. G. Morrison (Eds.), *The Oxford Handbook of Thinking and Reasoning* (pp. 606–630). Oxford University Press.
Heidegger, M. (2001). Being and Time. (J. Macquarrie & E. Robinson, Trans.). Oxford, UK: Blackwell.
Heimberg, R. G. (2002). Cognitive-behavioral therapy for social anxiety disorder: current status and future directions. *Biological Psychiatry*, *51*(1), 101–108.
Heiser, N. A., Turner, S. M., & Beidel, D. C. (2003). Shyness: relationship to social phobia and other psychiatric disorders. *Behaviour Research and Therapy*, *41*(2), 209–221. http://doi.org/10.1016/S0005-7967 (02)00003-7
Heiser, N. A., Turner, S. M., Beidel, D. C., & Roberson-Nay, R. (2009). Differentiating social phobia from shyness. *Journal of Anxiety Disorders*, *23*(4), 469–476. http://doi.org/10.1016/j.janxdis.2008.10.002
Henderson, L., & Zimbardo, P. (1998). Shyness. In R. Schwarzer, R. C. Silver, D. Spiegel, N. E. Adler, R. D. Parke, C. Peterson, & H. Friedman (Eds.), *Encyclopedia of Mental Health* (pp. 1–15). San Diego, CA.
Henderson, L., & Zimbardo, P. (2009). Shyness, social anxiety, and social phobia. In S. G. Hofmann & P. M. DiBartolo (Eds.), *Social anxiety Clinical, developmental, and social perspectives* (2nd ed.). Taramani, Chennai, India: Social Anxiety.
Henderson, L., Gilbert, P., & Zimbardo, P. (2014). Shyness, Social Anxiety, and Social Phobia. In S. G. Hofmann & P. M. DiBartolo (Eds.), *Social Anxiety* (3rd ed., pp. 95–115). Elsevier Inc. http://doi.org/ 10.1016/B978-0-12-394427-6.00004-2
Herbert, J. D., Hope, D. A., & Bellack, A. S. (1992). Validity of the distinction between generalized social phobia and avoidant personality disorder. *Journal of Abnormal Psychology*, *101*(2), 332–339.
Hinton, A. (2014). Understanding Context: Environment, Language, and Information Architecture. O'Reilly Media.
Hofmann, S. G. (2007). Cognitive factors that maintain social anxiety disorder: a comprehensive model and its treatment implications. *Cognitive Behaviour Therapy*, *36*(4), 1651–2316.
Hoggan, E. (2013). Haptic Interfaces. In S. Price, C. Jewitt, & B. Brown (Eds.), *The SAGE Handbook of Digital Technology Research* (pp. 342–358).

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction (TOCHI) – Special Issue on the Theory and Practice of Embodied Interaction in HCI and Interaction Design*, *7*(2), 174–196. http://doi.org/10.1145/353485.353487

Hollander, M., Wolfe, D. A., & Chicken, E. (2014). Nonparametric Statistical Methods (3rd ed.). Wiley.

Horgan, R. (1996). A Socioanalytic Perspective on the Five-Factor Model. In J. S. Wiggins (Ed.), *The Five-Factor Model of Personality* (pp. 161–179). London.

Hornecker, E. (2005). A design theme for tangible interaction: embodied facilitation. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*, 23–43.

Hornecker, E. (2012). Beyond affordance - tangibles' hybrid nature. *Proceeding of the 6th International Conference on Tangible, Embedded and Embodied Interaction*, 175–182. http://doi.org/10.1145/2148131.2148168

Hornecker, E., & Buur, J. (2006). Getting a grip on tangible interaction: a framework on physical space and social interaction. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*, 437–446.

Hou, L., Lai, J., & Liu, L. (2016). Secret Handshakes with Dynamic Expressive Matching Policy. In A. Marcus (Ed.), *Design, User Experience, and Usability. Theory, Methods, Tools and Practice* (Vol. 9722, pp. 461–476). Cham: Springer International Publishing. http://doi.org/10.1007/978-3-319-40253-6_28

Houde, S., & Hill, C. (1997). What do Prototypes Prototype? In M. G. Helander, T. K. Landauer, & P. V. Prabhu (Eds.), *Handbook of Human-Computer Interaction* (2nd ed., pp. 367–381). Elsevier. http://doi.org/10.1016/b978-044481862-1.50082-0

Howell, N., Devendorf, L., Tian, R. K., Galvez, T. V., Gong, N.-W., Poupyrev, I., et al. (2016). Biosignals as Social Cues: Ambiguity and Emotional Interpretation in Social Displays of Skin Conductance. *Proceeding of DIS'2016*, 1–6. http://doi.org/10.1145/2901790.2901850

Huber, D. E., & Healey, C. G. (2005). Visualizing data with motion (pp. 527–534). Presented at the VIS 05. IEEE Visualization, 2005, IEEE. http://doi.org/10.1109/VISUAL.2005.1532838

Hulme, N., Hirsch, C., & Stopa, L. (2012). Images of the self and self-esteem: do positive self-images improve self-esteem in social anxiety? *Cognitive Behaviour Therapy*, *41*(2), 163–173. http://doi.org/10.1080/16506073.2012.664557

Humphreys, G. W., Yoon, E. Y., Kumar, S., Lestou, V., Kitadono, K., Roberts, K. L., & Riddoch, M. J. (2010). The interaction of attention and action: from seeing action to acting on perception. *British Journal of Psychology (London, England: 1953)*, *101*(Pt 2), 185–206. http://doi.org/10.1348/000712609X458927

Hurtienne, Jörn, & Blessing, L. (2007a). Metaphors as tools for intuitive interaction with technology. Metaphorik. De.

Hurtienne, Jörn, Weber, K., & Blessing, L. (2008a). Prior Experience and Intuitive Use: Image Schemas in User Centred Design. In *Designing Inclusive Futures* (pp. 107–116). London: Springer, London. http://doi.org/10.1007/978-1-84800-211-1_11

Hurtienne, Jörn. (2009a). Cognition in HCI: An Ongoing Story. *Human Technology: an Interdisciplinary Journal on Humans in ICT Environments*, *5*(1), 12–28. http://doi.org/10.17011/ht/urn.20094141408

Hurtienne, Jörn. (2009b, July 18). *Image Schemas and Design for Intuitive Use*. Techniscie Universitat, Berlin.

Hurtienne, Jörn, & Blessing, L. (2007b). Design for Intuitive Use – Testing Image Schema Theory for User Interface Design (pp. 1–12). Presented at the International Conference on Engineering Design.

Hurtienne, Jörn, Israel, J. H., & Weber, K. (2008b). Cooking up real world business applications combining physicality, digitality, and image schemas. *Proceeding of the 6th International Conference on Tangible, Embedded and Embodied Interaction*, 239–246.

Hurtienne, Jörn, Klockner, K., Diefenbach, S., Nass, C., & Maier, A. (2015). Designing with Image Schemas: Resolving the Tension between Innovation, Inclusion and Intuitive Use. *Interacting with Computers*, *27*(3), 235–255. http://doi.org/10.1112/iwcomp/iwu049

Hurtienne, Jörn, Langdon, P., & Clarkson, P. J. (2009). Towards an Account of Sensorimotor Knowledge in Inclusive Product Design (Vol. 5614, pp. 251–260). Presented at the UAHCI '09 The 5th International Conference on Universal Access in Human-Computer Interaction. Addressing Diversity. Part I: Held as Part of HCI International, Berlin, Heidelberg: Springer Berlin Heidelberg. http://doi.org/10.1007/978-3-642-02707-9_28

Hutchby, I. (2001). Technologies, Texts and Affordances. *Sociology*, *35*(2), 441–456.

Hutchins, E. (1996). Cognition in the Wild (pp. 1–395). Bradford Book.

Hutchins, E. (2010). Cognitive Ecology. *Topics in Cognitive Science*, *2*(4), 705–715. http://doi.org/10.1111/j.1756-8765.2010.01089.x

Hutchins, E., Hollan, J. D., & Norman, D. A. (1985). Direct Manipulation Interfaces. *Human–Computer Interaction*, *1*(4), 311–338. http://doi.org/10.1207/s15327051hci0104_2

Imel, Z. E., Caperton, D. D., Tanana, M., & Atkins, D. C. (2017). Technology-enhanced human interaction in psychotherapy. *Journal of Counseling Psychology*, *64*(4), 385–393. http://doi.org/10.1037/cou0000213

Ishii, H., & Ullmer, B. (1997). Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. *CHI '97 Proceeding of the ACM SIGCHI Conference on Human Factors in Computing Systems*, 1–8.

Jacob, R. J. K., Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey, E. T., & Zigelbaum, J. (2007). Reality-based interaction: unifying the new generation of interaction styles. *CHI Extended Abstracts*, 2465–2470.

Jacob, R. J. K., Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey, E. T., & Zigelbaum, J. (2008). Reality-based interaction: a framework for post-WIMP interfaces (pp. 201–210). New York, USA: ACM. http://doi.org/10.1145/1357054.1357089

Jain, S., & Das, S. R. (2006). Collision avoidance in a dense RFID network (pp. 49–56). Presented at the WiNTECH'06, New York, New York, USA: ACM. http://doi.org/10.1145/1160987.1160997

Jarusriboonchai, P., Olsson, T., Prabhu, V., & Väänänen-Vainio-Mattila, K. (2015). CueSense: a Wearable Proximity-Aware Display Enhancing Encounters. *Proceeding of the 33rd Annual ACM Conference (Extended Abstract)*, 2127–2132. http://doi.org/10.1145/2702613.2732833

Jimenez-Molina, A., & KO, I.-Y. (2015). Cognitive resource-aware unobtrusive service provisioning in ambient intelligence environments. *Journal of Ambient Intelligence and Smart Environments*, *7*(1), 37–57. http://doi.org/10.3233/AIS-140299

Johnson, M. (1987). The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason (pp. 1–268). London, UK: The University of Chicago Press.

