Negotiating Experience and Communicating Information Through Abstract Metaphor

Courtney N. Reed
Sensorimotor Interaction,
Max Planck Institute for Informatics,
Saarland Informatics Campus
Saarbrücken, Germany
creed@mpi-inf.mpg.de

Paul Strohmeier
Sensorimotor Interaction,
Max Planck Institute for Informatics,
Saarland Informatics Campus
Saarbrücken, Germany
pastrohm@mpi-inf.mpg.de

Andrew McPherson
School of Electronic Engineering &
Computer Science,
Queen Mary University of London
London, UK
a.mcpherson@qmul.ac.uk

ABSTRACT

An implicit assumption in metaphor use is that it requires grounding in a familiar concept, prominently seen in the popular Desktop Metaphor. In human-to-human communication, however, abstract metaphors, without such grounding, are often used with great success. To understand when and why metaphors work, we present a case study of metaphor use in voice teaching. Voice educators must teach about subjective, sensory experiences and rely on abstract metaphor to express information about unseen and intangible processes inside the body. We present a thematic analysis of metaphor use by 12 voice teachers. We found that metaphor works not because of strong grounding in the familiar, but because of its ambiguity and flexibility, allowing shared understanding between individual lived experiences. We summarise our findings in a model of metaphor-based communication. This model can be used as an analysis tool within the existing taxonomies of metaphor in user interaction for better understanding why metaphor works in HCI. It can also be used as a design resource for thinking about metaphor use and abstracting metaphor strategies from both novel and existing designs.

CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models**; *Empirical studies in HCI*; *Interaction techniques.*

KEYWORDS

metaphor, data representations, human communication, sensory experience, design

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1 INTRODUCTION

Communicating information between different agents impacts every step of HCI and systems design. Design aspects must be understood between team members, and designers must communicate prospects to stakeholders and ultimately to users through interaction with the resultant system. However, in communicating our more abstract experiences, we are often limited by language to describe the innate; because individual lived experiences and embodied practices live within often wordless, tacit knowledge, it is difficult for us to articulate our experiences, even to ourselves. Metaphors as abstract representations are necessary tools for describing the world and our complex, subjective experiences living in it. In human-to-human communication, metaphors are used to mediate subjective information and knowledge between different people with the goal of mutual understanding between their individual lived experiences.

HCI research focuses predominantly on the communication and mutual understanding mediated between system and user, which has also relied on metaphorical representations of information. Traditional HCI metaphor, such as the "desktop metaphor," works by representing physical objects or actions in the real world [85]. These make the assumption that all digital activities are done in the same way as physical ones [12, 87]; this principle breaks down when representing abstract information about interaction, individual sensory perception, and subjective understanding. Considering the contemporary definition of "metaphor" as any cross-domain representation of information [66], HCI has leveraged other strategies which also function as metaphor, such as gestural communication [13, 74], symbolic representations [91, 102], and multi-modal data representations — for instance Huron et al.'s physicalisation of data through graspable data artefacts[53], Smith et al.'s sonification of the gestures in different practitioners' craft techniques,[88] and Kosara and Mackinlay's visualisation of data through visual storytelling [63]— to communicate information.

However, without a way to provide an individually bespoke experience to each user, metaphorical representations of information between systems and users depend on assumptions of mutual interpretations by diverse users. There is no one-size-fits-all interaction [89] and individual interaction must be acknowledged when communicating subjective knowledge between agents. HCI research has worked to develop tools and frameworks to help people better reflect on and share their perspectives in interaction, especially pertaining to more abstract and individual sensory experiences. Metaphor allows for the communication of bodily ways of knowing to both the self and to others [18]. The next step in this research is

to understand *why* metaphors work so well for sharing subjective sensory knowledge in human-to-human communication, and how these elements can be brought into HCI to acknowledge and work with individual lived experience.

To understand how humans are able to reach mutual understanding through metaphor, this paper turns to a practice that has long faced a similar challenge of communicating knowledge about subjective experiences: vocal pedagogy. Metaphor is critical in vocal education, which relies on the teacher's knowledge of their own sensory-based, subjective experience and ability to convey this to their student. The difficulty with this teaching environment is that the singer's relationship with their voice is based largely on internal sensations and feelings within the body. Vocal pedagogy presents a unique case study for human-to-human interaction; there is (traditionally) no computer mediation, no interface, and no support in this learning experience other than communication of sensation from one person to another.

We report a series of interviews with voice teachers conducted by the first author, who is a semi-professional vocalist and voice teacher as well as an HCI researcher. We find that metaphorical representations of subjective, sensory-based experiences work on the basis of creating mutual understanding between individuals, without the need for domain-specific knowledge, articulating embodied knowledge using pre-linguistic understanding, and using ambiguity to map information between individual lived experiences. From these findings, we propose a model of metaphor-based knowledge communication and understanding between people. We conclude by proposing how this model helps to examine the design of interactive systems and their use of metaphor. We revisit existing examples of interfaces and experientially-motivated design probes to demonstrate how this model helps us to reevaluate what we know about metaphor. We discuss in these examples how metaphor functions between human and technological agents to provide a basis for representing information and fostering mutual understanding in HCI.

2 RELATED WORK

2.1 Metaphor as Defined in HCI

HCI Metaphor traditionally focuses around WIMP (Windows, Icons, Menus and Pointers) organisation of digital actions. For instance, *icons* are small images which represent computer resources as familiar, physical objects, such as a trash bin representing file deletion or folders location in digital memory where documents are stored. The *Desktop Metaphor* was intended to make the computer relatable to and part of a typical office environment [12], often by recreating a physical desktop in a digital space [60]; for instance, windows represent physical sheets of paper. When computers became a part of typical office environments, metaphor made this complex technology, previously only usable by computer experts, accessible to users in other fields. The ability to interact with a digital desktop as one would with a physical desktop goes as far as to introduce physics properties so that papers will flutter down when dropped onto a pile [1], leveraging real-world physical interaction to make things as life-like as possible.

Icons provide a source of *Direct Manipulation*, as defined by Shneiderman and Maes, by providing interaction through direct representations of action, rather than indirect command line input [85]. Canfield Smith describes icons as effective because they have both visual and computer semantics; when dragging files to that trash bin icon, somewhere something is being deleted from the computer's memory [12]. Desktop Metaphor allows complex processes to be expressed as everyday functions, democratising computer use by providing familiarity to non-experts. However, there are also many instances of effective computer UI that does not involve icons, for instance Sutherland's Sketchpad representation of functional programming through manipulation of shapes and patterns [92], Voorhorst et al.'s graspable interfaces and gestural communication [103], Beaudouin-Lafon's CPN/Tools post-WIMP interaction through bi-manual interaction, toolglasses, and marking menus [5, 6], and Hornecker and Buur's case studies of tangibles and their expressive, embodied, and spacial representations [51]. Where Canfield Smith suggests that icons have fallen by the wayside due to a "failure of imagination," in coming up with new Desktop Metaphor objects, Beaudoin-Lafon suggests a breakaway from monolithic representations of physical objects through a variety post-WIMP interaction techniques [5]. This is because there are notable limits to the Desktop Metaphor, namely that simulating a real-world environment neglects the affordances of the digital world and enforces physical limitations that can easily be overcome with a computer [87]; for instance, processing thousands of digital documents — many more than can be physically placed on a desktop [23].

