Look! It's moving! Is it alive? How movement affects humans' affinity to living and non-living entities.

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Abstract—This article is about the relation between human observers and various human and non-human entities. Our focus is on humans' perception of movement. In particular how it affects the relationship to entities. We explore the way the movement of natural entities, locomoting animals and robots or the expressivity of dancers, play a vital part in our perception of these things. Humans' intuitive process of categorizing and attributing characteristics as a dialog and understanding of things, as found in the concept of metaphor, is central to our method.

Drawing from the linguistic concept of animacy, expressing how sentient or alive an entity is interpreted we propose a metric of quantitative measures to investigate whether conceptual boundaries of entities, like those between human and non-human, change when movement comes into play. By means of measuring subjective responses, the rating of features in relation to specific types of entities like humans, animals and machines, we develop and validate a measurement tool in two online surveys. In the first ($k = 93$), we determine particular regions for each type, and in the second ($k = 72$), we investigate whether these regions change when entities move. We present the methodology and empirical work. Our key findings are alongside the metric, an agency-framework informed by related work to locate shifts in participants' interpretation as degrees of animacy and agency ranging from intentional action to causal movement. We provide results demonstrating the effect of participants' interpretation of entities under two conditions, represented either static or dynamic, we can show that movement affects participants' interpretation. For example the shift of a human represented with mechanical movement, by virtue of breakdancing moves, towards the region designated to machines.

Index Terms—Animacy, Expressiveness, Language, Metaphors, Motion Perception, Nonverbal Communication, Quantitative Methods.

✦

1 INTRODUCTION

THE primary motivation for the work presented here comes from observations made during an exhibition featuring an artwork created by the first author. In the exhibition, an everyday object – a technologically modified hairbrush placed on a plinth – suddenly metamorphosed into a crawling animal-like robotic creature[1]. Observers' reactions to the hairbrush's movement ranged from refusing to favouring the object. Audience members reacted with cries of astonishment and comments like "creepy," "eerie," "almost like an animal," or "it is trying to commit suicide?" when the brush crawled towards the edge of its plinth. Furthermore, the work lead into discussion with visitors about their relations with objects and machines and elicited personal stories. One of the visitors revealed being an owner of a Roomba™ vacuum cleaner robot. She explained that she quite enjoys watching the robot not only because its is doing the job, but also because the "robot seems so lively, as it is doing something or other all the time."

The aim of this work is to understand how the observation of movement motivates changes in peoples' affinity towards an entity. To approach this we employ a linguistic strategy using language to indicate expressions of attitudes or

emotions as found in the responses to the crawling hairbrush or the Roomba robots' cleaning boogie. Emanating from humans attraction to the dynamic form of things (expressivity), the attribution of characteristics to entities (metaphors), derived from our dialogical nature and motivated by our ability to enter into relationships with our surroundings and make meaning is considered as a crucial concept in understanding how people relate to entities.

In the context section, we look at this relationship through various concepts and examples from literature and animation to show how language indicates differences in our affective relationship along the lines of interpreting an entity as animate or inanimate (animacy). Furthermore, we present movement (agency) as one of the primary elements in founding that relationship and conceptual ambiguities as a stylistic device to affect the relationship.

We then survey related work, mainly from cognitive psychology, with a focus on anthropomorphism and primarily using traits or descriptions to determine observers attribution of characteristics to human and non-human agents. These are then complemented with considerations of different forms of movement and how they affect people's affinity and interpretation, stemming from developmental psychology, computer graphic animation and human-robot interaction (HRI). The findings are transferred into an *agency-framework* to highlight observed movements, structures and kinematics as potentially being interpreted as animate or inanimate.

The resulting *agency-framework* developed here affords a conceptual structure that may be used to evaluate the

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1. See *Uruca Caliandrum* documentation: http://hasa-labs.org/orbit_en/uruca_caliandrum.php

varieties of interpretations investigated in two empirical studies. The method established and informed by the studies provides a computational approach to assess interpretative relationships of subjects to various images of entities as an attribution of qualities or features, developed in **Study A**. The features are used to built ontological categories representative for humans, animals, and machines. The result is a feature-space with three designated regions acting as a measurement tool. **Study B** subsequently provides measures for the effect of movement as the displacement of participants' response to static or dynamic representation of entities therein. Computing the subjective responses we can represent processed information using geometrical structure to indicate shifts in participants' interpretation in form of distances between the different interpretations of the entities in relation to the categories. These results are represented graphically by Principal Component Analysis and numerically by a triple of typicality-displacement in relation to the three regions.

The metric established in the methodology and informed by **Study A** and **B** could also be used as a quantitative method for analysing affects in subjective experiences of art installations, performances, or sculptural artworks, as well as in human-robot interaction.

2 CONTEXT

The aim of this section, which provides examples from literature and animation and associated concepts, is twofold. One goal is to present movement, emanating from humans' attraction to the dynamic form of things, as one of the primary factors that provokes affection, as well as a stylistic device used by artists e.g. in cartoons, bringing a drawing to life. The other goal is to demonstrate how linguistic phenomena, in particular metaphor, can be devices to evoke, express and indicate emotions, as, for example, found in poetry. Conclusively this section provides the rational to use the sociolinguistic device of the metaphor as an indicator for changes in the affective relationship. In congruence to the follow up methodology and studies, apparent in differences of attributing features.

2.1 Expressiveness – primacy of movement

Langer characterizes *expressiveness* as the dynamic form that is apparent in the eye of the beholder as changing intensity of qualities through motion, like the funnel of water, a dance or the momentary efflorescence of a bursting rocket. The dynamic form disappears as soon as the motion stops or slows beyond a certain degree [1, p.18]. For her, expressive form is any perceptible or imaginable whole that exhibits a relationship of parts, qualities or aspects within the whole. All these inseparable elements of subjective reality compose the "inward life" of human beings.

Our own movement and the expressive form of things are intimately related [2]. We learn through our bodily interaction with the world which forms a system of intimate beliefs about the conception of animacy and artificiality of things in the world [3]. Within this relationship, the expressiveness of things is considered as an immediate experience. Carey recognizes the "knowledge of spatiotemporal continuity and cohesion" [4, p.96] as a core cognition that is not conceptual.

Likewise Ingold [5, p.68] acknowledges the primacy of movement conceiving it ontological prior to the properties projected onto things.

2.2 Metaphors – interpretative relationship

Langer [1, p.23] furthermore explains that if we want to name something that is too new to have a name, like a gadget we have not seen before or a newly discovered creature, or to express a relationship for which we have no connective word, we mention or describe it with something analogous.

Lakoff and Johnson [6] correspondingly determine that human purposes typically require us to impose artificial boundaries that make physical phenomena discrete. To deal rationally with our experience we create ontological metaphors, through our subjective responses and descriptions, that go beyond purely behavioural or dispositional inferences. For instance, the reactions to the hairbrush exemplify affection and how people wittingly or unwittingly assign capacities considered as distinctly animate to inanimate entities evoked by movement.