Jones, W., Spool, J., Grudin, J., Bellotti, V., & Czerwinski, M. (2007). “Get real!” (pp. 1913–5). Presented at the CHI '07 extended abstracts, New York, New York, USA: ACM Press. http://doi.org/10.1145/1240866.1240922

Ju, W. (2015). The Design of Implicit Interactions. In J. Zimmerman, J. Forlizzi, & S. Evanson (Eds.), *Design Issues, Special issue on Design Research for Interaction Design* (p. 93). Morgan & Claypool Publishers.

Ju, W., & Leifer, L. (2008). The design of implicit interactions: Making interactive systems less obnoxious. *Design Issues*, *24*(3), 72–84. http://doi.org/10.1162/desi.2008.24.3.72

Judah, M. R., Grant, D., Lechner, W. V., & Mills, A. C. (2013). Working memory load moderates late attentional bias in social anxiety. *Cognition & Emotion*, *27*(3). http://doi.org/10.1080/02699931.2012.719490

Juola, J. F. (2016). Theories of focal and peripheral attention. In S. Bakker, D. Hausen, & T. Selker (Eds.), *Peripheral Interaction Challenges and Opportunities for HCI in the Periphery of Attention* (pp. 39–64).

Kalanithi, J. J., & Bove, V. M., Jr. (2008). Connectibles: Tangible Social Networks. *Proceeding of the 6th International Conference on Tangible, Embedded and Embodied Interaction*, 199.

Kampmann, I. L., Emmelkamp, P. M. G., Hartanto, D., Brinkman, W.-P., Zijlstra, B. J. H., & Morina, N. (2016). Exposure to virtual social interactions in the treatment of social anxiety disorder: A randomized controlled trial. *Behaviour Research and Therapy*, *77*, 147–156. http://doi.org/10.1016/j.brat.2015.12.016

Kaptelinin, V. (2014). Affordances and Design (pp. 1–116). The Interaction Design Foundation.

Kaptelinin, V., & Nardi, B. (2012). Affordances in HCI: toward a mediated action perspective. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 967–976. http://doi.org/10.1145/2207676.2208541

Kaufmann, L., & Clément, F. (2007). How Culture Comes to Mind: from Social Affordances to Cultural Analogies. *Intellectica*, *2*(46).

Kay, M., Haroz, S., Guha, S., & Dragicevic, P. (2016). Special Interest Group on Transparent Statistics in HCI. *CHI Extended Abstracts*.

Kaye, J. J., Boehner, K., Laaksolahti, J., & Ståhl, A. (2007). Evaluating experience-focused HCI (pp. 2117–2120). New York, New York, USA: ACM. http://doi.org/10.1145/1240866.1240962

Kernis, M. H. (2005). Measuring Self-Esteem in Context: The Importance of Stability of Self-Esteem in Psychological Functioning. *Journal of Personality*, *73*(6), 1569–1605. http://doi.org/10.1111/j.1467-6494.2005.00359.x

Kettley, S. (2007). Crafts praxis for critical wearables design. *Ai & Society*, *22*(1), 5–14. http://doi.org/10.1007/s00146-006-0075-0

Kettley, S. (2005, January 27). Framing the Ambiguous Wearable.

Khaorapapong, N., & Purver, M. (2012a). An Assistive Device for Shy Users in Face-to-Face Communication (pp. 1–3). Presented at the Doctoral Consortium at 16th Annual International Symposium on Wearable Computers.

Khaorapapong, N., & Purver, M. (2012b). Designing Unobtrusive Interfaces to Increase Naturalness of First Time Face-To-Face Interaction. *Presented at 16th Annual International Symposium on Wearable Computers*.

Khaorapapong, N., & Purver, M. (2012c). Icebreaker T-shirt: a Wearable Device for Easing Face-to-Face Interaction (pp. 1–1). Presented at the Demo session of 16th Annual International Symposium on Wearable Computers.

Khaorapapong, N., Purver, M., & Cox, D. (2013). Augmenting Real-world Social Networking with Vibrotactile Display. *Proceeding of the 7th International Conference on Tangible, Embedded and Embodied Interaction*, 1–8.
Kinderman, P., Allsopp, K., & Cooke, A. (2017). Responses to the Publication of the American Psychiatric Association's DSM-5. *Journal of Humanistic Psychology*, *57*(6), 625–649. http://doi.org/10.1177/0022167817698262
Kirsh, D. (2010). Thinking with external representations. *Ai & Society*, *25*(4), 441–454. http://doi.org/10.1007/s00146-010-0272-8
Kirsh, D. (2013). Embodied cognition and the magical future of interaction design. *ACM Transactions on Computer-Human Interaction (TOCHI) – Special Issue on the Theory and Practice of Embodied Interaction in HCI and Interaction Design*, *20*(1), 1–30. http://doi.org/10.1145/2442106.2442109
Kirsh, D., & Maglio, P. P. (1994). On Distinguishing Epistemic from Pragmatic Action. *Cognitive Science*, *18*(4), 513–549.
Kley, H., Tuschen-Caffier, B., & Heinrichs, N. (2012). Safety behaviors, self-focused attention and negative thinking in children with social anxiety disorder, socially anxious and non-anxious children. *Journal of Behavior Therapy and Experimental Psychiatry*, *43*(1), 548–555. http://doi.org/10.1016/j.jbtep.2011.07.008
Klumpp, H., & Amir, N. (2010). Preliminary Study of Attention Training to Threat and Neutral Faces on Anxious Reactivity to a Social Stressor in Social Anxiety. *Cognitive Therapy and Research*, *34*(3), 263–271. http://doi.org/10.1007/s10608-009-9251-0
Knorr-Cetina, K. (1996). Epistemics in society. In W. Heijman, H. Hetsen, & J. Frouws (Eds.), *Rural Reconstruction in a Market Economy* (pp. 55–73).
Knorr-Cetina, K. (1997). Sociality with Objects: Social Relationships in Postsocial Societies. *Theory, Culture and Society*, *14*(4), 1–43.
Knorr-Cetina, K. (2005). Objectual practice. In T. R. Schatzki, K. Knorr-Cetina, & E. von Savigny (Eds.), *The Practice Turn in Contemporary Theory* (pp. 184–197). London.
Knudsen, L., Morrison, A., & Andersen, H. J. (2011). *Design of vibrotactile navigation displays for elderly with memory disorders* (pp. 1–6). Media Technology, Department of Architecture, Design and Media Technology, Aalborg University.
Koch, C., & Tsuchiya, N. (2007). Attention and consciousness: two distinct brain processes. *Trends in Cognitive Sciences*, *11*(1), 16–22. http://doi.org/10.1016/j.tics.2006.10.012
Koffka, K. (1936). Principle of Gestalt Psychology. New York, USA: Harcourt, Brace and Company.
Koleva, B., Benford, S., Ng, K. H., & Rodden, T. (2003). A framework for tangible user interfaces. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication).*
Korzenny, F. (1978). A Theory of Electronic Propinquity. Communication Research, 5(1), 3–24. http://doi.org/10.1177/009365027800500101
Kovecses, Z. (2005). Metaphor in Culture: Universality and Variation (pp. 1–334). Cambridge, UK: Cambridge University Press.
Koyuncu, A., Çelebi, F., Ertekin, E., Kök, B. E., & Tükel, R. (2016). Attention deficit and hyperactivity in social anxiety disorder: relationship with trauma history and impulsivity. *ADHD Attention Deficit and Hyperactivity Disorders*, *8*(2), 95–100. http://doi.org/10.1007/s12402-016-0189-2
Krijn, M., Emmelkamp, P. M. G., Biemond, R., de Wilde de Ligny, C., Schuemie, M. J., & van der Mast, C. A. P. G. (2004). Treatment of acrophobia in virtual reality: The