Beyond the 2D surface of the screen, metaphorical representations are common in physical characteristics and audio references. *Product metaphors*, as defined by Hekkert and Cila, are cases where the design is made to reference the physical properties of another object or to indicate its use [44]. For instance, the authors reference the Pianobell, a set of 5 piano keys which are used as a doorbell, created by Li Jian [59] as an example of how physical representation, as well as cultural understanding of the functionality of a piano, can provide direction to a user about a different action; the doorbell invites someone to press the keys and indeed provides some fun, while achieving the goal of alerting the occupant that someone is at the door. Hekkert and Cila outline many "modes" of metaphorical mappings that can be used in design, demonstrating that mimicry through icons is not necessarily the only way to convey meaning: form, interaction, sound, movement, material/texture, smell/taste, the name of a source, or printed graphics are also salient features which can convey meaning [44].

This disparity between Desktop Metaphor and other representations of computer processes suggest that there is a tension between HCI and real life which causes a breakdown in what can be communicated by traditional HCI metaphor. Hornecker notes in response to physical embodiment through tangibles that social understanding provides grounding; they require learned associations through experience and context [71] and do not work merely because they are physical objects [51]. Although Canfield Smith is critical of Apple's movement away from the Desktop Metaphor [12], users are still able to use their phones through experience. Additionally, humans are able to understand and relate to each other through very abstract metaphor, particularly in cases where there are no external objects to be represented: in regards to sensory experiences, icon representation would be difficult and perhaps too rigid for representing something so difficult to express. This understanding,

and perhaps even the definition of Metaphor in HCI as a depiction of reality, is something which should be questioned [7].

2.2 Contemporary Metaphor Theory

Humans use metaphor in other, even abstract ways to exchange information and understanding. Lakoff and Johnson's contemporary metaphor theory describes a more flexible and multi-modal representation [66]: rather than depicting reality, metaphor is the way we map information existing in one domain to another. This mapping can take the form of words, but metaphor is cognitive and conceptual [66]; these mappings are made through metaphor entailments, through which a signifier (a known concept) implies about the signified (the unknown/unfamiliar concept) [3, 66]. Humans are able to understand and use abstract representations based on other life experience [67]; information can become easier to understand [7] and communicate [101] when expressed in a different modality. This explains why the Desktop Metaphor can be effective: we have taken a complex computer process and expressed the action through a relatable image we understand from the physical world. But, based on this contemporary metaphor theory, "Metaphor" is not just icons and should also include representations of unfamiliar processes through tangibles and multi-modal data representations, for instance visualisations. Through the remainder of the paper, we therefore refer to this contemporary theory when talking about metaphor as a concept, with the aim of expanding the way we think about metaphor in HCI.

2.2.1 Taxonomies of Metaphor. Barr et al. position this contemporary metaphor theory to address the use of Desktop Metaphor, expanding on Lakoff and Johnson's definition to outline a taxonomy of user interface metaphors [3]. This taxonomy defines *what* metaphors really are and and *where* they are used in HCI. Metaphors are classified by Barr et al. as instances which a metaphoric entailment provides direction to the user about a process; for example, "you can use folders to categorise your files" implies that digital files are able to be stored inside digital folders, and that using the computer's data storage system is inherently a file-storing process [3].Other taxonomies of metaphor in specific modalities have also been proposed; for instance, Zhao and Vande Moere outline a taxonomy for data sculpture, the practice of creating embodiment in in physical and visual representations of data (e.g., using rice grains to represent demographic data as a reference to the populations' relationship with food and consumption), and provide a classification of physicalisation strategies[110]. Gaver outlines a categorisation of data using auditory icons (e.g., the sound of the crumpling paper used in Apple's MacOS when a file is moved to the trash can - all a metaphor for deleting files from memory) and examines how different acoustic properties can convey weight, size, and movement in an interaction [31].

Nesbitt's Multi-Sensory Taxonomy (MS-Taxonomy) abstracts such perceptual categories of metaphor, focusing on the perceptual design space and mappings between data attributes and sensory properties. The goal of the taxonomy is to provide terminology which can be used regardless of the modality of the metaphor. Nesbitt classifies metaphors as being spatial (focusing on perception of scale and location), direct (related to parameters of the given modality, for instance "hardness" in the tactile domain), or temporal (related to changes perceived over time) [75] As Nesbitt describes, this model is not a counter to other models focusing on specific modalities; however, different taxonomies arise and are used depending on the aims of the modeller and the designer, as well as the aims of the interaction [75]. Our goal in this paper is likewise not to provide a taxonomy of metaphor or commentary on these existing taxonomies; rather, we focus here on how these metaphors are able to communicate sensory-experience and facilitate knowledge transfer between different agents in interaction.

2.2.2 Embodied Metaphor. Metaphor mappings are based in understanding of the body through proprioception and tacit knowledge [94, 95], as well as mental *imagery*, which allows us to imagine experiences without needing to actually experience them [34]. Lived experience helps us to form this mental imagery and neurological connections between feedback and action [64, 65], enabling us to plan further interactions [15, 20] and understand new or abstract information as it relates to our actions and existing understanding of our bodies at a higher cognitive level [56, 57]. The relationship we have with metaphor is also a constantly evolving one; these mappings are made up of mental *schema*, which are underlying ideas and concepts we observe in our interactions [61, 68]. Schema are built through experience and cultural exposure. These schema, with repeated association, become embodied over time and can be extended to more abstract concepts [2, 19], such as embodied directional schema [69]; for instance, the directional schema that future is forward and the past is backward, or that happy is up and sad is down are embodied metaphors [54]. Metaphor therefore allows us to understand and express our lived experience and embodiment. The schema associations we make between different interactions can sometimes be cross-linguistic [33], demonstrating that metaphor is rooted in the body and conceptual mental mappings [66], which can then inform language or other multi-modal mappings [64, 80]. Metaphor is **not reality**, but rather provides a way for us to apply our lived experience to understand new information and interaction with the world. This application was explored by Baur et al., who created a series of schema tokens and interactive objects to represent embodied schema and their associated relationships and processes [4]. The modelled schema in physical and visual form provided workshop participants with novel ways to imagine and examine processes, determine which sensory interactions they employed in working with the schema, and represent the same schema in different modalities [4]. Using these schema and familiarity with their high level cognitive mechanics, inspiration for new design can be based within existing embodied understanding.

2.2.3 Metaphor Phenomenology. Experiences are the result of our individual perception [43], made through our unique bodies and physical environments [62, 89]. This forms our understanding of and interaction with the world [55, 72]. Because of individuality and plurality of experiences, it can be difficult to understand the sensory and embodied relationships of another person [78, 93]. Although we might not currently call it metaphor, the focus on phenomenological and embodied perspectives in HCI [42, 47] has provided a number of approaches to express individual experience and information through abstract representations; for instance, Schiphorst explored movement and self-connection through the design of the

whisper installation, which used wearable networked garments to facilitate communication and connection to the wearers' bodies [84]. Somatics and somaesthetic design in particular use metaphor to explore embodied understanding of interaction [48, 86] and keep the body and movement in focus. For instance, body mapping can be used to provide a non-linguistic representation of experiences rooted in cognitive processes, which might otherwise be difficult to explain to others and even to ourselves [8, 18]. Self-experience and sensations in the body include Gastaldo et al.'s exploration of marginalisation experiences of different groups depitcted through narrative bodymapping[30]Ståhl et al.'s Pelvic Chair and Breathing Wings, which use soma sketching to design and depict experiences of pelvic floor and breathing awareness, respectively [90], Cochrane et al.'s exploration of painted body maps to explore group meditation experiences [16], and Núñez-Pacheco et al.'s exploration of using sculpting with modeling clay to explore felt sensations among designers in the HCI community [77]. Daudén Roquet and Sas used material speculation to create material metaphors [18] and temperature stimuli through WarmMind [19] to provide a tangible presence to sensory and embodied experiences in meditation. Mapping has also been used help express temporal change within the body in Tennent et al.'s graphical soma trajectories [97] and by Cochrane et al. to illustrate design choices and strategies to others [16].