Interpreting non-human entities like the hairbrush as intending to commit suicide embodies attributing human form or a human mind to the entity. This is described in the concept of *anthropomorphism*, characterised by the creation of human-like agents out of nonhumans [7], as a special form of metaphor. In this process, Epley [8] identifies three major key determinants: *Sociality*, *Effectance*, and *Elicited Knowledge*. At the core of their model is a process of induction of elicited knowledge, using existing knowledge about ourself or from conversing with others to guide inferences about properties, characteristics and mental states of non-human agents. Influenced by two motivational factors: sociality, the need and desire to establish social connections with others and effectance, the need to interact effectively.

Seibt [9] questions the relation and interaction with the environment and objects as *anthropomorphism*. She brings to question whether 'anthropomorphism' is the right label for make-believe projections of this kind. Referring to Walton [10], she says that interpreting a natural thing or an artefact as a companion does not necessarily imply treating it as a human being. Instead she says that we generally have a long-standing practice of projecting social roles onto our surrounding as a way to socialize the world and not to anthropomorphise it. Correspondingly Attfield [11] and Turkle [12] foster an interpretative account of cultural objects by emphasizing the importance of social history of everyday life in our relation to objects and things.

However, in as far as *anthropomorphism* is an inductive process or interpretations in the form of make-believe projections, it resembles the concept of metaphors as "understanding and experiencing one kind of thing in terms of another" [6, p.5], as for instance demonstrated in the attribution of the hairbrush's alleged suicidal tendencies. Moreover, humans' capacity for conceptual representation involves conceptual changes as an intuitive process [4, p.3]. Within this process of interpretation, language has the potential to capture ontological commitments [4, p.35]. This is illustrated for instance in the following as divergence in the attribution of *animacy* and *agency*.

2.3 Animacy – animate-inanimate distinction

Animacy as a semantic principle and linguistic concept provides indications of how sentient or alive the referent of a word is interpreted. Its variation is a matter of gradient rather than a simple animate and inanimate binary [13, p.27]. From this perspective, differences in the use of words describing an entity's animacy indicate differences in its interpretation. They can also be considered as a stylistic device to express and evoke emotions or attitudes through language.

In this way it is of interest for example in poetic writing to find smiling or dancing flowers, angry or cruel winds [14] or jumping rainbows [15, p.53]. Ruskin, in opposition to anthropomorphism, termed this pathetic fallacy [16]. Correspondingly, writing "[t]he lamp was *staring* at him" [17, p.57] could be considered as stylistic device playing with *animacy* and the concomitant attribution of human emotions and conduct to a lamp. For literature theory *animacy* is of interest because manifest in language it indicates the characterization of a referent ranging from human, animate to inanimate [18, p.47]. For instance referring to the wind as "[h]e closed the door", "[t]he wind closed the door", "[t]he door was closed by the wind" [18, p.49]. Thus, in contrast to the previous example of the lamp, describing it in a more factual language, as "shining at him" embodies differences along the lines of portraying an entity more as animate or inanimate.

This game with *animacy*, what Eisenstein [15] determines the principle of poetry, is even more apparent when movement comes into play as he writes in reference to Disney's animations.

2.4 Agency – movement and action

Agency is intimately related to *animacy*, and likewise both are a matter of gradient [13, p.29]. In this sense, different degrees of *agency* are apparent for instance in different movements of a lamp. Consider the renowned Pixar desktop lamp *Luxo Jr.*[2] moving organically or mechanically, or as if moved by an external agency, shed light on its animacy.

Along these lines Rakison and Poulin-Dubois [20] characterizes the degree of an entity's *agency* as likely to being more the recipient or more the agent of an action. Gallagher and Zahavi [21, p.44] describe this divergence from a subjective/first person perspective: When I'm walking, I'm not only the owner of the experience — the sense that it is my body that is moving — I've also the sense of agency as being the initiator, which is to say the author of the action. In contrast, when being nudged by someone, the experience lacks authorship, as the cause for the action comes from outside. In equal measures, referring to grammar and language, Jackendoff distinguishes between actor and experiencer [22, cited by [23][3]].

Thus variances in the interpretation of an entity's movement as being the recipient or agent of an action provides evidence whether it is apparent as degrees of *agency* ranging from *involuntary movement* to *intentional action*. Hence, for instance an animated desktop lamp moving by itself has more agency, characterized by author and ownership both seem to reside within the entity, while when being involuntary

2. See [19, p.189] and https://en.wikipedia.org/wiki/Luxo_Jr.
3. The original source of [22] was not available to the authors.

moved by someone its agency is becoming less, characterized by the apparent divergence of authorship and ownership of the action.

2.5 Affective relationships – the principle of poetry

It is commonly accepted that our relation to inanimate objects is different than to biological entities. However this relation comprises conceptual ambiguities. The affect towards movement, the expressive form of entities, on the one hand can be considered as part of our survival kit to distinguish animate from inanimate [24, p.257], on the other, hand in hand with the latter, as exemplified above, it is the survival kit of poetry.

The principle of poetry lies in the potential to transfigure, to transform, comprising an inversion of familiar relations between animate and the world of things [15, p.30]. The lively behaviour of a Roomba robot described above, or a breakdancer moving in a mechanical way, could be taken as examples representing a particular ontological uncertainty [25]: the enactment of the animate vs. inanimate contradiction found in a puppet-as-object or a puppet-as-person [26].

Gaver et al. [27] underline ambiguity as a powerful resource that can promote personal relationships fuelled by curiosity and engagement. They differentiate *ambiguity* as the attribution of our interpretation of objects, from fuzziness or inconsistency, which are attributes of objects. "This interpretative relationship is the source of ambiguity's appeal: by thwarting easy interpretation, ambiguous situations require to participate in meaning making" [27, 235]. In this way interpreting a stimulus, like the movement of a puppet or a lamp, belonging to multiple ontological categories (object/live) could be a source of repulsion and attraction. Belonging simultaneously to multiple ontological categories can elicit a state of discomfort because it is ambiguous and conflicting [28]. Eisenstein in turn considers more the attraction, as a secret of the "comic mechanism" [15, p.65], as "the comical it to be found in the incompatibility of the one with the other" [15, p.37].

Conclusively, changes in our affective relationship generally could be attributed to our "individual's pursuit of meaning" [29, cited by [30, p.359]]. Our "innate tendency to focus on life and lifelike processes" [31, p.1] and our intuitive process of categorizing and attributing characteristics as a dialog and understanding of things, typically require us to impose artificial boundaries that make physical phenomena discrete. When interpreting the phenomenological experience of an entity, like the ambiguous behaviour of a familiar hairbrush or a lamp transforming into a biological subject, different metaphors come into play. These subjective responses apparent in metaphorical descriptions can be operationalized as expressing differences in the affective relationship towards an entity. Shifts in this interpretative relationship represented in the concepts of *animacy* and *agency* are central to our study.