role of immersion and presence. *Behaviour Research and Therapy*, *42*(2), 229–239. http://doi.org/10.1016/S0005-7967 (03)00139-6
Krishna, G. (2015). The Best Interface Is No Interface: The simple path to brilliant technology. New Riders.
Krueger, J. (2011). Extended cognition and the space of social interaction. *Consciousness and Cognition*, *20*(3), 643–657. http://doi.org/10.1016/j.concog.2010.09.022
Kytö, M., & McGookin, D. (2017a). Augmenting Multi-Party Face-to-Face Interactions Amongst Strangers with User Generated Content, 1–37. http://doi.org/10.1007/s10606-017-9281-1
Kytö, M., & McGookin, D. (2017b). Investigating user generated presentations of self in face-to-face interaction between strangers. *Journal of Human Computer Studies*, *104*, 1–15. http://doi.org/10.1016/j.ijhcs.2017.02.007
La'davas, E. (2002). Functional and dynamic properties of visual peripersonal space. *Trends in Cognitive Sciences*, *6*(1), 17–22.
Laerd Statistics. (2013). Spearman's Rank-Order Correlation - A guide to when to use it, what it does and what the assumptions are. Retrieved March 16, 2017, from https://statistics.laerd.com/statistical-guides/spearmans-rank-order-correlation-statistical-guide.php
Laerd Statistics. (2017, February 9). Wilcoxon signed-rank test in SPSS Statistics | Laerd Statistics Premium. Retrieved April 12, 2018, from https://statistics.laerd.com/premium/spss/wsrt/wilcoxon-signed-rank-test-in-spss.php
Lakoff, G., & Johnson, M. (1980). Metaphors we live by. Chicago, USA: The University of Chicago Press.
Landstorfer, J., Pschetz, L., Kloes, M., & Wettach, R. (2007). SocialButton - Mobile Technology Enhancing Social Interaction (pp. 14–18). Presented at the International Conference on Next Generation Mobile Applications, Services and Technologies, IEEE. http://doi.org/10.1109/NGMAST.2007.4343395
Lane, C. (2007). Shyness: How Normal Behavior Became a Sickness. Yale University Press.
Lane, C. (2013). How Shyness Became an Illness and Other Cautionary Tales about the the DSM. In *Krankheitskonstruktionen und Krankheitstreiberei* (Vol. 2, pp. 55–73). Berlin: Springer VS, Wiesbaden. http://doi.org/10.1007/978-3-531-18784-6_3
Larkin, J. H., & Simon, H. A. (1987). Why a Diagram is (Sometimes) Worth Ten Thousand Words. *Cognitive Science*, *11*(1), 65–100. http://doi.org/10.1111/j.1551-6708.1987.tb00863.x
Lavie, N. (2001). Capacity limits in selective attention: behavioral evidence and implications for neural activity. In J. Braun & C. Koch (Eds.), *Visual Attention and Cortical Circuits* (pp. 49–68). Cambridge, Massachusetts.
Lawrence, J., & Payne, T. (2004). Exploiting Familiar Strangers: creating a community content distribution network by co-located individuals.
Lazar, J., Feng, J. H., & Hochheiser, H. (2017). Research Methods in Human-Computer Interaction. Wiley Publishing.
Lazarov, A., Pine, D. S., & Bar-Haim, Y. (2017). Gaze-Contingent Music Reward Therapy for Social Anxiety Disorder: A Randomized Controlled Trial. *The American Journal of Psychiatry*, *174*(7), 649–656. http://doi.org/10.1176/appi.ajp.2016.16080894
Leary, M. R., & Kowalski, R. (1997). Social Anxiety. New York, USA: Gilford Press.
Lee, S. C., & Starner, T. (2009). Mobile gesture interaction using wearable tactile displays. *CHI Extended Abstracts*, 3437. http://doi.org/10.1145/1520340.1520499

Lee, S. C., & Starner, T. (2010). BuzzWear: alert perception in wearable tactile displays on the wrist. *CHI '10 Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 433. http://doi.org/10.1145/1753326.1753392

Lee, S., & Smith, C. A. M. (2012). Criteria for Quantitative and Qualitative Data Integration. *CIN: Computers, Informatics, Nursing*, *30*(5), 251–256. http://doi.org/10.1097/NXN.0b013e31824b1f96

Lehrig, T., Krancher, O., & Dibbern, J. (2017). How Users Perceive and Actualize Affordances - An Exploratory Case Study of Collaboration Platforms. *The 38th International Conference on Information Systems*.

Lewin, K. (1936). Principles of Topological Psychology. (F. Heider & G. M. Heider, Trans.) (pp. 1–251). London, UK: McGraw_hill Book Company.

Lewis, C., Polson, P. G., Wharton, C., & Rieman, J. (1990). Testing a walkthrough methodology for theory-based design of walk-up-and-use interfaces (pp. 235–242). Presented at the the SIGCHI conference, New York, USA: ACM.

Li, R., Lu, B., & McDonald-Maier, K. D. (2015). Cognitive assisted living ambient system: a survey. *Digital Communications and Networks*, *1*(4), 229–252. http://doi.org/10.1016/j.dcan.2015.10.003

Li, S., Tan, J., Qian, M., & Liu, X. (2008). Continual training of attentional bias in social anxiety. *Behaviour Research and Therapy*, *46*(8), 905–912. http://doi.org/10.1016/j.brat.2008.04.005

Li, S.-S., Chang, Y. Y.-C., & Chiou, W.-B. (2017). Things online social networking can take away: Reminders of social networking sites undermine the desirability of offline socializing and pleasures. *Scandinavian Journal of Psychology*, *58*(2), 179–184. http://doi.org/10.1111/sjop.12348

Lim, Y. (2012). Disappearing interfaces. *Interactions*, *19*(5), 36. http://doi.org/10.1145/2334184.2334194

Lim, Y.-K., Stolterman, E., & Tenenberg, J. (2008). The anatomy of prototypes. *ACM Transactions on Computer-Human Interaction (TOCHI) – Special Issue on the Theory and Practice of Embodied Interaction in HCI and Interaction Design*, *15*(2), 1–27. http://doi.org/10.1145/1375761.1375762

Lois, J. (2003). Heroic Efforts. In *Heroic Efforts: the Emotional Culture of Search and Rescue Volunteers* (pp. 172–196). New York and London.

Lu, X., Watanabe, J., Liu, Q., Uji, M., Shono, M., & Kitamura, T. (2011). Internet and mobile phone text-messaging dependency: Factor structure and correlation with dysphoric mood among Japanese adults. *Computers in Human Behavior*, *27*(5), 1702–1709. http://doi.org/10.1016/j.chb.2011.02.009

Macaranas, A., Antle, A. N., & Riecke, B. E. (2012). Three Strategies for Designing Intuitive Natural User Interfaces. *Proceeding of the Designing Interactive Systems Conference*, 1–2.

Macaranas, A., Antle, A. N., & Riecke, B. E. (2015). What is Intuitive Interaction? Balancing Users' Performance and Satisfaction with Natural User Interfaces. *Interacting with Computers*, *27*(3), 357–370. http://doi.org/10.1093/iwc/iwv003

MacLeod, C., & Rutherford, E. (2004). Information-processing approaches: Assessing the selective functioning of attention, interpretation, and retrieval. In R. G. Heimberg, C. L. Turk, & D. S. Mennin (Eds.), *Generalized anxiety disorder Advances in research and practice* (pp. 109–142). New York.

Mahns, D. A., Perkins, N. M., Sahai, V., Robinson, L., & Rowe, M. J. (2006). Vibrotactile Frequency Discrimination in Human Hairy Skin. *Journal of Neurophysiology*, *95*(3), 1442–1450. http://doi.org/10.1152/jn.00483.2005

Mandler, J. M., & Cánovas, C. P. (2014). On defining image schemas. *Language and Cognition*, *6*(04), 510–532. http://doi.org/10.1017/langcog.2014.14

Mangalam, M., & Fragaszy, D. M. (2016). Transforming the body-only system into the body-plus-tool system. *Animal Behaviour*, *117*, 115–122. http://doi.org/10.1016/j.anbehav.2016.04.016

Mankoff, J., & Dey, A. K. (2003). From Conception to Design: A Practical Guide to Designing Ambient Displays. In K. O'Hara, M. Perry, & E. Churchill (Eds.), *Public and Situated Displays* (pp. 210–230). Dordrecht.

Mankoff, J., Dey, A. K., Hsieh, G., Kientz, J., Lederer, S., & Ames, M. (2003). Heuristic evaluation of ambient displays. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 169–176. http://doi.org/10.1145/642611.642642

Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *The Annals of Mathematical Statistics*.

Maravita, A., & Iriki, A. (2004). Tools for the body (schema). *Trends in Cognitive Sciences*, *8*(2), 79–86. http://doi.org/10.1016/j.tics.2003.12.008

Marsh, K. L., Richardson, M. J., & Schmidt, R. C. (2009). Social Connection through Joint Action and Interpersonal Coordination. *Topics in Cognitive Science*, *1*(2), 320–339. http://doi.org/10.1111/j.1756-8765.2009.01022.x

Marshall, P., & Hornecker, E. (2013). Theories of Embodiment in HCI. In S. Price, C. Jewitt, & B. Brown (Eds.), *The SAGE Handbook of Digital Technology Research* (pp. 144–158). London, UK: SAGE Publications Ltd. http://doi.org/10.4135/9781446282229.n11

Matthews, T., Dey, A. K., Mankoff, J., Carter, S., & Rattenbury, T. (2004). A toolkit for managing user attention in peripheral displays. *The 17th Annual ACM Symposium*, 247–256. http://doi.org/10.1145/1029632.1029676

Matthews, T., Hsieh, G., & Mankoff, J. (2009). Evaluating Peripheral Displays. In P. Markopoulos, B. De Ruyter, & W. Mackay (Eds.), *Awareness Systems* (pp. 447–472). London: Springer London. http://doi.org/10.1007/978-1-84882-477-5

Matthews, T., Rattenbury, T., & Carter, S. (2003). *A peripheral display toolkit* (No. CSD-03-1258). U.C. Berkeley.

Matthews, T., Rattenbury, T., & Carter, S. (2007). Defining, designing, and evaluating peripheral displays: An analysis using activity theory. *Human–Computer Interaction*. http://doi.org/10.1080/hhci20.v022.i01-02;article:article:10.1080/07370020701307997;journal:journal:hhci20;wgroup:string:Publication

Matthies, D. J. C., Perrault, S. T., Lecolinet, E., & Zhao, S. (2014). Peripheral Microinteraction for Wearable Computing (pp. 1–4). Presented at the Workshop on Peripheral Interaction Shaping the Research and Design Space at CHI.