These mapping practices are metaphor, helping participants to find words for reflection and offering a substitute for language [8]. By redefining metaphor in HCI within contemporary theory, we can encompass these practices and open the possibility for expressing information in abstract, multi-modal ways, without being limited to physical objects. Metaphor is not monolithic, being more hermeneutic and dependent on the interpretation and understanding of the individual. This approach in expressing information can fulfill the need to acknowledge the plurality of the human experience and understanding, rather than attempting to find a "true" or perfect representation. Humans are relatively good at expressing their tacit knowledge and understanding through metaphor, as seen in the approaches mentioned above.

2.3 Metaphor in the Voice Lesson

Barr et al.'s expansion of contemporary metaphor theory provides a systematic taxonomy of metaphor in user interfaces in some HCI contexts, a categorisation by their functionality in systems, and suggestions of heuristics to better employ metaphor entailments in interactive systems[3]. However, there is still a missing component in understanding metaphor theory in HCI: *how* metaphor entailments actually create these mappings. To understand the process of knowledge transfer and *how* metaphor is used to map and create mutual understanding of experiences between individuals, we focus in a specific domain that relies on it — voice educators. We study voice educators and singing practice because the nature of the voice requires heavy reliance on metaphor to the extent that traditional vocal pedagogy is built around it [24, 58]. The voice lesson is a valuable place to study metaphor because it involves communication of knowledge about a non-externally visible body part and internal sensory experience which is based on subjective perception. Despite the challenges involved in working with the voice, humans have been very successful at teaching one another to sing using metaphor. For vocal pedagogy, metaphor is considered to be critical to understanding these sensorimotor experiences and relaying them to others [37, 38]. Jestley describes how voice teachers consider metaphor to be "the main vocabulary or language for describing what they actually sense while singing" [58]. This is not for a lack of understanding of the interaction, but rather because the act of learning and using the voice occurs within a sensory domain; singers innately think about singing in a sensory and non-verbal way [45].

Dunbar-Wells presents a model of metaphor-based voice teaching which theorises how metaphor works between the voice teacher and their student, summarised in Figure 1. The teacher's metaphor is presented, where it is translated by the student into a multi-modal, sensory-based image. The metaphor triggers an image which is individual and based in the students' own understanding. This is then internalised and then mapped to physical adjustments in their vocal physiology, resulting in a change in tone outcome [25, 26]. The teacher therefore needs to understand and articulate what they experience in their own body [27, 35] and the student must apply their own understanding and experience through imagery to recreate that sensation [17, 34]. Voice teachers generally prefer to avoid information overload and keep focus on feeling and action, rather than anatomy [58, 73]; in fact, most voice teachers have no knowledge of their anatomy [11]. Compared with Desktop Metaphor, metaphor in the voice lesson actively *avoids* being a truthful representation of how the body works. Both rely on what we will call the *receiving agent* (e.g., a user or student) to interpret the reference given by a *communicating agent* (machine or teacher).

We therefore use voice pedagogy as an environment to study how metaphor is used to communicate subjective, sensory experience and help others understand information in novel interactions. In such a strictly human-to-human interaction, we aim to determine why metaphor works so well and what makes it distinct from traditional metaphor in HCI. By understanding better how humans use metaphor, we can redefine Metaphor in the HCI context to encompass why these different methods of communicating information, from icons to body mapping, are successful. Through this understanding, we propose a model of metaphor-based information transfer which provides insight for mediating knowledge in human-computer relationships.

3 METHOD

We conducted a series of interviews to explore how, in human-to-human communication in the voice lesson, information can be shared between individuals using metaphor-based communication and teaching strategies. We worked with voice teachers because students do not yet have experience with organising metaphor-based teaching strategies. Teachers have been on both ends of the communication and are able to contribute their knowledge in this role, as well as insights from their own experience as students. We focus on beginner vocal technique in this study because lessons at an early stage in the singing career typically focus more on building a relationship with the body, physical movements, and behavior needed for healthy singing, rather than the nuances of any particular musical style. We are thus able to work with teachers in a mix of teaching environments and musical genres. The end

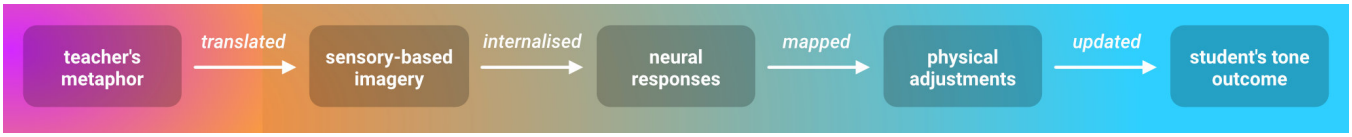

Figure 1: Dunbar-Wells's model of metaphor transfer in the voice lesson [24, p. 152]. This figure depicts the top down process of metaphor provided by the teacher (communicating agent, left) being translated into the student's (receiving agent) understanding through sensory-based imagery. It is then internalised and mapped to physical adjustments, updating how the student executes their singing (right).

goal of each teacher is largely the same: the student should have awareness of the movement of breath in and out of the body and the appropriate level of tension and resistance to pass air through the larynx and control the resulting sound. The teacher must therefore convey information about behavior for the student to recreate, negotiating their different lived experiences and physical bodies. This is done through metaphor.

Compared to the models of metaphor outlined by Lakoff and Johnson and Barr et al., discussed previously, our aim is not to provide a classification of the types of metaphor used in human-to-human communication. Rather, we focus on the functionality of these metaphors – why they work well to communicate about individual, sensory experiences and what are the key elements of their format and delivery – in order to expand on contemporary metaphor theory. The goal of this research is to uncover and provide a model for how metaphor is able to negotiate experience and communicate information between two entities.

3.1 Study

3.1.1 Participants. Twelve voice teachers (10 female, 2 male) participated in the study. The participants were recruited through the first author's musical groups and social media groups specifically focused on vocal education. The teachers were diverse in terms of personal background, teaching practice, and vocal genre. All of the participants currently teach in English but have a variety of national backgrounds, including the UK (3), USA (2), Greece (1), Sweden (1), Singapore (1), Austria (1), and three dual nationals: Portugal/UK, Hong Kong/Malaysia, and Italy/USA. The participants range in age from 25-72 years (M = 38.67, SD = 15.2) and work in a variety of styles, with an even split of 6 classical (art song, opera, choral singing) and 6 contemporary vocal styles (theatre, pop) teachers. All participants had been teaching for at least 6 years, with the most being 35 years (M = 13.25, SD = 9.67)

3.1.2 Apparatus. To investigate potential reasons *why* different metaphor approaches were used, we examined the teachers' mental imagery abilities. We used a set of self-reporting questionnaires, including the Bucknell Auditory Imagery Scale (BAIS) for auditory imagery ability [41], the Movement Imagery Questionnaire 3 (MIQ-3) for visual and kinetic imagery ability [106]. The aim was to determine if a particular kind of metaphor was preferred or used because a teacher had more aptitude for that mode of mental imagery (e.g., someone who is able to produce auditory images well might use auditory metaphor to explain their experience to someone else). The participants received a digital copy of these questionnaires to complete prior to the virtual interview, along with informed consent forms for the study.