3 RELATED WORK

In the previous section we highlighted metaphors as a sociolinguistic and stylistic device to provoke and indicate differences in terms of affect described in words as degrees

of animacy and agency. Accordingly, in this section we first look at studies examining participants' relationships to entities like humans, non-human animals and machines, mainly in terms of *anthropomorphism* evaluating conceptual changes based on feature attribution. Subsequently these are put alongside a body of work looking at differences in attributions as an effect of movement.

The aim is to amend the concepts of animacy and agency with research in social perception e.g., animation, using visual motion cues to probe observers' ability to discriminate animate from inanimate visual stimuli or HRI, using physical interaction to elicit different interpretations in observers. As a result these findings are composed into an *animacy-framework* to be used as a conceptual structure to frame and evaluate the consecutive empirical work.

3.1 Anthropomorphism – conceptual transitions

One of the motivations behind the design of our study was an unpublished technical report by Kiesler and Goetz [32]. To evaluate inanimate and mechanistic elements of "mental models", they set up a study comparing participants' responses to two versions of a questionnaire. By asking one group of respondents to rate the human-like qualities of attributes and another about machine-like qualities, they obtained a list in which the difference between the responses was assumed to reflect the manner in which traits where perceived.

Similarly, Waytz et al. [33] provided non-anthropomorphic (observable or functional features like "useful", "durable") and anthropomorphic traits ("seeing", "feeling") and asked people to rate them in response to non-human agents, concluding that individual differences in *anthropomorphism* exist and matter for creating an empathic connection with non-human agents, for judgements of responsibility and culpability, and for creating social influence. Using equal measures, Epley et al. [7] investigate differences in peoples' interpretation of entities like gadgets, gods and greyhounds. By having people rating five "anthropomorphic mental-states," e.g., the extent to which the gadget has "a mind of its own," "intentions," "free will," "consciousness," and "experiences emotions," they demonstrate that people tend to anthropomorphise non-human agents such as animals and gadgets, but also indicate tendencies of *dehumanization*, when people characterize human agents as non-human.

How dimensions of human social cognition are applied to non-human objects is demonstrated by Eyssel and Hegel [34]. Having people infer certain traits to different designs of a robot, their results indicate that participants applied gender stereotypes that typically characterize human-human social cognitive processes to robots.

The denial of human attributes to other people and likening them to non-humans (dehumanization) as a subtle and everyday phenomenon is supported by Loughnan and Haslam's work and findings [35]. By prompting people to do go/no-go association tasks of traits they assess differences among social categories of humans, 'other humans' and non-humans. The result indicate effects of *infrahumanization* and *self-humanizing*: people attribute fewer uniquely human emotions to others (out-groups) than to members of their group (in-group) and human-nature traits are attributed to the self more than to the others. Concluding that in our social perception dehumanizing and infrahumanizing is fundamental.

That people's intimacy to animals and objects similarly effect the relationship is shown by Kiesler et al. [36]. In a study comparing people's explanation of behaviours of dogs, fish or animated artefacts they provide evidence that being an owner prompts stronger psychological explanation, e.g., higher degree of attribution intentionality to the animals' behaviour and increasing emotional attachment.

3.2 Agency – measure effects of movement

As the concept of agency illustrated, an entity's movement characteristic affect the way thoughts and actions are directed to entities. In this respect Gelman et al. [37] recognize that the fundamental difference between whether events are identified along the lines of social and nonsocial is that the former involve animate objects, like people or animals, while the latter is referring to nonliving things.

Early exploration of conceptions and meaning attributed to the stimuli of movement originate from [38], [39], [40]. These works experimentally uncovered people's tendency to interpret observed action of simple objects or non-figurative unitary dots movements displayed on screens as apparent behaviour. In analogy to the concepts of animacy and agency illustrated in the Context section 2.3 above, they reveal that while some movements elicited "factual" or *inanimate* descriptions, others explain it more in "social" or *animate* terminology apparent in the use of attributions like motivations, emotions, age, gender and relationships to objects.

In the tradition of these early empirical works, using screen based animations, Blythe et al. [24] experimentally show that a single object's movement stripped away from all environmental context, posture and facial information is enough for people to differentiate motion cues from the *inanimate* domain of physical movement (causal) into the domain of *animate* intentions and desires such as chasing, playing and courting. Accordingly, Scholl and Tremoulet [41] demonstrate that an entities' simple motion cues like changes in velocity and direction in absence of any reference background can produce an impression of animacy. Similarly, using point-light displays Simion et al. [42, p.43] provide a perspective from developmental studies indicating that for several vertebrate species, including humans, the most obvious feature that distinguishes *animate* from *inanimate* *entities* is self-propelled motion, as opposed to objects that require external force in order to move. Their hypothesis that a primitive bias towards detecting social agents is innate is supported by an experiment by Mascalzoni et al. [43] demonstrating that newly-hatched chicks possess an innate sensitivity allowing them to differentiate and prefer a self-propelled causal agent (presented by screen/computer-based animation sequences) as a target for imprinting.

Mori [44] hypothesized that the presence of movement would affect the relation between human observers and figurative displays of entities, e.g. puppets, robots, zombies or humans, and change the shape of his well-known uncanny valley. MacDorman [45] provides empirical evidence assessing participants' ratings in terms of parameters determined

to reassemble the uncanny valley (familiarity, strangeness and eeriness) towards video clips showing a spectrum of entities morphing from human to robot (e.g. from Philip K. Dick to Qrio). However as Zlotowski et al. [46] point out for the most part the morphed images are not realistic hence the result being rated as unfamiliar by participants is not surprising.

Equally to Mori's hypotheses of the primacy of movement, Vidal [25] identifies movement rather than any specific detail of the appearance as the main channel for the dialogue between an entity and humans. This is experimentally supported by Lehmann et al. [47], having people rating semantic pairs of traits in regard to a robot interacting with a human shown on a video screen. Their results illustrate that movement even if it is not socially engaging behaviour, facilitates the propensity of humans to ascribe intentions to agents (robotic objects) as activating the attribution of agency.

Similarly, Hendriks et al. [48] provide evidence that humans have a strong tendency to be cued by the behaviour of robots. In an experiment they had participants rating traits to videos of a vacuum cleaner robot to which five previously ascertained personality characteristics had been applied. Their result revealed that the perceived personality matches with the intended product personality.

Equally this is supported by the work of Bartneck et al. [49], focusing on embodiment by applying different behaviours to physical robots and evaluating participants facial expressions and hesitation to turn them off. Their results suggest that for the perception of a robot's animacy the behaviour is more important than its embodiment. Likewise Saerbeck and Bartneck's [50] findings, assessing participant's written responses to different animations applied to two robots, indicate that the same motion parameters applied to different robots are interpreted in the same emotional categories, e.g. all participants used emotional adjectives to describe the robots behaviour, independent of the difference in the physical appearance/setup.