Mattick, R. P., & Clarke, J. C. (1998). Development and validation of measures of social phobia scrutiny fear and social interaction anxiety. *Behaviour Research and Therapy*.

Mayer, J. M., Hiltz, S. R., & Jones, Q. (2015). Making social matching context-aware: Design concepts and open challenges. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*, 545–554. http://doi.org/10.1145/2702123.2702343

Mayo-Wilson, E., Dias, S., Mavranezouli, I., Kew, K., Clark, D. M., Ades, A. E., & Pilling, S. (2014). Psychological and pharmacological interventions for social anxiety disorder in adults: a systematic review and network meta-analysis. *The Lancet Psychiatry*, *1*(5), 368–376. http://doi.org/10.1016/s2215-0366(14)70329-3

McCambridge, J., Witton, J., & Elbourne, D. R. (2014). Systematic review of the Hawthorne effect: New concepts are needed to study research participation effects. *Journal of Clinical Epidemiology*, *67*(3), 267–277. http://doi.org/10.1016/j.jclinepi.2013.08.015

McCarthy, J. F. (2002). Using Public Displays to Create Conversation Opportunities. Presented at the Workshop on Public, Community, and Situated Displays, New Orleans, LA, USA.

McCarthy, J. F., Costa, T. J., & Liongosari, E. S. (2001). UniCast, OutCast & GroupCast: An Exploration of New Interaction Paradigms for Ubiquitous, Peripheral Displays (pp. 1–5). Presented at the Symposium on Ubiquitous Computing Ubicomp.

McCrickard, D. S., Catrambone, R., Chewar, C. M., & Stasko, J. T. (2003a). Establishing tradeoffs that leverage attention for utility: empirically evaluating information display in notification systems. *International Journal of Human-Computer Studies*, *58*(5), 547–582. http://doi.org/10.1016/S1071-5819 (03)00022-3

McCrickard, D. S., Chewar, C. M., & Somervell, J. P. (2003b). A model for notification systems evaluation—assessing user goals for multitasking activity. *ACM Transactions on Computer-Human Interaction*.

McCrickard, D. S., Czerwinski, M., Human, L. B. I. J. O., & Rodden, T. (2003c). Introduction: design and evaluation of notification user interfaces. *International Journal of Human-Computer Studies*, *58*(5), 509–514.

McDonald, I. (2009). Social Object Theory: The Secret Ingredient for Powering Social Influence Marketing Campaigns. *Sydney Digital Outlook Report*, 58–62.

McDonald, J. H. (2014a). Correlation and Linear Regression. In *Handbook of Biological Statistics*. Sparky House Publishing.

McDonald, J. H. (2014b). Handbook of Biological Statistics (3rd ed., pp. 1–305). Sparky House Publishing.

McKenna, I. (2013). *Cognitive Behavioural Therapies for Social Anxiety Disorder: A Systematic Review of Current Theories and Research* (pp. 1–27).

McLeod, H. (2017, March 7). Social Objects: Everything You Ever Wanted to Know! Retrieved March 16, 2018, from https://www.gapingvoid.com/blog/2007/12/31/social-objects-for-beginners/

McNeil, D. W. (2001). Evolution of Terminology and Constructs in Social Anxiety and its Disorders. In S. G. Hofmann & P. M. DiBartolo (Eds.), *From social anxiety to social phobia Multiple perspectives* (pp. 8–19). Elsevier. http://doi.org/10.1016/b978-0-12-375096-9.00001-8

McNeil, D. W. (2010). Evolution of Terminology and Constructs in Social Anxiety and its Disorders. In S. G. Hofmann & P. M. DiBartolo (Eds.), *Social Anxiety* (2nd ed., pp. 3–21). London: Elsevier. http://doi.org/10.1016/B978-0-12-375096-9.00001-8

McNeill, W. H. (1995). Muscular Bonding. In *Keeping Together in Time: Dance and Drill in Human History* (pp. 1–12). Cambridge, MA.

McNemar, Q. (1947). Note on the sampling error of the difference between correlated proportions or percentages. *Psychometrika*.

Meidlinger, P. C., & Hope, D. A. (2014). Diversity Considerations in the Assessment and Treatment of Social Anxiety Disorder. In J. W. Weeks (Ed.), *The Wiley Blackwell Handbook of Social Anxiety Disorder* (pp. 223–246). Chichester, UK: John Wiley & Sons, Ltd.

Melchior, L. A., & Cheek, J. M. (1990). Shyness and Anxious Self-Preoccupation during a Social Interaction. *Social Behavior and Personality. Communication, Cognition, and Anxiety. [Special Issue]*, *5*(2), 117–130.

Menary, R. (2017). Introduction: The Extended Mind in Focus. In R. Menary (Ed.), *The Extended Mind (Life and Mind: Philosophical Issues in Biology and Psychology)* (pp. 1–25). The MIT Press.

Merleau-Ponty, M. (2004). The World of Perception. (O. Davis, Trans.) (pp. 1–136). London, UK: Routledge.

Merleau-Ponty, M. (2005). Phenomenology of Perception. (C. Smith, Trans.) (pp. 1–569). Routledge.
Miers, A. C., Blöte, A. W., Heyne, D. A., & Westenberg, P. M. (2014). Developmental pathways of social avoidance across adolescence: The role of social anxiety and negative cognition. *Journal of Anxiety Disorders*, *28*(8), 787–794. http://doi.org/10.1016/j.janxdis.2014.09.008
Milgram, S. (1977). The Familiar Stranger: An Aspect of Urban Anonymity. In S. Milgram (Ed.), *The individual in a social world* (pp. 51–53). Reading, MA.
Miloff, A., Marklund, A., & Carlbring, P. (2015). The challenger app for social anxiety disorder: New advances in mobile psychological treatment. *Invent*, *2*(4), 382–391. http://doi.org/10.1016/j.invent.2015.08.001
Moller, H. J., Bal, H., & Potwarka, L. R. (2014). Recreating leisure. How immersive environments can promote wellbeing. In G. Riva, J. Waterworth, & D. Murray (Eds.), *Interacting with Presence: HCI and the Sense of Presence in Computer-mediated Environments* (pp. 102–122). Warsaw/Berlin: degruyter.com. http://doi.org/10.2478/9783110409697.7
Montero-Marin, J., Garcia-Campayo, J., López-Montoyo, A., Zabaleta-Del-Olmo, E., & Cuijpers, P. (2018). Is cognitive-behavioural therapy more effective than relaxation therapy in the treatment of anxiety disorders? A meta-analysis. *Psychological Medicine*, *48*(9), 1427–1436. http://doi.org/10.1017/S0033291717003099
Moran, T. P. (1981). An Applied Psychology of the User. *ACM Computing Surveys (CSUR)*, *13*(1).
Moray, N. (2018). Attention in Dichotic Listening: Affective Cues and the Influence of Instructions. *Quarterly Journal of Experimental Psychology*, *11*(1), 56–60. http://doi.org/10.1080/17470215908416289
Morina, N., Brinkman, W.-P., Hartanto, D., & Emmelkamp, P. M. G. (2014). Sense of presence and anxiety during virtual social interactions between a human and virtual human. *PeerJ*, *2*(5), e337–9. http://doi.org/10.7717/peerj.337
Morse, J. M. (1991). Approaches to Qualitative-Quantitative Methodological Triangulation. *Nursing Research*, *40*(2), 120–123. http://doi.org/10.1097/00006199-199103000-00014
Morse, J. M., & Niehaus, L. (2009). Mixed Method Design: Principles and Procedures. Oxon, UK: Routledge.
Moscovitch, D. A. (2009). What Is the Core Fear in Social Phobia? A New Model to Facilitate Individualized Case Conceptualization and Treatment. *Cognitive and Behavioral Practice*, *16*(2), 123–134. http://doi.org/10.1016/j.cbpra.2008.04.002
Motti, V. G., & Caine, K. (2016). Smart Wearables or Dumb Wearables? *Proceeding of the 34th ACM International Conference*, 1–10. http://doi.org/10.1145/2987592.2987606
Mullaney, J. L. (1999). Making It “Count”: Mental Weighing and Identity Attribution. *Symbolic Interaction*, *22*(3), 269–283. http://doi.org/10.1525/si.1999.22.3.269
Myles, K., & Binseel, M. S. (2007). *The Tactile Modality*. Army Research Laboratory, Aberdeen Proving Ground.
Møller, T., & Kettley, S. (2017). Wearable health technology design: A humanist accessory approach. *International Journal of Design*, *11*(3), 35–49.
Najmi, S., Amir, N., Frosio, K. E., & Ayers, C. (2015). The effects of cognitive load on attention control in subclinical anxiety and generalised anxiety disorder. http://doi.org/10.1080/02699931.2014.975188
Nakagawa, S., & Cuthill, I. C. (2007). Effect size, confidence interval and statistical significance: a practical guide for biologists, *82*(4), 591–605. http://doi.org/10.1111/j.1469-185X.2007.00027.x

Nastasi, B. K., Hitchcock, J., Sarkar, S., Burkholder, G., Varjas, K., & Jayasena, A. (2007). Mixed Methods in Intervention Research: Theory to Adaptation. *Journal of Mixed Methods Research*, *1*(2), 164–182. http://doi.org/10.1177/1558689806298181

National Collaborating Centre for Mental Health UK. (2013). Social Anxiety Disorder: Recognition, Assessment and Treatment. British Psychological Society.