3.1.3 Procedure. The interviews were conducted virtually either on Zoom or Skype and were audio-video recorded. The teachers were interviewed about the metaphors they encountered as students and those they use in their own teaching. We discussed the fundamental vocal practices of *supported breathing* (providing muscular support and control for air flow), *posture* (aligning the body to control tension), *sound production* (creating sounds and changing pitch through tension in the laryngeal muscles), and *sound shaping* (controlling resonant spaces with the soft tissues of the mouth and throat). The interview consisted of three parts, beginning with a brief introduction to the teachers' musical styles, lesson settings, and other background information. This was followed by a discussion of metaphors they had experienced as students, and then discussion of their own teaching methods, including their thoughts on the role of metaphor in the voice lesson. The interview questions in detail can be found in Appendix A. The interview was designed to last 30 minutes, but were open-ended to allow participants to describe more details or further experience if desired. True interview times were generally longer, lasting between 29.3 (29:16) and 48.9 (48:57) minutes (M = 37.6, SD = 6.3 minutes). The study received ethical approval from and followed participant data handling and ethical guidelines outlined by [university anonymised].

4 ANALYSIS

We begin first by analysing the results of the BAIS and MIQ-3 questionnaires, provided and completed prior to the interviews, to determine whether their imagery ability was part of *why* they used particular metaphors in their demonstration. Then, we analyse the data gathered from the interview to conduct a thematic analysis and explore further why different references are used and work well within the voice lesson, and potentially for other information communication in HCI and design.

4.1 The Role of Imagery Ability

Teachers used auditory, kinetic, and visual metaphors. For example, P11 introduces students to sounds they are capable of by using the auditory reference of a siren sound: *"I do a lot of whooping Whoop whoop whoop! *a high whooping in the head voice, her hand comes up and makes small circular motions by the side of her head near the eyes*."*). P4's direction on posturing uses kinetic metaphor: *"You're gonna pretend that there's there's a egg between your scapula *points to the centre between the shoulders*... shoulders back and just keep that egg there *rolls their shoulders back and ducks their chin*

slightly. Squeeze it back *they move between a tensed squeezing of the shoulders and a relaxed position*."*). P10's directions for focusing the sound through the nasal passages for clear resonance in the face use visual metaphor: *"Look at that poster in front of you pick, you know that person's face or that hand and try and imagine all your sound is focusing on that once like a laser *hands move from the side of the face to converge together in front*"*). We examined each reference provided by the teachers during the interviews. Each metaphor was categorised by the modalities it employed in its reference; this might have been a single modality or a multi-modal reference. For instance, P11's reference here uses an auditory reference to a siren, a simultaneously kinetic and visual reference in the motion of the hand mimicking each articulation and its airflow. In order to determine if teachers used metaphors of a certain modality because they have higher aptitude for that modality, we used a Spearman's ranked correlation test to evaluate metaphor modalities used with the results of the BAIS and MIQ-3 questionnaires.

4.2 Reflexive Thematic Analysis

The interviews were transcribed automatically using otter.ai and were manually corrected while adding additional information from the video capture, down to the level of utterances and facial expressions. Physical hand gestures and body movements were also notated with the conversation text with asterisks (*). This was done manually for familiarization with the data and acknowledgment of the multi-modality of the metaphors [100]. We used a reflexive inductive thematic analysis approach [9, 10] to examine the metaphors the participants used in their teaching practices. Initial coding was done over a period of two months by the first author, a semi-professional vocalist with 10+ years of practice and education, to provide further insight and introspection within their own history of receiving voice lessons and working in vocal education. Themes were organised and chosen together among all authors in further iterative review of the codes over a subsequent two months of theme organisation.

5 FINDINGS

5.1 Metaphor Modalities

The teachers referenced a variety of auditory, kinetic, and visual metaphors. In total, there were 54 auditory images referenced, 270 kinetic images, and 237 visual images. There were no significant correlations found between the teachers' imagery abilities and the types of metaphor used. A summary table of the teachers' responses to the imagery self-assessments and full factorial results of the correlation analysis can be found in Appendix B. This suggests that teachers did not use different metaphor modalities simply due to their ability to produce that modality mental image; rather, metaphors were chosen and used for other reasons, which became more apparent through thematic analysis:

5.2 How Metaphor Conveys Information

We defined four major themes which capture how metaphor works to convey information on sensory-based experiences and transfer knowledge. Abstract reference is useful in communicating experience through four key features: metaphor *relies on embodied experience, rather than pre-existing or domain specific knowledge*, *works independently of language, communicates core components and limits unnecessary detail*, and *uses intentional ambiguity to enable individual sense-making*. These themes demonstrate how metaphor is able to convey information by using experiences independent of the target context to remove the need for pre-existing knowledge of a new task. Metaphor also operates on a higher, conceptual level of understanding, meaning that the exact language and reference provided does not need to be definite; rather, the metaphor can be flexible and adapted to capture the conceptual understanding in a variety of references. Because of this flexibility, teachers are able to adapt the references depending on the needs of their students and negotiate a mapping which functions between their shared experiences. At the same time, the metaphors also require the limiting of what is communicated; too much or too little information breaks the reference's ambiguity and flexibility, demonstrating that teachers and designers alike must choose what and how much information needs to be conveyed to achieve initial understanding. The themes together describe a process of how metaphor is created and used to negotiate information between the lived experience of the teacher and student:

5.2.1 Metaphor relies on embodied experience, rather than pre-existing or domain specific knowledge. Metaphors examined in this study focused on experience outside of the specific context, using tacit knowledge independent of singing; the teacher does not assume the student would already understand the specific vocal practice and rather relies on existing relationships with the body. For instance Participant (P) 12 uses an abstract reference of imaginary "*alien noses*" on the lower abdomen to teach her students proper breathing: *"...we talk about having a belt full of alien noses* *her hands come around her abdomen* *and when they're breathing in, the breathing [comes in here]... we really want to get that connection."* The breath is obviously not drawn in through the abdomen, but this metaphor directs awareness for a sensation which is likely not familiar — the singer must learn attention to breathing and careful control of tension in the diaphragm muscle. By creating an abstract image of the breathing outside the stomach, one can become aware of the tension in and movement of the muscle. As in this case, metaphor can be created when there are limited experiences to pull from, providing an evocative (and in this case, also humorous) image to communicate information. Although it may be hard to imagine what a specialised and new skill like diaphragmatic breathing feels like, we can, through proprioceptive senses and tacit knowledge, imagine what it might feel like if our noses were on our stomachs [95, 96].

Other metaphor directly references previous experiences from real-life; for instance, P10 mentioned her own teacher had used a metaphor of smelling potpourri to elicit the same breathing behaviour. This reference, although open-ended and not specifically discussing any particular sensations, allowed P10 to concentrate on the feeling of this breath and what she described as a "*buzz*" in her sinuses. She was able to apply her tacit knowledge to explore this new feeling in her face, but she did not understand exactly why the metaphor worked so well, expressing surprise that she could instantly understand: *"The first time my teacher said this. Oh, oh, my god. How do I feel it there? How does that work?"* The metaphor was not explained by P10's teacher, nor is it explained by P10 when

she uses it in her own, present-day voice lessons. The metaphor requires little explanation because the student will already have the embodied experience and imagery intact from similar lived experience to make this connection.

For P10, the goal is to create awareness of existing bodily knowledge by focusing on these sensations. This focus then becomes rooted in imagery [20, 65]: *"When you're learning something new - first you want to make things very conscious. Then the next step is to automatise it."* This aspect of metaphor use is highly applicable and already acknowledged in somaesthetic practice and design, particularly in exercises which explore body perception through representations in other sensory modalities [16, 19, 77]. This act of making things conscious implies that the awareness of the sensation already exists in some form, but that careful thought and introspective reflection are needed to bring it to the forefront [48]. The attention on details of experience also allows smaller individual gestures to be pulled from larger, embodied action paths [36, 39, 40]. Focus on the the experience helps us to understand the low-level movement and technique behind it [46].