Differences in movement characteristics are considered by Darling et al. [51]. They examined participants affect towards no movement and lifelike movements of little *Hexabug Nano* robot toys. They observed the influence on participants perceived animacy by measuring the subjects' hesitation time striking the robots with a hammer. No significant effect was found.

The predictability of a movement is a focal point in the work of Eyssel et al. [52]. They assess differences in participants' anthropomorphic interference in terms of attributions of traits to a short video showing a *Flobi* robot. The predictability of the robot's behaviour and participants' anticipation for future interaction with the robot (future-HRI) was modified by providing different descriptions of the robot (low vs. high predictability/no vs. anticipation of future-HRI) prior to the trait association task. Their findings indicate that when social relevance is increased through anticipation of an interaction, anthropomorphic interferences increase for predictable and unpredictable behaving robots, while unpredictable behaviour does not increase anthropomorphism when there's no interaction anticipated by the participants. Furthermore their finding that unpredictability leads to an increase of attention provides empirical support for the effect of ambiguity outlined in the Context section 2.5.

3.3 Assessing the interpretative relationship

Conclusively, participants' interpretations in these studies are predominantly assessed using traits or features to indicate to what degree an entity appears to have *agency* and *animacy*. These different degress are evident for example in potential shifts e.g., human to non-human (anthropomorphism) or vice versa dehumanizing humans, as a relational mapping from a source domain to a target domain analogously with the sociolinguistic device of metaphor [53, p.95]. In equal measure to the examples and concepts delineated in the Context section these works empirically disclose on the one hand the role of movement and on the other the use of language as an indicator for differences in the affective relationship as summarized in Figure 1.

The use of words for evaluation is controversial though, as pointed out by Gelman [54, p.159], in one of Stewart's studies [56] subjects responded by choosing between the attributions of 'alive creature,' 'non-alive object,' 'can't tell' which in turn were assigned degrees of *inanimacy* scores of 0, 1, and 2 for use in parametric analyses. However, 'non-alive' is a predicate that has multiple meanings, including 'dead' which is a predicate that can be used sensibly with animate noun phrases. In equal measures, Coeckelberg and Gunkel [57] indicate the very term "the animal" is not morally neutral but already makes a decision about the status of the animal. They refer to Derrida [58, p.41] denoting it "l'animot" in that respect, to call attention to the words potential of influencing and priming people's appreciation of an entity by applying the property of the category, e.g., animal. Coeckelberg and Gunkel furthermore identify the issue of understanding others, e.g., an alien creature, a sophisticated robot, a socially active computer, or even another human, is never a simple black/white or either/or issue rather than a matter of degree.

With this in mind, the framework we established is a relational approach on two levels. First, we establish a relationship between subjects and their interpretation of various entities using various features used to describe movement and behaviour. Second, participants' interpretation is not just a rating of accept the feature as true or false rather than coming with a scope of attribution ranging from "not at all" to "very much."

4 STUDIES

In general the work presented here is about subjective interpretations. In particular, it concerns metaphorical attribution of features to entities presented with and without movement. We attempt to assess to what degree an entity appears to an observer to have features of *agency* and *animacy* as outlined in the previous sections. We use the concept of metaphors as, in accordance with Duffy [59, p.181] who disagrees with [60], we think humans do not "mindlessly apply social rules and expectations to computers" [60, p.81] that provide an explanation of (a system's) behaviour such as people projecting intrinsic intentionality. To our mind, the observer's interpretation is not analysable in terms of any explanatory system of functional or intentional states of the object. Rather, it can only be interpreted as what it is like [61], because "nothing is metaphysically hidden. However ignorant we are of octopuses, aliens, and robots,
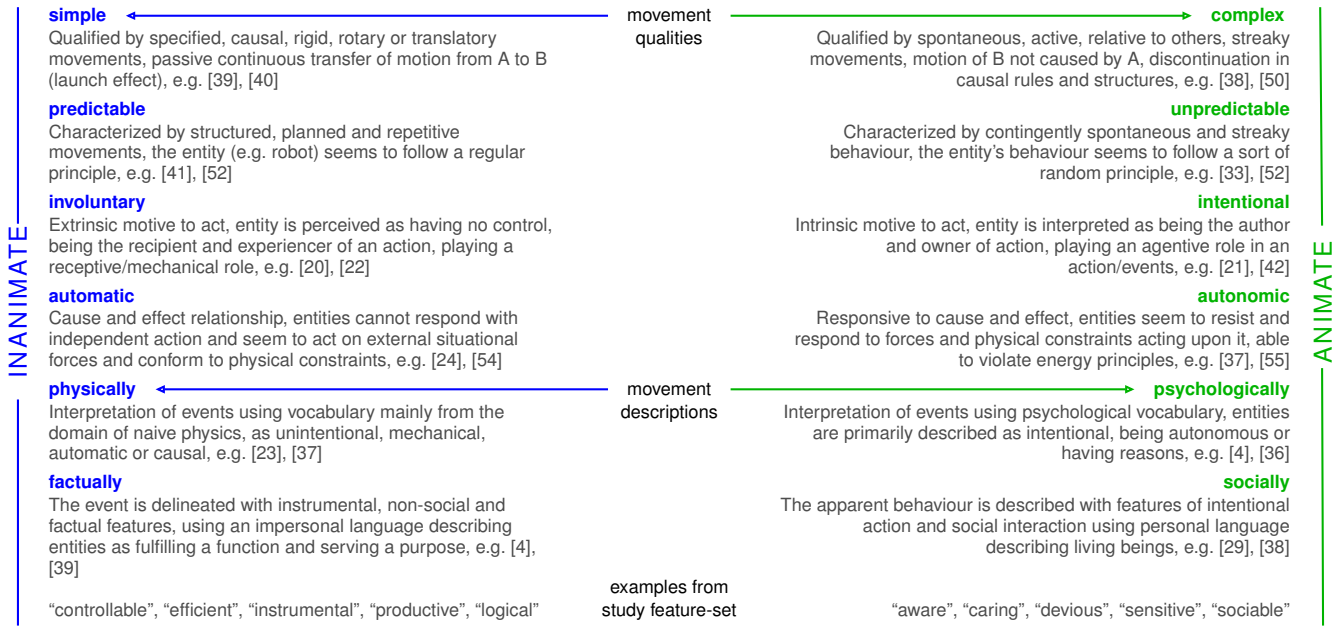
Fig. 1. Agency framework summarizing related works. The deployed topology provides dichotomies as degrees between animate and inanimate (horizontal) and organized by cognitive complexity from elementary non-figurative movement qualities to complex metaphors used to describe movement (vertical), to facilitate illustrating shifts in peoples interpretation of an entity's apparent action in terms of feature attributions comprising degrees of animacy and agency.

nothing about them is truly hidden from us, that is to say the other side of a metaphysical veil" [62, p.26].

These interpretations, methodologically grounded in "folk phenomenology [provide] description of experience stemming from subjective or first person analysis, which feels can be exported, with limited modification, to other experiencers of the same or similar phenomena" [63, p.3 referring to [64]]. In this way, computing subjective responses to various entities represented with and without movement results in intersubjective or shared features attributed to the representation of the entity under the specific condition. The relation between these shared features are subsequently calculated, compared and discussed.