Naumann, A., Hurtienne, J., Israel, J. H., Mohs, C., Kindsmüller, M. C., Meyer, H. A., & Hußlein, S. (2007). Intuitive Use of User Interfaces: Defining a Vague Concept. In *Engineering Psychology and Cognitive Ergonomics* (Vol. 4562, pp. 128–136). Berlin, Heidelberg: Springer, Berlin, Heidelberg. http://doi.org/10.1007/978-3-540-73331-7_14

Nelson, E.-L., Barnard, M., & Cain, S. (2003). Treating childhood depression over videoconferencing. *Telemedicine Journal and E-Health: the Official Journal of the American Telemedicine Association*, *9*(1), 49–55. http://doi.org/10.1089/153056203763317648

Neumann, M. F., Ng, R., Rhodes, G., & Palermo, R. (2017). Ensemble coding of face identity is not independent of the coding of individual identity. *Quarterly Journal of Experimental Psychology (2006)*, 1–27. http://doi.org/10.1080/17470218.2017.1318409

Nielsen, J. (1992). Finding Usability Problems through Heuristic Evaluation. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 373–380.

Nielsen, J. (1993). Noncommand User Interfaces. *Communications of the ACM*, *36*(4), 83–99. http://doi.org/10.1145/255950.153582

Nielsen, J., & Molich, R. (1990). Heuristic evaluation of user interfaces. *Proceedings of the SIGCHI conference on Human factors in computing systems Empowering people - CHI '90* (pp. 249–256). New York, New York, USA: ACM. http://doi.org/10.1145/97243.97281

Noë, A. (2004). Action in Perception (pp. 1–291). Cambridge, MA: MIT Press.

Norman, D. A. (1968). TOWARD A THEORY OF MEMORY AND ATTENTION. *Psychological Review*, *75*(6), 1–15.

Norman, D. A. (1998). The Invisible Computer (1st ed.). Cambridge, Massachusetts: The MIT Press.

Norman, D. A. (2002). The Design of Everyday Things. New York: Basic Books.

Norman, D. A. (2010). Natural user interfaces are not natural. *Interactions*, *17*(3), 6–10.

Norton, A. R., & Abbott, M. J. (2016). Self-Focused Cognition in Social Anxiety: A Review of the Theoretical and Empirical Literature. *Behaviour Change*, *33*(01), 44–64. http://doi.org/10.1017/bec.2016.2

Novick, D. G., & Hollingsed, T. (2007). Usability inspection methods after 15 years of research and practice (pp. 249–255). Presented at the 25th annual ACM international conference, New York, USA: ACM.

O'Hara, K., Harper, R., Mentis, H., Sellen, A., & Taylor, A. (2013). On the naturalness of touchless: Putting the "interaction" back into NUI. *ACM Transactions on Computer-Human Interaction (TOCHI) – Special Issue on the Theory and Practice of Embodied Interaction in HCI and Interaction Design*, *20*(1), 1–25. http://doi.org/10.1145/2442106.2442111

O'Regan, J. K., & Noë, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences*, *24*(5), 939–1031.

Oakley, I., Kim, Y., Lee, J., & Ryu, J. (2006). Determining the Feasibility of Forearm Mounted Vibrotactile Displays (pp. 27–34). Presented at the 2006 14th Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, IEEE. http://doi.org/10.1109/haptic.2006.1627079

Olivera, F., García-Herranz, M., & Haya, P. A. (2011). Do not disturb: Physical interfaces for parallel peripheral interactions. *Ubicomp 2006*, *6947 LNCS* (PART 2), 479–486. http://doi.org/10.1007/978-3-642-23771-3_36
Olivera, F., Rivas, A., & Iturriaga, F. (2014). Using subtle interaction for non-intrusive social networks. *IEEE Latin America …*, *12*(3), 524–529. http://doi.org/10.1109/TLA.2014.6827883
Ollendick, T. H., White, S. W., Richey, J., Kim-Spoon, J., Ryan, S. M., Wieckowski, A. T., et al. (2018). Attention Bias Modification Treatment for Adolescents with Social Anxiety Disorder. *Behavior Therapy*, 1–14. http://doi.org/10.1016/j.beth.2018.04.002
Onwuegbuzie, A. J., Bustamante, R. M., & Nelson, J. A. (2009). Mixed Research as a Tool for Developing Quantitative Instruments. *Journal of Mixed Methods Research*, *4*(1), 56–78. http://doi.org/10.1177/1558689809355805
Oswald, D., Sherratt, F., & Smith, S. (2014). Handling the Hawthorne effect: The challenges surrounding a participant observer. *Review of Social Studies*, *1*(1), 53–74. http://doi.org/10.21586/ross0000004
Oulasvirta, A. (2008). Designing mobile awareness cues. *Proceeding of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services*, 43–52. http://doi.org/10.1145/1409240.1409246
Oulasvirta, A., Petit, R., Raento, M., & Tiitta, S. (2007). Interpreting and Acting on Mobile Awareness Cues. *Human–Computer Interaction*, 97–135.
Oulasvirta, A., Tamminen, S., Roto, V., & Kuorelahti, J. (2005). Interaction in 4-second bursts - the fragmented nature of attentional resources in mobile HCI. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 919–928. http://doi.org/10.1145/1054972.1055101
Oviatt, S. (2006). Human-centered design meets cognitive load theory (pp. 871–880). Presented at the 14th annual ACM international conference, New York, USA: ACM Press. http://doi.org/10.1145/1180639.1180831
Pacherie, E. (2013). How does it feel to act together? *Phenomenology and the Cognitive Sciences*, *13*(1), 25–46. http://doi.org/10.1007/s11097-013-9329-8
Parks, M. R., & Floyd, K. (1996). Making friends in Cyberspace. *Journal of Communication*, *46*(1), 80–97. http://doi.org/10.1111/j.1460-2466.1996.tb01462.x
Paulos, E., & Goodman, E. (2004). The familiar stranger: anxiety, comfort, and play in public places. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*.
Peters, L. (2000). Discriminant validity of the social phobia and anxiety inventory (SPAI), the social phobia scale (SPS) and the social interaction anxiety scale (SIAS). *Behaviour Research and Therapy*.
Peters, L., Sunderland, M., Andrews, G., Rapee, R. M., & Mattick, R. P. (2012). Development of a short form Social Interaction Anxiety (SIAS) and Social Phobia Scale (SPS) using nonparametric item response theory: the SIAS-6 and the SPS-6. *Psychological Assessment*, *24*(1), 66–76. http://doi.org/10.1037/a0024544
Pfeifer, R., & Bongard, J. (2006). How the Body Shapes the Way We Think. MIT Press.
Phillips, J. R., & Johnson, K. O. (1981). Tactile spatial resolution. III. A continuum mechanics model of skin predicting mechanoreceptor responses to bars, edges, and gratings. *Journal of Neurophysiology*, *46*(6), 1204–1225. http://doi.org/10.1152/jn.1981.46.6.1204
Pielot, M., & Oliveira, R. de. (2013). Peripheral vibro-tactile displays. *Proceeding of the 15th International Conference*, 1–10. http://doi.org/10.1145/2493190.2493197

Pierce, T. (2009). Social anxiety and technology: Face-to-face communication versus technological communication among teens. *Computers in Human Behavior*, *25*(6), 1367–1372. http://doi.org/10.1016/j.chb.2009.06.003

Pilling, S., Mayo-Wilson, E., Mavranezouli, I., Kew, K., Taylor, C., Clark, D. M., Guideline Development Group. (2013, May 22). Recognition, assessment and treatment of social anxiety disorder: summary of NICE guidance. *BMJ (Clinical Research Ed.)*. British Medical Journal Publishing Group. http://doi.org/10.1136/bmj.f2541

Pittman, M., & Reich, B. (2016). Social media and loneliness: Why an Instagram picture may be worth more than a thousand Twitter words. *Computers in Human Behavior*, *62*(C), 155–167. http://doi.org/10.1016/j.chb.2016.03.084

Plano Clark, V. L. (2005). *Cross-disciplinary analysis of the use of mixed methods in physics education research, counseling psychology, and primary care*. University of Nebraska.

Plano Clark, V. L., & Ivankova, N. V. (2016). Mixed methods research: A guide to the field. London, UK: Sage.

Pohl, H., Medrek, J., & Rohs, M. (2016). ScatterWatch: Subtle Notifications via Indirect Illumination Scattered in the Skin. *MobileHCI '16 Proceeding of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services*, 7–16. http://doi.org/10.1145/2935334.2935351

Poslad, S. (2009). Ubiquitous Computing. John Wiley & Sons.

Pousman, Z., & Stasko, J. (2006). A taxonomy of ambient information systems: four patterns of design. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*, 67–74.

Price, S., Roussos, G., Falcão, T. P., & Sheridan, J. G. (2009). *Technology and embodiment: relationships and implications for knowledge, creativity and communication* (pp. 1–22). London Knowledge Lab.

Probst, K. (2016). Peripheral Interaction in Desktop Computing: Why It’s Worth Stepping Beyond Traditional Mouse and Keyboard. In *Peripheral Interaction* (pp. 183–205). Cham: Springer, Cham. http://doi.org/10.1007/978-3-319-29523-7_9

Profita, H. P., Clawson, J., Gilliland, S., Zeagler, C., Starner, T., Budd, J., & Do, E. Y.-L. (2013). Don't mind me touching my wrist (p. 89). Presented at the 17th annual international symposium, New York, New York, USA: ACM Press. http://doi.org/10.1145/2493988.2494331

Puttaswamy, K. P. N., & Ben Y Zhao. (2010). Preserving privacy in location-based mobile social applications. *Proceeding of the 11th Workshop on Mobile Computing Systems & Applications*, 1.