The key benefit is that the metaphors require no existing knowledge of the task to work. None of the metaphors provided rely on understanding of particular concepts or even in a singular modality; in fact, while we might expect singers to heavily use metaphors based in auditory schema, auditory metaphors were barely used compared to visual and kinetic references. This indicates that metaphor goes against the notion of domain-specific knowledge; there is no precursor to understanding the metaphors. With a focus on tacit knowledge of the body, the metaphor can be used within different lived experience. In both an educational and design context, metaphor is a way of leveling the existing knowledge of the different parties in order to communicate. This is beneficial for example in design, which is never a truly solo activity; when working with stakeholders, other team members, or potential users with varying background, metaphor is useful in that it does not require a pre-existing understanding. The designer is not in a privileged position when sharing design and its process through metaphor. Consolidating knowledge into a generalised and non-precise communication allows for different perspectives to be understood on a level playing field.

5.2.2 Metaphor works independently of language. Another critical consideration is in the understanding that metaphor is not believed to be rooted in language, but rather in the body [33]. Although all of the voice teachers interviewed instruct primarily in English, the majority of the teachers in this study are dual- or even trilingual. With the understanding that some teachers may use or were taught with metaphors expressed in other languages as students, the interview prompted teachers to provide details on how the metaphor might be expressed in the original language. None of the teachers provided metaphors in another language; when asked about their own vocal training in other languages, the responses were along the lines of *"Well, I guess it's the same [in the native language],"* (P1). P10 elaborated further *"I know how it feels for me when I do this, so I just express that feeling in English."* While metaphor may be expressed often through language (e.g., linguistic metaphor), the underlying schema is rooted in understanding of the body [66]. Cross-cultural examination of metaphor suggests that patterns of metaphorical understanding are common across languages and that the power of the underlying schema is rooted in embodiment, creating some mutual understanding across human backgrounds [33].

This directly demonstrates how tacit knowledge can supersede language; although our communication is often expressed through language, the understanding is rooted somewhere in a wordless knowledge of the body. In a design space, this highlights how metaphor can assist understanding between individuals. The language is less important than the underlying information. To use another metaphor, *the map is not the terrain:* Metaphor is not the experience itself, but rather a tool for articulating and representing that experience in an understandable way. This of course can take the form of language, but representations through other modalities might also be applicable and there are multiple formats which can be used to reach the same end information [6, 103]. This also highlights the importance of wordless characterisation of experience in tools such as body mapping. With the internalised awareness of our experience, it is possible for us to divulge details in color, shape, texture, and other non-linguistic based communication [16]. It is therefore advantageous to pay attention to these unifying, cross-cultural schema when we find them; by providing wordless modalities of expression, we open understanding to other humans. This enables us to communicate experience without the need to find the perfect, specific vocabulary, or explain nuanced details.

5.2.3 Metaphor communicates core components and limits unnecessary detail. The teachers in this study demonstrated that information is conveyed by making conscious decisions on what components are necessary to create understanding and what should be deliberately withheld to avoid confusion. The vast majority of voice teachers do not have explicit anatomical knowledge about how their body works [11]. In fact, many teachers do not desire to have more knowledge of voice physiology or teach it to students [58], seeing it as a distraction and *"information overload"* (P10) for most students. During the interview, the final question asked teachers whether they felt it was more beneficial to use explicit information or stay strictly in the metaphorical domain, or some combination of both. None of the teachers felt that physiology should be taught to students; although a few (3 out of the 12) had researched it themselves, they all felt the teacher's responsibility to convey the information to the student in a metaphor-based and sensory-focused way, aiming for function within the body itself and providing a way to understand technical terminology through images [107]. P11 stated that there must be some degree of trust in what we feel: *"The body knows how to do this!..."* The body knows best, and we do not need to know how everything works anatomically to understand how it should feel. P5 commented that *"I think we we do run the risk of saying too much... you spend most of your time trying to dampen it down, [to] get students to not work so hard on trying to understand it all. Just function better."*

We see here that teachers make conscious decisions on what information is necessary in communication. Vocal pedagogy existed before any refined understanding of anatomy and many accomplished singers have no understanding of the physiological processes of creating sound. It is important that we as HCI researchers and designers acknowledge this as well; decisions must be made about what level of understanding is necessary. As well, we do run

the risk of over-engineering systems and providing too many details to the end user. In many cases, understanding and association of action and result can be achieved without fully explaining the interaction. To some degree, we must trust the body and the interpretation of others. When we are able to focus on language which conveys only what is necessary, we can provide clear interaction paradigms which do not aim to explain or describe, but rather to guide another individual to an understanding contextualised for their own perception.

5.2.4 Metaphor uses intentional ambiguity to enable individual sense-making. The use of non-precise communication provides a way of sharing experience. Metaphor relies heavily on the ambiguity of the references, which are intentionally vague or not explained. Ambiguity is used to benefit the student's mapping to inherent knowledge of their body and outside experiences to new tasks. *Metaphors are not concepts*; rather, the underlying schema are mapped to new information and feedback. The teachers do not aim to describe, but rather to approximate sensations based on their own understanding. Often, these metaphors are open-ended and allow the student to interpret them with minimal guidance. Because metaphors do not have meaning in themselves, but rather convey meaning, there is no singular perfect metaphor to use when describing a sensation or experience. Desktop Metaphor aimed to mimic real-world objects to allow office workers to apply their knowledge to computers; however, the *Save* icon remains a floppy disk, with many computer users having grown up in the time after its existence. This prompted a well-known joke about someone having "3D-printed the 'Save' icon" when seeing one in real-life for the first time [28] and also suggests that metaphor works not because it represents something physical, but rather that meaning can be interpreted based on use and lived experience.

This is consistent from a phenomenological or hermeneutic perspective. Different teachers, experiencing movement in their individual bodies and with different backgrounds, will all have different perception of performing the same task [21, 67, 99]. The understanding of own experiences comes from teachers' lived experience and first-person reflection [46, 49, 76]. Ambiguity in the metaphors provides a means for translation of this understanding to their students. For instance, P4, P5, P11, and P12 all use the word "*spinning*," paired with a circular hand movement to represent movement of the air continuously out of the body over a period of time. The idea of spinning air is not particularly nuanced in its description, but this is a popular metaphor in reference to airflow. The first author has also heard this term a number of times. The lack of detail means that students can apply their own interpretations to match the sensations they experience while performing breathing exercises. All metaphors by definition have this characteristic of subjectivity, similar to the resulting sensory experience.

Using tacit knowledge, this ambiguity becomes personally applicable. Instead of directing a student on what a sensory experience should consist of, the teacher uses the metaphor to induce relevant sensations in their students [70]. For instance, the use of the "*marionette*," or the "*puppet on a string*" as a metaphor for posturing is used by P4, P10, P12, P22, and P24. By providing this metaphor, the teacher can help the student to bring awareness to the posture starting from the head down. Although not having experienced the sensation first-hand, the imagination of the lifting of the neck, back, and arms is possible through tacit knowledge. The student is then free to interpret their own sensations of lengthening the spine and aligning their neck, without any other prompting or explanations from the teacher. In this way, the teacher can cause a sensorimotor reaction for the student without needing to verbally describe their own specific internal sensations of alignment. The metaphor is connected with the sensory feedback and becomes a way for the student to understand the new experience.