To that effect this section reports two empirical studies based on quantitative methods to measure participants' relation to entities and potential perceptual shifts elicited by movement and behaviour.

In the fashion of Gärdenfors' theory of phenomenal conceptual spaces [65], aiming at describing the psychological structure of the perception and memories of humans and animals, the aim here is twofold. First, determine and compute observers subjective interpretations of various types of entities, like humans, animals, and machines. Second, represent them in a geometrical feature-space. Participants' responses were represented in geometrical structure, computed using Principal Component Analysis (PCA) and vector displacement. This method establishes a relational approach with the objective of obtaining a spatial representation. Hence it facilitates illustration and assessment of differences between participants' relationship to entities. This is measured as distances between interpretations of entities, and through shifts in similarity and dissimilarity between entities, to make judgements on how movement affects this relationship.

The methodology presented is informed and validated in two online studies, gathering subjects' responses to various pictures of entities represented with and without movement. Both studies used pictures and videos of humans, animals or machines to study if and how movement has an effect on people's understanding of living and non-living agents, as manifest in the concepts of agency and animacy. **Study A** provides the process to build and calibrate a feature-space based on a spatial representation of participants' interpretations obtained from ratings of different traits or features in response to images. The result provides a measurement tool for **Study B**, using the feature-space as a foundation, to examine the effect of movement, again using subject's responses to a subset of the features.

The research was approved by Queen Mary University of London's ethics committee. The participants provided their informed consent before seeing the presentation and responding to the questions.

4.1 Study A – Building and calibrating the feature-space

This study is motivated by the aim to built a *feature-space* using empirical data and computing the responses of subjects collected via an online study. This is carried out by means of collecting subjects' interpretations – rating of features on a Likert scale to image representations from categories of either humans, animals or machines. The choice of the categories of machines and humans emanated from work by [32] and was extended with animals following an email conversation with Sarah Kiesler. Processing the responses in respect to the *categories* results in a *feature-space* based on empirical data, to be used as a measurement tool for the follow up study. This

part requires three steps whose method and procedure we subsequently describe.

4.1.1 Step I – gather the data

The objective is to gather the data from subjects' interpretations, resulting from individual responses relating features to three different picture-sets representative for the categories of humans, animals and machines.

Method

To collect the data and build a feature-space, a study was carried out in an online framework. The data was acquired by showing each participant randomized one of three different picture-sets. Each set was based on 20 randomized pictures from one category of humans, animals or machines. Participants were asked to interpret a set of 70 features in regard to their picture set, by rating them on a Likert scale from 0-6. Distributing the picture-sets of each category equally over the participants served as a independent variable.

The categories are humans, animals and machines. Each picture set is a slide show of 20 randomized pictures representing exclusively that category. With the problematic terminology of the categories mentioned in the related work Section 3.3 in mind, an indirect method was deployed. Instead of using the terminology of the categories – e.g., asking "how human-like is this?" – picture sets representative of a category were displayed to avoid priming.

To group the picture sets of different categories, the *Golden Record* was used as a case history and model. The *Golden Record* was sent into the universe on-board the Voyager space probe in 1977, alongside other media, with a carefully assembled set of images selected with the intent to communicate our planet to extraterrestrials[4]. With the assistance of the United Nations Photo Library, which kindly gave access to their archive, certain pictures could be replaced with a more recent version.

The features are based on a set of traits, represented by 70 adjectives characteristic of human and non-human behaviour – e.g., caring, goal-driven, graceful, spontaneous, structured; the complete list is provided in Appendix Table 2. Some of the traits were motivated by Kiesler's [32] study; these were extended with items from work by Epley [8] and Waytz [33], such as: anthropomorphic traits like thoughtful, considerate, sympathetic; non-anthropomorphic traits or functional features like durable, useful, logical; furthermore false fillers taken from Fussel et al. [66] e.g. wooden or ceramic. We wished to avoid using items that have differential response format e.g. machinelike–humanlike or unfriendly–friendly, so as to not provide differential poles. This can be an issue in terms of priming as it facilitates identifying the underlying measuring dimension [67].

Subsequent to the presentation of the picture-set, with the statement, "To what extent are each of the attributes below applicable to your general impression of the images you have seen in the slide-show?", participants are invited to rate the features in response to the given picture-set on a Likert scale from 0-6 with three anchor points: 0 for "Not at all", 3 for "Undecided" and 6 for "Very Much".

4. Link to *Golden record* documentation: http://voyager.jpl.nasa.gov/spacecraft/goldenrec.html

Procedure

The participants' contributions where collected over three months within a Qualtrics framework, and amounted to a total of 126 respondents out of which $k = 93$ completed all questions. The remaining 33 were excluded as a result of missing or repetitive answers. From the selected 83, the age ranged from 18 to over 65, 49% between 35-54 and 40% in the 26-34 range, with 64% male, 31% female, 4% 'prefer not to say' and 1% other. With a total of $k = 93$ participants, individuals rating of the same set of features in response to images of one of the categories resulted in three different clusters or *regions*: human H ($k = 33$), animal A ($k = 29$) and machine M ($k = 31$). The framework was set to distribute the categories evenly over the participants, however, the disparity in these numbers results from the removal of respondents with not applicable (NA) values due to their missing out one or more ratings.

4.1.2 Step II – process the data to obtain the feature-space

The objective for this step is to locate a point for each participant in a multidimensional space, spanned by the features, and designate regions representing the categories of humans, animals and machines.

Method

This is carried out by calculating and geometrically representing the individuals' interpretation, resulting from the rating of the features in respect to the images. From this, a feature-space with designated regions for humans, animals and machines is obtained.

The feature-space consists of 70 dimensions, as there are 70 features, based on participant's ratings of the features in correspondence to the categories. Applying PCA allows to geometrically depict the allocation and designation of particular regions representing the humans, animals and machines categories in the feature-space.

The regions are determined by the three categories of the picture-sets: humans, animals and machines. The regions are allocated using the individuals' ratings of the features which correspond to the category of pictures shown to them.

Procedure

For each participant's rating, a point is allocated in a multidimensional feature-space with designated regions representing the responses to the picture-sets of either humans, animals and machines. PCA is used to represent individuals' responses in relation to the images in a geometrical structure with distinct regions for the categories as illustrated in Figure 2, here on the basis of the two most significant components.

In the feature-space, the points are coloured for each participant according to the category the person has rated with respect to the corresponding picture-set, resulting in regions for the categories of human, animal or machine. For elucidation a "normal probability ellipsoid" with a percentile of 68% is drawn around the regions for each category.