Rabby, M. K., through, J. W. M. R., & Rodden, T. (2002). Computer-mediated communication effects on relationship formation and maintenance. In D. J. Canary & M. Dainton (Eds.), (pp. 141–162). London, UK: Psychology Press.

Ramakrishnan, K. M., & Deavours, D. D. (2006). Performance benchmarks for passive UHF RFID tags. Presented at the Proceeding of 13th Conference on Measuring, Modelling and Evaluation of Computer and Communication Systems.

Rapee, R. M., & Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behaviour Research and Therapy*, 741–756.

Raskin, J. (1994, September). Intuitive equals familiar. *Viewpoint*, *37*(9), 17–18.

Reis, H. T., Maniaci, M. R., Caprariello, P. A., Eastwick, P. W., & Finkel, E. J. (2011). Familiarity does indeed promote attraction in live interaction. *Journal of Personality and Social Psychology, 101*(3), 557–570. http://doi.org/10.1037/a0022885

Richardson, M. J., Marsh, K. L., & Baron, R. M. (2007). Judging and actualizing intrapersonal and interpersonal affordances. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(4), 845–859. http://doi.org/10.1037/0096-1523.33.4.845

Riek, L. D. (2016). Robotics Technology in Mental Health Care. *Artificial Intelligence in Behavioral and Mental Health Care* (pp. 185–203). Elsevier. http://doi.org/10.1016/b978-0-12-420248-1.00008-8

Riener, A., & Ferscha, A. (2008). Raising Awareness about Space via Vibro-Tactile Notifications. *EuroSSC*, *5279*(2), 235–245. http://doi.org/10.1007/978-3-540-88793-5_18

Riva, G., & Mantovani, F. (2014). Extending the Self through the Tools and the Others: a General Framework for Presence and Social Presence in Mediated Interactions. In G. Riva, J. Waterworth, & D. Murray (Eds.), *Interacting with Presence: HCI and the Sense of Presence in Computer-mediated Environments*. Warsaw, Poland: DE GRUYTER OPEN. http://doi.org/10.2478/9783110409697.1

Rizzo, A. (2006). The origin and design of intentional affordances. *Proceeding of the 6th Conference on Designing Interactive Systems*, 239–240.

Robbins, B. D., Kamens, S. R., & Elkins, D. N. (2017). DSM-5 Reform Efforts by the Society for Humanistic Psychology. *Journal of Humanistic Psychology*, *57*(6), 602–624. http://doi.org/10.1177/0022167817698617

Rogers, Y. (2006). Moving on from Weiser's vision of calm computing: Engaging ubicomp experiences. *International Conference on Ubiquitous Computing*.

Rogers, Y. (2011). Interaction Design Gone Wild: Striving for Wild Theory. *Interactions*, (July-August), 58–62.

Rogers, Y. (2012). HCI Theory: Classical, Modern, and Contemporary
(pp. 1–131). Morgan & Claypool Publishers.

Rosnow, R. L., & Rosenthal, R. (1989). Statistical procedures and the justification of knowledge in psychological science. *American Psychologist*, *44*(10), 1276–1284. http://doi.org/10.1037//0003-066x.44.10.1276

Rubegni, E., Memarovic, N., & Langheinrich, M. (2011). Talking to Strangers: Using Large Public Displays to Facilitate Social Interaction. In A. Marcus (Ed.), *Design, User Experience, and Usability. Theory, Methods, Tools and Practice* (Vol. 6770, pp. 195–204). Berlin, Heidelberg: Springer Berlin Heidelberg. http://doi.org/10.1007/978-3-642-21708-1_23

Ryan, N., Pascoe, J., & Morse, D. (1997). Enhanced reality fieldwork: the context aware archaeological assistant. *Computer Applications & Quantitative Methods in Archaeology*.

Sacks, H. (1992). Lecture on Conversation Volumes I & II. (G. Jefferson, Ed.) (pp. 1–922). Oxford, UK: Blackwell Publishing.

Saffer, D. (2008). Designing Gestural Interfaces. O'Reilly Media, Inc.

Sale, J. E. M., Lohfeld, L. H., & Brazil, K. (2002). Revisiting the Quantitative-Qualitative Debate: Implications for Mixed-Methods Research. *Quality and Quantity*, *36*(1), 43–53. http://doi.org/10.1023/A:1014301607592

Sarfraz, M. S., Constantinescu, A., Zuzej, M., & Stiefelhagen, R. (2017). A Multimodal Assistive System for Helping Visually Impaired in Social Interactions. *Informatik-Spektrum*, *40*(6), 540–545. http://doi.org/10.1007/s00287-017-1077-7

Sas, C., & Dix, A. (2009). Designing for reflection on experience. *CHI'09 Extended Abstracts on Human Factors in Computing Systems*, 4741–4744.

Sawhney, N., & Schmandt, C. (1999). Nomadic radio: scaleable and contextual notification for wearable audio messaging. *Proceeding of the SIGCHI Conference on*

Human Factors in Computing Systems, 96–103. http://doi.org/10.1145/302979.303005

Scaini, S., Belotti, R., Ogliari, A., & Battaglia, M. (2016). A comprehensive meta-analysis of cognitive-behavioral interventions for social anxiety disorder in children and adolescents. *Journal of Anxiety Disorders*, *42*, 105–112. http://doi.org/10.1016/j.janxdis.2016.05.008

Schatzki, T. R., Knorr-Cetina, K., & Thermann, von, A. (2005). The Practice Turn in Contemporary Theory. Routledge.

Schellekens, K., Giaccardi, E., Day, D., Hung, H., Quiros, L. C., Gedik, E., & Martella, C. (2015). Impact of connected objects on social encounters. Presented at the 4th Participatory Innovation Conference, Hague, Netherlands.

Schmidt, A. (2000). Implicit human computer interaction through context. *Personal Technologies*, *4*(2-3), 191–199. http://doi.org/10.1007/BF01324126

Schmidt, N. B., Richey, J. A., Buckner, J. D., & Timpano, K. R. (2009). Attention training for generalized social anxiety disorder. *Journal of Abnormal Psychology*, *118*(1), 5–14. http://doi.org/10.1037/a0013643

Schneider, W., & Shiffrin, R. M. (1977). Controlled and Automatic Human Information Processing: I. Detection, Search, and Attention. *Psychological Review*, *84*(1), 1–66.

Scott, S. (2006). The medicalisation of shyness: from social misfits to social fitness. *Sociology of Health and Illness*, *28*(2), 133–153. http://doi.org/10.1111/j.1467-9566.2006.00485.x

Scott, S. (2007). Shyness and Society. Palgrave Macmillan.

Sengers, P., & Gaver, B. (2006). Staying open to interpretation - engaging multiple meanings in design and evaluation. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*, 99–108.

Shaer, O., & Hornecker, E. (2010). Tangible User Interfaces: Past, Present and Future Directions. *Foundations and Trends in Human Computer Interaction*, *3*(1-2), 1–137. http://doi.org/10.1561/1100000026

Shaer, O., & Jacob, R. J. K. (2009). A specification paradigm for the design and implementation of tangible user interfaces. *ACM Transactions on Computer-Human Interaction (TOCHI) – Special Issue on the Theory and Practice of Embodied Interaction in HCI and Interaction Design*, *16*(4), 1–39. http://doi.org/10.1145/1614390.1614395

Shami, N., Leshed, G., & Klein, D. (2005). Context of use evaluation of peripheral displays (CUEPD). *Ubicomp 2006*, *3585 LNCS* (Chapter 47), 579–587. http://doi.org/10.1007/11555261_47

Sheeks, M. S., & Birchmeier, Z. P. (2007). Shyness, Sociability, and the Use of Computer-Mediated Communication in Relationship Development. *Cyber Psychology & Behavior*, *10*(1), 64–70. http://doi.org/10.1089/cpb.2006.9991

Sheridan, J. G., Lafond-Favieres, V., & Newstetter, W. C. (2000). Spectators at a geek show: an ethnographic inquiry into wearable computing (pp. 195–196). Presented at the Digest of Papers. Fourth International Symposium on Wearable Computers, IEEE Comput. Soc. http://doi.org/10.1109/iswc.2000.888498

Shibata, T., Peck, E. M., Afergan, D., Hincks, S. W., Yuksel, B. F., & Jacob, R. J. K. (2014). Building implicit interfaces for wearable computers with physiological inputs. *UIST'14 Adjunct Proceeding of the 27th Annual ACM Symposium on User Interface Software and Technology*, 89–90. http://doi.org/10.1145/2658779.2658790

Simon, N. (2010). Social Objects. In *The Participatory Museum* (pp. 1–45).