Ambiguity in this communication, as in design, allows for personal investment and relationships with our interactions [32]. We must allow the learner or user to internalise information in their own sensory language by finding balance between describing, showing, and guiding through metaphor. The material taught in the lesson is shaped by the individual and becomes a part of self-understanding [104]. Rather than creating a one-sensation-fits-all model or forcing a sensation from their own perspective, teachers understand that metaphors must be adapted if they do not work effectively. For instance, P4 works as an Estill Master Trainer — Estill voice theory relies heavily on body sensation, incorporation of sensory experience from other life, and kinetic representation of vocal technique. As well, this teacher was quite passionate about their use of kinetic metaphors and representation during the interview process: *"And for me, you know, this like 'sing more or think more blue, think more orange.' It never worked for me. I was like, What is he saying? What does it mean?... You need to practice the sensations and connect them to the physiology..."*. Although the kinetic sensations are the focus of and compose most of the specific pedagogy she uses, she further elaborated that she takes cues off her students and tailors the metaphor around their understanding. When working with students who have difficulty using kinetic representations or are not used to maintaining attention to physical sensations, she will switch to other references provided by the student and negotiate between the two: *"If singing on a pink fluffy cloud does it for you and is your metaphor to trigger you into that [behaviour] every time? Do it."* She uses other trigger words from the students' own recounting of a behaviour, like *"tuck"* for posture alignment, to reference the process back to the student in their own words and then reconnecting it to new kinetic sensations in her own pedagogy. There can be no single-user approach to sensation or communication of experience [89]. By taking into consideration the modality in which we represent these interactions, how people relate to their environment and their body, and how this is impacted by past experience and other societal factors, the student or user ideally will be able to come to their own interpretation, rooted in their own internal awareness of their body

P17 describes that *"It's a feeling that they can hold on to, and they can return to [it] and they know how to return to [it]... you know where to go to get to that that place... to record this feeling by using your your eyes and using your sense of touch."* We may not have a detailed, verbal way of explaining what we do, but we know how to get there, what it feels like, and how to return to it later through recall of the mental images we form in interaction. As in the case of P10 and their potpourri, the sensation came without understanding why. We see many cases of teachers not exactly understanding why a metaphor works but knowing that it does through the awareness of a sensation. Understanding the differences in individual

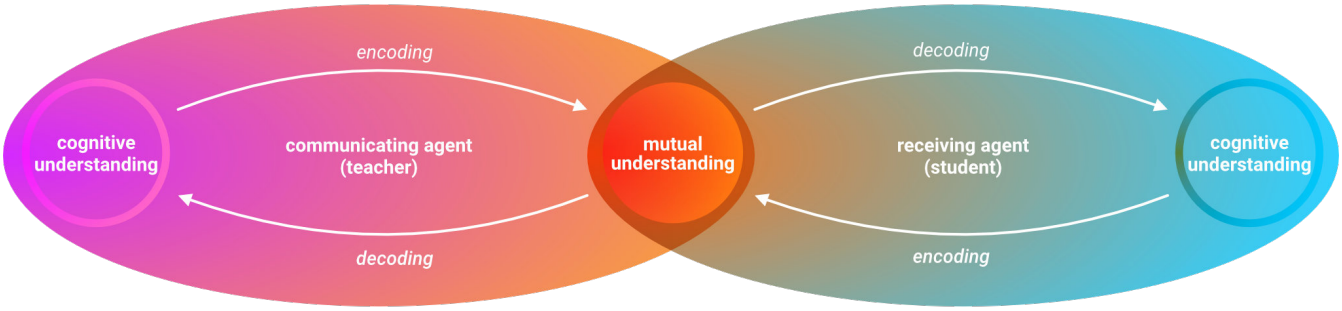

Figure 2: A model of metaphor communication, derived from this study, demonstrating how metaphor negotiates information between individual lived experiences. The larger bubbles represent the lived experience of the communicating agent (left, pink) and the receiving agent (right, blue). Metaphor is represented by the arrows, which unite elements of lived experience in mutual understanding by the two parties.

perception to metaphor can lead to increased communication during design. As done in body mapping and other somatic practices, the study of our reaction to another person's sensory experience can reveal nuances of our own interaction [79]. Ambiguity could also be used as a tool for discussing meaning in HCI [32] to evoke a variety of perspectives and understanding between individuals in the design process. Through use of ambiguity, we can not only transfer knowledge between different understandings, but create personal connection to this knowledge rooted in individual bodies.

6 DISCUSSION

The examination of metaphors used by voice teachers in their lessons reveals why abstract metaphor is useful and necessary to communicate information, particularly about subjective embodied experience. These themes together demonstrate how mutual understanding of subjective, sensory experience is shared between individuals and further inform ways in which information can be communicated between humans and technological agents.

6.1 A Model of Metaphor-Based Communication

Based on these facets of metaphor learned from the voice teacher, we propose a refined look at how metaphor is negotiated between two human agents:

> Metaphor negotiates information between a communicating agent and a receiving agent using an abstract reference. The communicating agent (e.g., a teacher or designer) encodes information into metaphor, based on their lived experience. The metaphor is then decoded and internalised by the receiving agent (e.g., a student or end-user) into their own lived experience. This process is flexible, iterative, and manipulated by both parties.

The flexible, iterative nature of this model distinguishes it from our traditional views of metaphor in HCI. See also the visual representation in Figure 2.

In human-to-human communication, information is modulated between both the communicating and receiving agents; both teacher and student must adapt and revise the metaphor together to achieve mutual understanding. Although the responsibility of the adaptation is perhaps more on the communicating agent — the teacher, in this case — they are able to provide flexibility and update their reference to reach shared understanding. The metaphor is grounded in pre-linguistic tacit knowledge and leverages ambiguity to help the decoding of the reference. In fact, we see the metaphors themselves are very specific, providing evocative references, while being unrelated to the task at hand. The metaphors convey information by relying on embodied experience without the need for domain-specific knowledge or specific linguistic representations; rather, the communicating agent (e.g., a teacher or a designer) focuses communicating core components and uses ambiguity in the reference to translate their refined knowledge of the mechanics into the basis of shared knowledge and individual lived experience. This allows the communicating agent to provide a reference which can be understood by the receiving agent, who can further refine its exact meaning within their own understanding. The communicating agent does not assume the interpretation will be the same, focusing on flexible presentation of only what is essential to achieve understanding between the two's lived experiences.

Human agents can together adapt and revise this model, with the metaphor acting as a conduit for exchanging knowledge. Currently, technological communicating agents struggle to produce this flexibility and reactivity, using non-dynamic references and hard-coded metaphor. These are dictated by the designer, who must make a decision on the "best" way to convey this information. The onus is on the receiving agent to interpret and decode this reference appropriately. This means the computer's expression is, in some way, assumed as "truth" that the user should know. Comparatively, as seen with the adaptation of metaphor by P4 in Section 5.2.4, the onus is rather on the communicating agent to put together the receiving agent's understanding and come up with cues and references which function well. Although objective information might be communicated effectively, as seen in icons and Desktop Metaphor, subjective information is lost in assuming individual experience will lead to the same interpretation. Rigid conceptual metaphors have a limitation in how far the concept can be taken [87]. Data represented in this way might fall into some of the pitfalls