4.1.3 Step III – optimize the feature-space

This step provides instructions how to optimize the feature-space in two forms: First, a feature-reduction removes
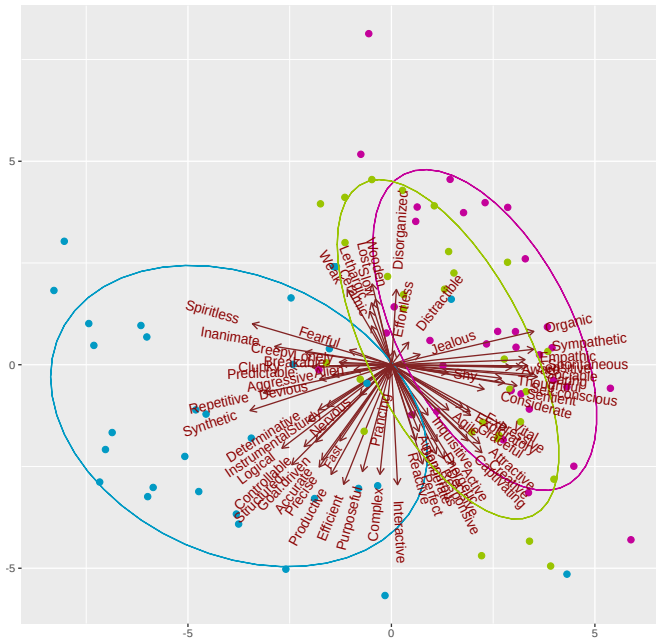
Fig. 2. The two principal components of the feature-space resulting from Study A, showing designated regions with their normal probability ellipsoids for the categories of humans (magenta), animals (green) and machines (blue). The brown vectors denote the eigenvectors for the individual named traits.

features that provide little information, to reduce the total number of features. Second, the mean-interpretation resulting from the centroids of each region-cluster is calculated as a measurement for further examinations of the space.

Method

The outlined method result in a feature-space of a geometrical structure with designated regions and their mean-interpretations to facilitate judgement of prospective shifts in the space. Furthermore, transposing the data results in a reduced feature-set by removing irrelevant features to optimize the time people spend on the rating.

The feature reduction is carried out using a greedy stepwise backward elimination method to remove irrelevant distractors and optimise the feature-space to the most significant/relevant features. The aim is to find correlations or featureless dimensions, e.g., by delineating the convergence of features like "goal-driven" and "purposeful".

To achieve this dimensionality reduction the feature-set is processed with a recursive feature elimination method provided by the machine learning software Weka [68]. By feeding the dimensions, the ratings of the 70 features, and the three categories as classifiers into Weka, a feature selection through backward elimination can be executed as follows: Weka's "greedy stepwise rejection" method [68, p.327] with a "CFS subset evaluator" [69] selects and removes *features* incrementally and concurrently with supervised learning based on classifiers, which are the categories here.

The mean interpretations are determined by calculating the centroid of each regions' cluster. With a sample-rate of k participants, and specified as mean-interpretation of that particular category, the resulting: *human mean-interpretation = $\hat{H}$,*
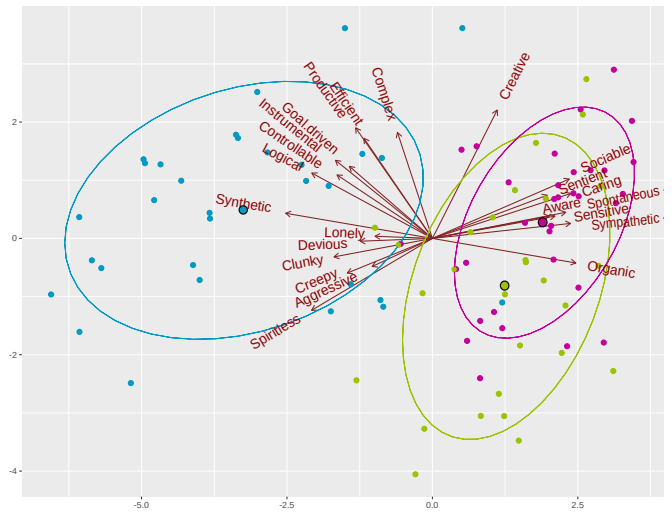

Fig. 3. The reduced feature-space, as a result of Study A, with designated regions, colored as before, and centroids (circled in black) representing mean-interpretations.

animals mean-interpretation = $\hat{A}$, machines mean-interpretation = $\hat{M}$ can be determined as in Equation 1.

$$\hat{H} = \frac{1}{n}\sum_{i=1}^{n} h_i \quad , \quad \hat{A} = \frac{1}{n}\sum_{i=1}^{n} a_i \quad , \quad \hat{M} = \frac{1}{n}\sum_{i=1}^{n} m_i \quad (1)$$
$$n = 70$$

Procedure

To optimize the feature-space first the feature reduction was carried out, subsequently the mean-interpretation was calculated.

The feature reduction applied to the data collected in this study lead to a reduction of the dimensions in the feature-space to 23. Applying the Greedy stepwise rejection method described above, starting with 70 features and then throwing them out one at a time, choosing the worst one at each step, resulted in a reduced feature-set of $\mathbb{R}^n, n = 23$ representative *features*. This result was obtained with Weka Version 3.6.14 using the "CFS subset evaluator" on the full training set with the default threshold for the greedy stepwise selection[5]

Mean interpretations are calculated as centroids of each regions' data cluster applying Equation 1.

4.1.4 Study A – Result

The results are computed following the three steps above.
Step 1 provides the subjects' interpretation obtained from the responses to the images from different categories.
Step 2 processes the responses resulting in a calibrated feature-space with distinct regions for the categories of humans, animals and machines as shown in Figure 2.
Step 3 reduces the dimensionality of the feature-space from 70 to 23 features and provides a geometric structure with the reduced feature-set allocated in the feature-space with regions and mean-interpretations (Centroids) for the given categories, as illustrated in Figure 3.

5. For completeness the value of the threshold is $-1.7976931348623157E308$

This calibrated and reduced feature-space allows for the prediction of participants' interpretations of entities in terms of the human, animal and machine regions specified. In this way the reduced feature-space provides a measurement tool serving as foundation for **Study B**.

4.2 Study B – measure effect of movement

This study is using the calibrated and reduced feature-space resulting from **Study A** as a measurement instrument to examine if and how the representation of movement affects participants' relations to various entities. By computing participants' interpretation of entities in respect to their spatialization in the feature-space the aim is to provide a quantitative measure showing differences in participants' affect towards entities as an effect of movement. The corresponding three steps are reported in the following paragraphs.

4.2.1 Step I – gathering the data

Just as in **Study A** the data is gathered in a Qualtrics online framework, asking individuals to rate features in response to images of either *static* or *dynamic* entities which is the independent variable.

Method

The static and dynamic entities are 16 in number. These are presented to the participant as either a set of eight static entities, or eight dynamic entities. The static entities are displayed as still pictures, and the dynamic entities as short 4-5 second video sequence.