Simons, D. J. (2014). The Value of Direct Replication. *Perspectives on Psychological Science*, *9*(1), 76–80. http://doi.org/10.1177/1745691613514755

Sinclair, M., & Ashkanasy, N. M. (2005). Intuition: Myth or a Decision-Making Tool? *Management Learning*, *36*(3), 353–370. http://doi.org/10.1177/1350507605055351
Smith, J. D., Vertegaal, R., & Sohn, C. (2005). ViewPointer: lightweight calibration-free eye tracking for ubiquitous handsfree deixis (pp. 53–61). New York, New York, USA: ACM. http://doi.org/10.1145/1095034.1095043
Sofia, K. O., & Jones, L. (2013). Mechanical and Psychophysical Studies of Surface Wave Propagation during Vibrotactile Stimulation. *IEEE Transactions on Haptics*, *6*(3), 320–329. http://doi.org/10.1109/TOH.2013.1
Sokoler, T., & Svensson, M. S. (2007). Embracing ambiguity in the design of non-stigmatizing digital technology for social interaction among senior citizens. *Behaviour and Information Technology*, *26*(4), 297–307. http://doi.org/10.1080/01449290601173549
Song, H., Zmyslinski-Seelig, A., Kim, J., Drent, A., Victor, A., Omori, K., & Allen, M. (2014). Does Facebook make you lonely?: A meta analysis. *Computers in Human Behavior*, *36*(C), 446–452. http://doi.org/10.1016/j.chb.2014.04.011
Spearman, C. (1904). The proof and measurement of association between two things. *The American Journal of Psychology*.
Starner, T. E. (2002). Attention, Memory, and Wearable Interfaces. *IEEE Pervasive Computing*, *1*(4), 88–91. http://doi.org/10.1109/MPRV.2002.1158283
Stasko, J. T., McColgin, D., Miller, T., Plaue, C. M., & Pousman, Z. L. (2005). Evaluating the InfoCanvas Peripheral Awareness System: A Longitudinal, In Situ Study.
Stein, M. B. (1999). Coming face-to-face with social phobia. *American Family Physician*, *60*(8), 2244–2245.
Steinman, S. A., Gorlin, E. I., & Teachman, B. A. (2014). Cognitive Biases among Individuals with Social Anxiety
. In J. W. Weeks (Ed.), *The Wiley Blackwell Handbook of Social Anxiety Disorder* (pp. 323–343). Chichester, UK: John Wiley & Sons, Ltd.
Stoffregen, T. A., & Mantel, B. (2015). Exploratory movement and affordances in design. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, *29*(03), 257–265. http://doi.org/10.1017/S0890060415000190
Stoffregen, T. A., Bardy, B. G., & Mantel, B. (2006). Affordances in the design of enactive systems. *Virtual Reality*, *10*(1), 4–10. http://doi.org/10.1007/s10055-006-0025-7
Stolz, T., Schulz, A., Krieger, T., Vincent, A., Urech, A., Moser, C., et al. (2018). A mobile app for social anxiety disorder: A three-arm randomized controlled trial comparing mobile and PC-based guided self-help interventions. *Journal of Consulting and Clinical Psychology*, *86*(6), 493–504. http://doi.org/10.1037/ccp0000301
Stopa, L. (2009). Why is the Self Important in Understanding and Treating Social Phobia? *Cognitive Behaviour Therapy*, *38 Suppl 1*(48), 1651–2316.
Stopa, L., Brown, M. A., Luke, M. A., & Hirsch, C. R. (2010). Constructing a self: The role of self-structure and self-certainty in social anxiety. *Behaviour Research and Therapy*, *48*(10), 955–965. http://doi.org/10.1016/j.brat.2010.05.028
Streitz, N., Röcker, C., Prante, T., Stenzel, R., & van Alphen, D. (2009). *Situated Interaction with Ambient Information: Facilitating Awareness and Communication in Ubiquitous Work Environments* (pp. 1–5).
Suler, J. (2004). The Online Disinhibition Effect. *Cyber Psychology & Behavior*, *7*(3), 321–326. http://doi.org/10.1089/1094931041291295

Sullivan, G. M., & Feinn, R. (2012). Using Effect Size—or Why the PValue Is Not Enough. *Journal of Graduate Medical Education*, *4*(3), 279–282. http://doi.org/10.4300/JGME-D-12-00156.1

Suwita, A., Böcker, M., Mühlbach, L., & Runde, D. (1997). Overcoming human factors deficiencies of videocommunications systems by means of advanced image technologies. *Displays*, *17*(2), 75–88. http://doi.org/10.1016/s0141-9382 (96)01023-2

Svanæs, D. (2001). Context-Aware Technology - A Phenomenological Perspective. *Human–Computer Interaction*, *16*(2), 379–400. http://doi.org/10.1207/S15327051HCI16234_17

Svanæs, D., & Verplank, W. (2000). In Search of Metaphors for Tangible User Interfaces. *Proceeding of the Designing Augmented Reality Environments*, 1–9.

Svensson, M. S., & Sokoler, T. (2008). Ticket-to-talk-television - designing for the circumstantial nature of everyday social interaction. *Proceeding of the 5th Nordic Conference on Human-Computer Interaction: Building Bridges*, 334. http://doi.org/10.1145/1463160.1463197

Taylor, C. T., Bomyea, J., & Amir, N. (2010). Attentional bias away from positive social information mediates the link between social anxiety and anxiety vulnerability to a social stressor. *Journal of Anxiety Disorders*, *24*(4), 403–408. http://doi.org/10.1016/j.janxdis.2010.02.004

Teddlie, C., & Tashakkori, A. (2009). Foundations of Mixed Methods Research: Integrating Quantitative and Qualitative Techniques in the Social and Behavioral Sciences. London, UK: Sage.

Thieme, A., Wallace, J., Thomas, J., Le Chen, K., Krämer, N., & Olivier, P. (2011). Lovers' box: Designing for reflection within romantic relationships. *Journal of Human Computer Studies*, *69*(5), 283–297. http://doi.org/10.1016/j.ijhcs.2010.12.006

Throne, B. (2003). Carl Rogers (2nd ed.). London, UK: SAGE Publications.

Tokunaga, R. S., & Rains, S. A. (2010). An Evaluation of Two Characterizations of the Relationships Between Problematic Internet Use, Time Spent Using the Internet, and Psychosocial Problems. *Human Communication Research*, *36*(4), 512–545. http://doi.org/10.1111/j.1468-2958.2010.01386.x

Tomasello, M., & Carpenter, M. (2007). Shared intentionality. *Developmental Science*, *10*(1), 121–125. http://doi.org/10.1111/j.1467-7687.2007.00573.x

Toney, A., Mulley, B., Thomas, B. H., & Piekarski, W. (2002). Minimal Social Weight User Interactions for Wearable Computers in Business Suits. *Proceeding of the 6th International Symposium on Wearable Computers*, 57–64.

Toney, A., Mulley, B., Thomas, B. H., & Piekarski, W. (2003). Social weight: designing to minimise the social consequences arising from technology use by the mobile professional. *Personal and Ubiquitous Computing*, *7*(5), 309–320. http://doi.org/10.1007/s00779-003-0245-8

Treisman, A. (1964). Monitoring and storage of irrelevant messages in selective attention. *Journal of Verbal Learning and Verbal Behavior*, *3*, 449–459.

Treisman, A. M. (1985). Preattentive processing in vision. *Computer Vision, Graphics, and Image Processing*, *31*(2), 156–177. http://doi.org/10.1016/S0734-189X (85)80004-9

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*(1), 97–136. http://doi.org/10.1016/0010-0285(80)90005-5

Trochim, W., & Donnelly, J. P. (2006). The Research Methods Knowledge Base (3rd ed.). Cincinnati, OH, USA: Atomic Dog Publishing Inc.

Tukey, J. W. (1991). The Philosophy of Multiple Comparisons. *Statistical Science*, *6*(1), 100–116. http://doi.org/10.1214/ss/1177011945

Tuomela, R. (2006). Joint Intention, We-Mode and I-Mode. *Midwest Studies in Philosophy*, *30*(1), 35–58. http://doi.org/10.1111/j.1475-4975.2006.00127.x
Turner, P. (2008). Towards an account of intuitiveness. *Behaviour & IT*, *27*(6), 475–482.
Turowetz, J., & Hollander, M. M. (2012). Assessing the experience of speed dating. *Discourse Studies*, *14*(5), 635–658. http://doi.org/10.1177/1461445612454083
Tversky, B., Zacks, J., Lee, P. U., & Heiser, J. (2000). Lines, Blobs, Crosses and Arrows - Diagrammatic Communication with Schematic Figures. *Diagrams*.
Ullrich, D., & Diefenbach, S. (2010a). From magical experience to effortlessness (pp. 801–804). Presented at the NordiCHI '10 Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries, New York, USA: ACM Press. http://doi.org/10.1145/1868914.1869033
Ullrich, D., & Diefenbach, S. (2010b). INTUI. Exploring the Facets of Intuitive Interaction. *Mensch & Computer 2010*, 251–260. http://doi.org/10.1524/9783486853483.251
Urban Atmospheres. (2004). Jabberwocky. Retrieved July 19, 2017, from http://www.urban-atmospheres.net/Jabberwocky/info.htm
Valkenburg, P. M., & Peter, J. (2011). Online Communication Among Adolescents: An Integrated Model of Its Attraction, Opportunities, and Risks. *Journal of Adolescent Health*, *48*(2), 121–127. http://doi.org/10.1016/j.jadohealth.2010.08.020
van Dam, A. (1997). Post-WIMP user interfaces. *Communications of the ACM*, *40*(2), 63–67. http://doi.org/10.1145/253671.253708
Van Der Linden, J., Schoonderwaldt, E., & Bird, J. (2009). Good vibrations: Guiding body movements with vibrotactile feedback. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*, 13–18.
van der Wel, R. P. R. D. (2015). Me and we: Metacognition and performance evaluation of joint actions. *Cognition*, *140*, 49–59. http://doi.org/10.1016/j.cognition.2015.03.011
van der Wel, R. P. R. D., Sebanz, N., & Knoblich, G. (2012). The sense of agency during skill learning in individuals and dyads. *Consciousness and Cognition*, *21*(3), 1267–1279. http://doi.org/10.1016/j.concog.2012.04.001
van Erp, J. (2002). Guidelines for the use of vibro-tactile displays in human computer interaction. Presented at the 6th conference on Designing Interactive systems.
van Gemert-Pijnen, J. E., Nijland, N., van Limburg, M., Ossebaard, H. C., Kelders, S. M., Eysenbach, G., & Seydel, E. R. (2011). A Holistic Framework to Improve the Uptake and Impact of eHealth Technologies. *Journal of Medical Internet Research*, *13*(4), e111–18. http://doi.org/10.2196/jmir.1672
Veale, D. (2003). Treatment of social phobia. *Advances in Psychiatric Treatment*, *9*(4), 258–264. http://doi.org/10.1192/apt.9.4.258
Verbeek, P. P. (2005). What things do: Philosophical reflections on technology, agency, and design. (R. P. Crease, Trans.). University Park, Pennsylvania: The Pennsylvania State University Press.
Vermeeren, A. P. O. S., Law, E. L.-C., Roto, V., Obrist, M., Hoonhout, J., & Väänänen-Vainio-Mattila, K. (2010). User experience evaluation methods - current state and development needs. *Proceedings of the Second Nordic Conference on Human-Computer Interaction*, 521–530.
Vesper, C., Abramova, E., Bütepage, J., Ciardo, F., Crossey, B., Effenberg, A., et al. (2017). Joint Action: Mental Representations, Shared Information and General Mechanisms for Coordinating with Others. *Frontiers in Psychology*, *07*(254), 1109–7. http://doi.org/10.3389/fpsyg.2016.02039