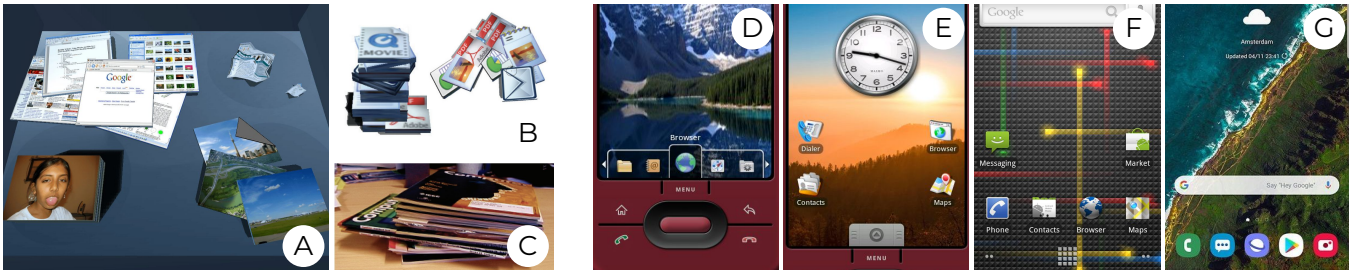

Figure 3: Some designs, both inside and outside of academia, expand on the Desktop Metaphor (left); for example, BumpTop's virtual 3D desktops (a) and literal stacking and piling metaphors (b, c) [1]. Android (right) used metaphors much more loosely: The app menu was originally accessed through a physical button (d), then a drawer metaphor (e), and then by clicking an iconic representation of the menu (f), before abandoning visual metaphor all together and using a swipe gesture instead (g).

of the Quantified Self paradigm, leading human receiving agents to misinterpret aspects about themselves or allow the technological communicating agent to overgeneralise their experience [82].

6.2 Expanding the Concept of Metaphor in HCI

If we think of metaphor in its contemporary sense as a flexible mapping of information between one modality and another, we can explore a variety of applications in a new light. Metaphor works not because it is a depiction of reality, but because of lived experience. This leads to an interesting challenge in HCI; while being ambiguous, we must also specifically appeal to individual lived experience. Traditional models of human input of parameter space resulting in machine output as calculation and "truth" are changing rapidly. In cases of sensory experience, we no longer assume there is a ground truth between different bodies. As well, technological agency means that the designer may not always be dictating the metaphor or information communication. We see as well a switch in the roles of human and technology agents in metaphor communication, for instance in the growing popularity of generative art through tools like Dall-E and Midjourney. In these cases, AI must interpret often abstract and ambiguous human input in a non-objective way and come up with a similarly ambiguous result. This, vocal pedagogy metaphor, is a bi-directional and iterative interaction wherein the abstract representation is exchanged and updated until the computer and human agree on the result.

Existing practices such as body mapping also depict metaphor's role in helping us to understand aspects of subjective experience. The next step is in conveying this information in a relatable way. Metaphor can be used to explore this negotiation of mutual understanding. This has been the focus of recent work in sensory translation [98, 109] and data narratives. For instance, research has focused on how audiences can be supported in learning and responding to data in expressed in narrative sonification [108] and visualisation [22], which act as metaphor to express data. Material experiences have focused on similar interactions, for instance between Friske et al.'s "maker" and "interpreter" in interpreting and re-making personal data [29]; this dynamic might be thought of as a specific instance of physical and sonic materials as metaphor, being used to negotiate understanding between the maker as the communicating agent and the interpreter as the receiving agent. This practice further fits into this revised model of metaphor, allowing narratives based in individual experiences to entangle and co-exist. Taking additional steps to focus on conceptual mappings and using ambiguity and non-domain specific knowledge, as done by the teachers here, can potentially increase understanding in these instances.

With this model, we can return to address our understanding of metaphor in HCI. The proposed model answers the *why* components of the functionality of contemporary metaphors, as outlined by Lakoff and Johnson and Barr et al. In line with the existing taxonomy, we can address strategies to create and evaluate metaphor in HCI, regardless of their specific type. This model also provides a missing connection to several existing taxonomies of metaphor; although we do not endeavor to explore or unify the existing classifications of metaphor and theories about their categorisation, our contribution to this space is a general model of the functionality of metaphor and how information transfer for metaphor as a whole. Together, the research space then outlines *what* constitutes a metaphor and the kinds of metaphor entailments and mappings that can be used, and now also *how* and *why* metaphors are able to provide these connections.

In terms of practical implementation, this model aligns well with other existing taxonomies of data representation and helps to describe some strategies suggested for creating metaphors in design. In their models of data visualisation, Zhao and Vande Moere include three key components for implementation: 1) the metaphor must be easy to identify, 2) the metaphor must have both 'motor' and 'cultural' affordance which provides structure for interaction, and 3) the metaphor must be intuitive and function without prior training [110]. Our proposed model of metaphor-based information transfer captures these components as they function together: the metaphor should not require any pre-existing domain-specific knowledge because the schema it relies on exist already in embodied understanding, shaped by cultural and functional experience from other instances in life. Our model of metaphor-based information transfer also aligns with Nesbitt's MS-Taxonomy, demonstrating that there are shared mapping characteristics independent of modality[75]; being based on cognitive schema, the resulting metaphor can be adapted and reused, and indeed re-articulated through different modalities as needed for communication between agents with different lived experience.

Figure 4: The Heart Sounds Bench (a,c) allows one or two people to sit together (b,c) and, with the help of stethoscopes connected to the inside of the bench (d), listen to a sonification of their heartbeats [52]. Photos used with permission of Howell et al.

6.3 Operationalising Metaphor in Design

A skeptical reader at this point might ask what the utility of this work is: We do not offer any solutions to problems in this paper, nor do we provide concrete design recommendations for future work. However, there are other ways in which such a theoretical contribution as ours contributes to design in HCI, providing the direction for future work within design research. Oulasivirta and Hornbæk highlight that one of the roles of theory in design is to "redefine problems and sensitize designers to the design problem" [81]. This is also the intention behind this work. We wish to invite designers and researchers to take a step back and re-evaluate what we believe to know about metaphor. In doing so, we provide a theoretical contribution [105] by updating the accepted relationship between agents and metaphors (c.f., [105]), and by suggesting that Metaphor is a continuous, mutually iterative, and reflective process, rather than a unidirectional and discrete phenomena, as suggested, for example, by Dunbar-Wells in the vocal pedagogy context [24].

6.3.1 Evaluating communication strategies in traditional interfaces. These updated, evolving relationships between agents and metaphor in the proposed model can help us think about metaphor use in traditional HCI. To highlight this, let us reflect back on the development of Android phones and the idea of 3D naturalistic desktop interfaces: Both emerged in the mid to late 2000s, and, while Android phones are still with us, the idea of a 3D virtual desktop operating system appears somewhat absurd from today's point of view. Focusing only on the use of metaphor, this might be surprising, as the 3D desktop is a direct continuation of an existing, successful metaphor with a clear, easy-to-understand analogy [1, 14]. Android phones, on the other hand, do not use such a clear metaphor; in fact, over the multiple iterations of the Android software, the metaphors used have often radically changed [83].

Both observations can be explained with our model. For example, 3D and physics-based desktop systems attempted to improve interaction by adding naturalistic detail (Figure 3a) and leveraging specific knowledge of the world, such as the behavior of stacks of documents (Figure 3b and c). As we have shown, this added fidelity and incorporation of domain specific knowledge is not necessarily something that improves the usage of metaphor. By removing the ambiguity of less naturalistic implementations present in desktop methods, the ambiguity required for individual sense-making is lost. Therefore, looking at the usage of metaphor alone, our model suggests why these trends did not catch on.