The images of the entities are sourced from the authors video archive or Youtube videos, as the Voyager record nor the UN photo archive used in the first part provide moving image material. The 8 entities are represented by one of the following: of humans, a breakdancer (entity 1) or a contemporary dancer (2); of animals, an earthworm (3) or a housefly (4); of machines, a washing machine (5) or a Roomba vacuum cleaner robot (6); and of natural entities, clouds (7) or leaves in the wind (8) (see Table 1).

The choice of images primarily originate from chats during the exhibition of the hairbrush, discussions in the research group and to some extent from related works. Some of them where chosen as people reported to find them attractive (clouds) or repulsive (worm), others in particular because of peoples account of being surprised and intrigued by their behaviour e.g. "lively robot", "dancing washing machine", "mechanically marching fly", "randomness of leaves".

The interpretative relationship is constituted in the same way as in **Study A** by individuals' ratings of features. Here participants are randomly shown four pictures, all of them either of *static* or *dynamic* entities. After each instance, participants are asked to affiliate the reduced feature-set on the same Likert scale as in **Study A**. The online framework was set for a balanced order of presentation, covering all possible combinations of the images, to mitigate the potential of confounding variables within the different entities. As a consequence, the responses of at least $\binom{8}{4} = 70$ participants were required.

Procedure

The procedure for this online study corresponds to **Study A**. Participants were shown images of various entities and subsequently an interpretative relationship was established by having participants rate features. However, here the reduced feature-set of 23 features is used and the independent variable is set by entities presented either as static or dynamic.

The participants amounted to a total of 83 out of which $k = 72$ completed all questions. The study was running for two months with 57% of the participants identifying themselves as male, 41% as female, and 1% as other. With an age range of 58% between 35-54 years, 37% between 26-34, 3% between 18-25, and 3% between 55-64 years of age. The framework was set to equally distribute the instances over the participants, however respondents with not applicable (NA) values due to their missing out of one or more ratings were removed. This resulted in an distribution (k) of the ratings over the entities as shown in Table 1.

4.2.2 Step II - processing the data

Method

To provide a quantitative measure showing differences in participants' affect towards entities e.g., the effect of movement as a difference in participants' interpretation to static and dynamic images, *typicality* is defined, based on first calculating mean-interpretations. The typicality comprises three values resulting from measurement of the entities' mean-interpretation in relation to the mean-interpretation of humans, animals and machines. Consequently the effect of movement is determined by the difference between the typicality of the static and dynamic interpretations.

The mean interpretations of the static and dynamic entities are the centroids calculated from the cluster resulting from participants' ratings, corresponding to the representation of the entities as either static (E^s) or dynamic (E^d), hence the mean-interpretations of the entities – $\hat{E}^s$ and $\hat{E}^d$ – are resolved as shown in Equation 2.

$$\hat{E}^s = \frac{1}{n}\sum_{i=1}^{n} e_i^s \quad , \quad \hat{E}^d = \frac{1}{n}\sum_{i=1}^{n} e_i^d \qquad (2)$$

The typicality of an entity consists of three values resulting from measurements of the entity in relation to the three categories of humans, animals and machines. The triple values as determined in Equation 3 are calculated by measuring the distance between the entities E^s or E^d in relation to $\hat{H}, \hat{A}, \hat{M}$.

$$typicality\ of\ \hat{E} = <\|\hat{\mathbf{E}} - \hat{\mathbf{H}}\|, \|\hat{\mathbf{E}} - \hat{\mathbf{A}}\|, \|\hat{\mathbf{E}} - \hat{\mathbf{M}}\| > \quad (3)$$
$$n = number\ of\ features$$

Procedure

The data is projected into the feature-space processing it correspondingly to **Study A** by allocating points in the space for each participants' responses and colour them according to whether the person has rated it in respect to the static or dynamic entity. Subsequently, the respective mean-interpretation is calculated from Equation 2 and the typicality in relation to the means of the regions of humans, animals and machines as given by Equation 3.

4.2.3 Step III – measure the effect of movement

Method

Differences between entities' interpretation can be shown graphically by representing the information within the feature-space by plotting regions of the projected data within principal components. However with the distance measurement of the typicality defined in the above Equation 3 distances between entities e.g., static and dynamic can be compared. Hence a quantitative measure to show effects of movement of an entity, shifts between the static and dynamic interpretations, can be determined by the displacement-vector resulting from the subtraction of the static from the dynamic typicality as stated in Equation 4. The displacement of the typicality expressed in a trivalent value of displacement vectors can be used to determine effects within the entities but also to compare across the entities.

$$
\begin{aligned}
\mathrm{d}(\hat{\mathbf{E}}^{\mathbf{s}}, \hat{\mathbf{E}}^{\mathbf{d}}) &= <\|\hat{\mathbf{E}}^{\mathbf{s}} - \hat{\mathbf{H}}\|, \|\hat{\mathbf{E}}^{\mathbf{s}} - \hat{\mathbf{A}}\|, \|\hat{\mathbf{E}}^{\mathbf{s}} - \hat{\mathbf{M}}\| > \\
&- <\|\hat{\mathbf{E}}^{\mathbf{d}} - \hat{\mathbf{H}}\|, \|\hat{\mathbf{E}}^{\mathbf{d}} - \hat{\mathbf{A}}\|, \|\hat{\mathbf{E}}^{\mathbf{d}} - \hat{\mathbf{M}}\| >
\end{aligned}
\tag{4}
$$

Procedure

As a consequence of the entities' data projected and processed the effect of movement on the one hand can be illustrated by plotting the respective static and dynamic interpretation of the entity as shown in Figure 4. Additionally, the numbers expressed by the divergence resulting from subtracting the typicality of the dynamic entity from the static (as stated in Equation 4) results in a trivalent value of typicality-displacement in relation to the categories of humans, animals and machines.

4.2.4 Study B – Results

Results showing differences in participants' interpretation of entities as an effect of movement are calculated following the three steps described above.

Step 1 responses are collected from individuals rating static or dynamic entities in relation to the reduced feature-set.

Step 2 participants' ratings of the entities are projected into the measurement tool, the feature-space. The interpretations of the static and dynamic entities and mean-interpretations resulting from Equation 2 are allocated in relation to the regions for the given categories and a metric of typicality for the entities is implemented using Equation 3.

Step 3 provides measurements for the effect of movement as a difference between the static and dynamic interpretation: Divergence in distance measure resulting from subtracting the typicality of the dynamic entity (E^d) from the static (E^s) as stated in Equation 4. The consequential displacement vector ($\hat{\mathbf{E}}^{\mathbf{s}}, \hat{\mathbf{E}}^{\mathbf{d}}$) returns a quantitative measure enabling a comparison between differences in participants' relation to entities as an effect of movement as for example illustrated for the *Breakdancer* in Figure 4.