Ville Antila, J. P. (2012). Understanding the Privacy Implications of Using Context-based Awareness Cues in Social Networks. *Proceeding of the IEEE International Conference on Pervasive Computing and Communications Workshops*, 1–6.
Viney, K., & Viney, P. (1996). Handshake: A Course in Communication. Oxford, UK: Oxford University Press.
Virzi, R. A., Sokolov, J. L., & Karis, D. (1996). Usability problem identification using both low- and high-fidelity prototypes (pp. 236–243). Presented at the the SIGCHI conference, New York, New York, USA: ACM Press. http://doi.org/10.1145/238386.238516
Vredenburg, K., Mao, J.-Y., Smith, P. W., & Carey, T. (2002). A survey of user-centered design practice. *Proceeding of the SIGCHI Conference on Human Factors in Computing Systems*, 471–478.
Vyas, D., Chisalita, C. M., & van der Veer, G. C. (2006). Affordance in Interaction. *Proceeding of the 13th Eurpoean Conference on Cognitive Ergonomics Trust and Control in Complex Socio-Technical Systems*, 92–99.
Vytal, K., Cornwell, B., Arkin, N., & Grillon, C. (2012). Describing the interplay between anxiety and cognition: From impaired performance under low cognitive load to reduced anxiety under high load. *Psychophysiology*, *49*(6), 842–852. http://doi.org/10.1111/j.1469-8986.2012.01358.x
Waga, K., Tabarcea, A., & Fränti, P. (2011). Context aware recommendation of location-based data. *Proceeding of the 15th International Conference on System Theory, Control and Computing*, 1–6.
Wagman, J. B., & Carello, C. (2003). Haptically creating affordances: The user-tool interface. *Journal of Experimental Psychology: Applied*, *9*(3), 175–186. http://doi.org/10.1037/1076-898X.9.3.175
Walther, J. B. (2011). Theories of computer-mediated communication and interpersonal relations. In M. L. Knapp & J. A. Daly (Eds.), *The handbook of interpersonal communication* (pp. 443–479). CA: The handbook of interpersonal communication.
Ware, C. (2012). Information Visualization: Perception for Design (3rd ed.). Massachusetts, USA: Morgan Kaufmann.
Weinstein, S. (1968). Intensive and Extensive Aspects of Tactile Sensitivity as a Function of Body Part, Sex and Laterality. In D. Kenshalo (Ed.), *The Skin Senses* (pp. 195–218). IL, USA: Proceeding of the 1st International Symposium on Skin Senses.
Weiser, M. (1991). The computer for the 21st century. *Scientific American Special Issue*, 78–89.
Weiser, M., & Brown, J. (1996). The coming age of calm technology updated version of “Designing Calm Technology.” PowerGrid Journal.
Weiser, M., & Brown, J. S. (1995). Designing Calm Technology. *Power Grid Journal*, *1*(1).
Wentzel, J., van der Vaart, R., Bohlmeijer, E. T., & van Gemert-Pijnen, J. E. W. C. (2016). Mixing Online and Face-to-Face Therapy: How to Benefit From Blended Care in Mental Health Care. *JMIR Mental Health*, *3*(1), e9–7. http://doi.org/10.2196/mental.4534
Werner, J., Wettach, R., & Hornecker, E. (2008). United-pulse: Feeling Your Partner's Pulse. *Proceeding of 10th International Conference on Human Computer Interaction with Mobile Devices and Services - MobileHCI '08*. http://doi.org/10.1145/1409240.1409338
Whalen, J., Gallistel, C. R., & Gelman, R. (1999). Nonverbal counting in humans: The psychophysics of number representation. *Psychological Science*, *10*(2), 130–137. http://doi.org/10.1111/1467-9280.00120

Wickens, C. D. (1981). *Processing Resource in attention – Dual task performance and workload assessment* (pp. 1–55). Office of Naval Research, Engineering Psychology Program.

Widyanto, L., & Griffiths, M. (2011). An Empirical Study of Problematic Internet Use and Self-Esteem, *1*(1), 13–24. http://doi.org/10.4018/ijcbpl.2011010102

Wilcox, R. R. (1992). Why can methods for comparing means have relatively low power, and what can you do to correct the problem? *Current Directions in Psychological Science*.

Wildemuth, B. M. (1993). Post-positivist research: two examples of methodological pluralism. *The Library Quarterly*, *63*(4), 450–468. http://doi.org/10.1086/602621

Williams, A., Farnham, S., & Counts, S. (2006). Exploring wearable ambient displays for social awareness. *CHI Extended Abstracts*, 1529. http://doi.org/10.1145/1125451.1125731

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, *9*(4), 625–636.

Wiltshire, T. J., Snow, S. L., Lobato, E. J. C., & Fiore, S. M. (2014). Leveraging Social Judgment Theory to Examine the Relationship between Social Cues and Signals in Human-Robot Interactions. *Proceeding of the Human Factors and Ergonomics Society the 58th Annual Meeting*, *58*(1), 1336–1340. http://doi.org/10.1177/1541931214581279

Winter, M. (2013). Inch-scale interactive displays for social object annotation. *Proceeding of Physical Interaction Workshop on Real World User Interfaces at the 2013 ACM Conference on Pervasive and Ubiquitous Computing (Adjunct Publication)*, 183–186. http://doi.org/10.1145/2494091.2494151

Witmer, B. G., & Singer, M. J. (1998). Measuring Presence in Virtual Environments: A presence Questionnaire. *Presence: Teleoperators and Virtual Environments*, *7*(3), 225–240.

Witt, H., & Kenn, H. (2006). Towards implicit interaction by using wearable interaction device sensors for more than one task. *Mobility'2016 Proceeding of the 3rd International Conference on Mobile Technology, Applications and Systems*, 1–6. http://doi.org/10.1145/1292331.1292354

Wong, J., Gordon, E. A., & Heimberg, R. G. (2014). Cognitive-Behavioral Models of Social Anxiety Disorder. In J. W. Weeks (Ed.), *The Wiley Blackwell Handbook of Social Anxiety Disorder* (pp. 3–23). Chichester, UK.

Wright, J. H., Wright, A. S., Salmon, P., Beck, A. T., Kuykendall, J., Goldsmith, L. J., & Zickel, M. B. (2002). Development and initial testing of a multimedia program for computer-assisted cognitive therapy. *American Journal of Psychotherapy*, *56*(1), 76–86.

Xu, B., Chin, A., Wang, H., Chang, L., Zhang, K., Yin, F., et al. (2011). Physical Proximity and Online User Behaviour in an Indoor Mobile Social Networking Application. *iThings/CPSCom*. http://doi.org/10.1109/iThings/CPSCom.2011.74","publicationTitle":"Internet

Yen, P.-Y., & Bakken, S. (2009). A Comparison of Usability Evaluation Methods - Heuristic Evaluation versus End-User Think-Aloud Protocol - An Example from a Web-based Communication Tool for Nurse Scheduling. *Amia*, *2009*, 714–718.

Yuen, E. K., Herbert, J. D., Forman, E. M., Goetter, E. M., Comer, R., & Bradley, J.-C. (2013). Treatment of Social Anxiety Disorder Using Online Virtual Environments in Second Life. *Behavior Therapy*, *44*(1), 51–61. http://doi.org/10.1016/j.beth.2012.06.001

Zhao, Shuang, Luo, X., Ma, X., Bai, B., Zhao, Y., Zou, W., et al. (2018). Exploiting Proximity-Based Mobile Apps for Large-Scale Location Privacy Probing. *Security and Communication Networks*, *2018*, 1–22. http://doi.org/10.1155/2018/3182402

Zimbardo, P. G. (1981). Shyness: what it is, what to do about it. London: Pan Books Ltd.

Zwaan, R. A., & Madden, C. J. (2017). Embodied Sentence Comprehension. In D. Pecher & R. A. Zwaan (Eds.), *The grounding of cognition* (pp. 224–245). Cambridge, UK.