Looking at the Android UI — for instance, the metaphor for accessing the app drawer — we see that, over time, it has used a physical button (Figure 3d), a literal drawer metaphor requiring sliding to open (Figure 3e), a virtual button visualized as an iconic representation of the app drawer (Figure 3f), or no visual metaphor at all (Figure 3g). Without further reflection, such inconsistent metaphors might appear problematic. However, our proposed model suggests that a metaphor's content is secondary to its function of fostering mutual understanding. Designers are free to adapt the metaphor for accessing the app drawer as the underlying understanding (the existence of an app drawer that can be accessed from the home screen) is never disrupted. This same underlying understanding makes it effortless for users to adapt to changing metaphors as Android versions change. This example also highlights that the iterative process described in the proposed model can exist on multiple time-scales, in this case spanning more than a decade.

6.3.2 Evaluating design probes with a metaphor-based communication model. In addition to re-examining the design process and metaphor communication, this model helps to understand existing designs. We believe this model will be especially beneficial to those focused on subjective experience and sensory-emotional communication. The data representations in somaesthetic design and projects like those mentioned in Section 2.2 are indeed metaphor, and this is easy to see when using our model as a framework for examining the communication in these designs. Designers and researchers may find it helpful to apply this new model of metaphor-based communication when examining such probes and the design process:

Howell et al.'s Heart Sounds Bench allows people to sit together and, with the help of stethoscopes connected to the inside of the bench, listen to the sound of their heartbeats (Figure 4). Their unfiltered and noisy heartbeat sounds can be heard by the others sitting on and around the bench, an auditory metaphor of the heartbeat representing life and connection between people [52].

Aligned with our model of metaphor communication, we see how the sonification *relies on embodied experience*: the visceral discomfort that can arise when hearing one's own heart beat and vulnerability in sharing an intimate source of data with others.

As well, there are cultural and emotional components — love, excitement, nervousness — associated with heartbeat sounds. The sonification *works independently of language*, relying on conceptual understanding of the heartbeat as a source of life energy, and *communicates core components while limiting unnecessary detail*. Other aspects of the heartbeat, such as its rate, might have provided objective information about someone on the bench; rather, the sonification *uses intentional ambiguity to enable individual sense-making* of that person and their emotional state.

Such designs are successful at communicating subjective experience about the self and soma. In this very brief examination, we have outlined how aspects of the design might be using metaphorical affordances to convey the goals of the designers. Often, decisions made in design are made based on implicit understanding and feeling; using this model in Research through Design practice helps examine these communication practices and underpin their substance and the *why* in interaction approaches. In this way, this model helps to provide a language for describing communication strategies and how information is negotiated between agents. Approaches and underlying schema and concepts can then be identified and abstracted beyond their individual instances for use by other designers. The model as used here provides a tool to investigate strong concepts within intermediate-level knowledge[50]. Future work examining data representation strategies and how they evolve over the design process will likely add to the basis of strong concepts which can be used by other designers. Focus on the interactive aspects of designs and *why* designs effectively communicate can help to further ground the specifics of individual experience, knowledge, and understanding within higher level theory of communication.

7 CONCLUSION

This paper presents a study of metaphor as it is used to negotiate understanding between communicating and receiving agents — specifically, voice teachers and their students in the context of the voice lesson. Drawing on existing examination of metaphor and taxonomies of its use in HCI, we focus on *how* metaphor is able to communicate experience. We present a thematic analysis to demonstrate that metaphor functions not because of its grounding in reality, but rather in embodied experience. Due to its flexibility, ambiguity, and non-domain specific context, metaphor is able to unite individual lived experience. Based on these findings, we demonstrate a model of metaphor which addresses the history of HCI metaphors and brings them into modern HCI perspectives of individuality and plurality of experience. Through this model, we demonstrate why metaphor works and how its role in human-to-human interaction can inform better communication and understanding between human and technological agents.

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A INTERVIEW SCRIPT & PROMPTS

The interview was designed to take approximately 30 minutes, but is open to last as long as the participant wants to discuss their teaching methods or background in vocal pedagogy. The following were used as prompts for the interviews:

Intro & Background Questions:

This portion of the interview is just to get a general background of your teaching and singing career.

(1) How long have you been singing, approximately? E.g., is it something you have always done, or did you develop an interest in it later?
(2) What is your own most predominant style/what musical style do you most enjoy singing?
(3) Are you regularly performing?
(4) How long have you been teaching, approximately?
(5) What style(s) do you predominantly teach?
(6) Have you studied teaching practices (voice or otherwise) or have any certifications?

How You Learned to Sing:

I want to know more about how you learned when you were a student. When you were a beginning voice student...

(7) At what age did you have your first one-to-one voice instruction?
(8) Do you remember your teacher using any metaphorical language in the voice lesson, especially any that stuck with you? (*this is to encourage teachers to think about some of the more evocative metaphors they have heard and to get them into thinking of and remembering the abstract references they had heard as students.*
(9) Did your teacher include voice physiology in the lesson? If yes, to what extent did your teacher discuss/show/mention physiological technique?
(10) How might your teacher have described these fundamental techniques to you?:
    - Supported breathing?
    - Body posture and avoiding tension or strain (particularly in the neck or the larynx)?
    - Sound production in the larynx?
    - Resonance spaces and shaping vowels/mouth space?

How You Teach Others to Sing:

Let's now go through metaphors as if you were teaching a beginner student. You can instruct to me, as if I'm a beginner voice student, on the following metaphors:

(11) How would you instruct on:
    - Supported breathing; for instance, if I'm using too much air too quickly and don't have good control over my airflow?
    - Body posture; for instance, if I'm slouching and maybe have my shoulders rolled forward?
    - Avoiding tension; for instance, if I've locked my muscles or if I'm reaching with my chin and getting pinched sound when I sing high notes?
    - Resonance; for instance, I'm struggling to project my sound or I'm not shaping my vowels well and I've started to sing through a nasal sound?
(12) In general, what is your feeling on the use of metaphor in voice education compared to physiology?
(13) Would you prefer physiology or metaphor used more often/less often, or in some combination?
(14) How do you feel physiological and metaphorical instruction might benefit or detract from the lesson?

B IMAGERY MODALITIES AND METAPHOR

Imagery Self-Assessments

MIQ-3			
Pt	**Internal Visual**	**External Visual**	**Kinesthetic**
1	6.00	6.25	5.75
4	4.75	6.00	3.75
5	6.00	6.00	6.25
8	5.00	6.00	3.25
10	7.00	6.00	6.50
11	5.50	6.75	6.75
12	6.75	6.00	5.00
17	5.00	5.00	5.75
18	6.50	6.75	6.00
19	5.75	6.50	5.50
22	5.75	5.75	5.75
24	6.50	5.75	5.75
M	5.88	6.06	5.50
SD	0.73	0.478	1.04

Table 1: Participant self-assessed scores kinaesthetic and visual ability scores on the MIQ-3.

BAIS		
Pt	**Auditory Vividness**	**Auditory Control**
1	4.00	5.14
4	5.42	4.86
5	5.14	4.36
8	4.36	4.64
10	6.07	5.79
11	6.43	6.71
12	5.57	4.93
17	4.07	4.14
18	6.71	6.86
19	6.00	6.57
22	5.93	5.64
24	6.50	6.79
M	5.52	5.54
SD	0.94	0.99

Table 2: Participant self-assessed auditory imagery ability scores on the BAIS.

Correlates Between Imagery Assessment and Imagery Modalities

Imagery Type	**Scale Measure**	S	ρ	p
Visual	Internal Visual	179.06	.37	.23
	External Visual	382.97	-.34	.28
Kinetic	Kinaesthetic	246.74	.14	.67
Auditory	Auditory Vividness	271.85	.05	.88
	Auditory Control	215.25	.25	.44

Table 3: Results of Spearman's Ranked Correlation testing. There were no significant correlations between self-assessed imagery ability and the metaphor modality used. ρ represents the strength of the correlation, the p value represents its statistical significance.