5 RESULTS

As a result of both parts of the study using the procedure deployed in the methodology we are able to illustrate differences in participants' interpretative relationship affected by a representation of an entity with movement.
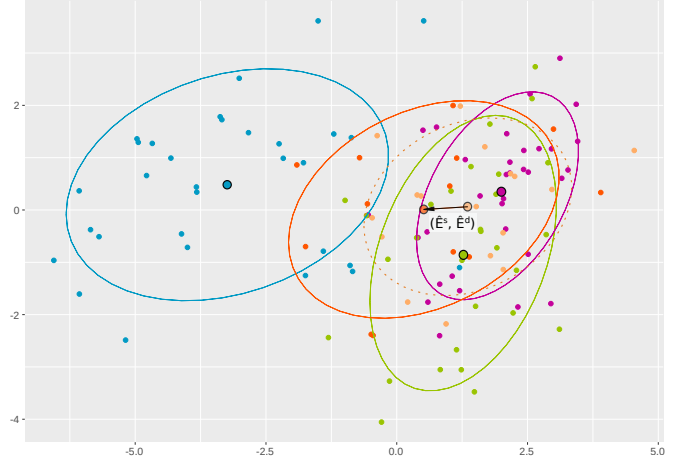

Fig. 4. Results of Study B, showing shifts in participants' affect towards a breakdancer's (orange) static (pale-dotted) and dynamic (continuous) *mean-interpretations* within regions colored as before.

The methodology of computing the subjective responses, established in both parts of the study, uses the findings from **Study A**, the reduced and calibrated feature-space, as a 'ruler' or measuring instrument and allocate therein **Study B**'s responses to static and dynamic entities. PCA is used for understanding the space in terms of individual dimensions and to visualize the regions. For the typicality resulting from the distance measures between the centroid vectors, the full dimensionality of the space is taken into account. With this approach, depicting different regions representative for different interpretations and concomitant mean-interpretations, a typicality-displacement can be measured and show changes in participants' affect towards movement: Visually by means of displaying the shift of the regions illustrated by PCA as well as in numbers concomitant to the geometrical distance of the mean-interpretations.

The results indicate a shift as for example in the interpretation of a video of a human represented with mechanical movement, by virtue of breakdancing moves, in comparison to a static picture towards the region designated to machines. For this example the shifts in participant's interpretation between a static and dynamic entity is illustrated by the arrow pointing from the static mean-interpretation to the corresponding dynamic mean-interpretation, as shown in Figure 4.

The numerical results of the typicality measurements and concomitant displacement between the static an dynamic entities are listed in Table 1. Shifts in the typicality measurement are specified by the results of the displacement of typicality, expressed by $\mathrm{d}(\hat{\mathbf{E}}^{\mathbf{s}}, \hat{\mathbf{E}}^{\mathbf{d}})$ as determined in Equation 4.

6 EVALUATION AND DISCUSSION

The developed agency-framework shown in Figure 1 represents perceptual and conceptual characteristics of an interpretation of an entity along the ontological categories of living and non-living. The deployed topology provides dichotomies to illustrate shifts as degrees of metaphorical attribution of features to be used in the evaluation. This is supported by works assessing anthropomorphism as shifts

TABLE 1
Study results – typicality displacement as a result of computing the difference between the static and dynamic interpretations

Study A Categories $k =$	Human 33		Animal 29		Machine 31		Natural Entities	
Study B Entities	Breakdancer	Dancer	Worm	Fly	Washing-machine	Roomba-robot	Clouds	Leaves
$k =$	E^s 17 E^d 13	E^s 18 E^d 15	E^s 13 E^d 17	E^s 14 E^d 15	E^s 16 E^d 15	E^s 16 E^d 18	E^s 18 E^d 14	E^s 17 E^d 14
$d(\hat{E^s}, \hat{E^d})$								
to human	-0.97	-0.44	-0.47	0.8	-0.45	-0.85	-0.64	-0.58
to animal	-1.53	0.23	0.1	0.75	-0.19	-0.65	-0.36	0.08
to machine	1.3	-0.38	-0.09	-0.22	0.96	0.57	-0.31	-0.21

in ontological commitments from human to non-human, and correspondingly judgements of agency based on an interpretation of an entity as animate or inanimate.

Correspondingly, **Study A** provides the procedure to obtain a feature-space: based on individual interpretations, the rating of traits, particular regions for three ontological categories human, animal and machine, are determined and allocated in a geometrical structure. For the second study, **Study B**, the dimensionality of the feature-space was reduced and the influence of movement on this classification was analysed. By having participants' interpret entities displayed as either static or dynamic using the same set of features, the results could be projected into the feature-space. To express the effect of movement, possible shifts in entities static and dynamic interpretation, a typicality measurement was introduced. Calculating the displacement vector between the mean-interpretation of the static and dynamic entities (the three distances to the mean-interpretations of the categories), resulted in a three-part typicality measurement providing shifts in distances in regard to humans, animals and machines' interpretation. It is important to understand that the use of statistics here is interpretative and not inferential.

In the following, the measurements[6] of each entity is presented and discussed. To further emphasise the findings, the reader's attention is brought to variations in the attribution of agency and animacy as depicted in the agency-framework. Additionally the results are viewed in a different way by picking driving features in respect to their mean rating as found in Table 3 (see Appendix). Driving features are features that contrast substantially in the mean ratings between the static and dynamic. This subjective analysis, picking individual features, is used to supplement the findings and methodology employing the whole feature-space.

Human entities

In the case of the **Breakdancer** changes in the affective relationship as typicality-displacement is indicated by the shift towards the region of machines and away from the animal and human realms: the typicality becomes fairly negative (-0.97) in relation to humans; to an almost 50% stronger degree (-1.53) towards the animal-typicality; and strongly

6. Because of the non-normal data, medians were also calculated. The results are very similar, therefore the geometrical interpretation on the basis of means is deployed, which is easy and intuitively to understand.

positive (1.3) in regard to machine-typicality. Throughout the dataset these displacements are the ones showing the highest effect. The **Dancer**'s interpretation in turn shows a flimsier typicality-displacement away from the regions of humans (-0.44) and machines (-0.38) and to less than half of those distances a shift towards animals (0.23).

The typicality-displacement implies the **Breakdancer**'s dynamic interpretation is attributed less *intentional* and more *automatic* and *involuntary* qualities. This is pertinent to the mechanical movement, which in a poetic way transfigures a human through it's movement appearing similar to an automaton. This shift in the affective relationship is supported by driving features. For instance the increase of *controllable* with the dynamic's mean rating (dynamic: 0.41, static: -0.35) converging to machines (0.34). Notation: subsequently we denote the values in the brackets for static as 's' and for dynamic as 'd'. The static **Breakdancer** is furthermore interpreted as less *synthetic* (s: -0.51) in correspondence with humans (-0.56) and animals (-0.62), while the dynamic is almost undecided (d: -0.08) for this feature that is mostly applicable to machines (0.46). However the contribution of the individual feature is not always evident in their contribution to the overall result. As for example the moving **Breakdancer** was rated less *aggressive* (d: -0.64), approximating the mean for humans (-0.57), while the undecidedness in terms of the static (-0.02) could be ascribed to the posture in the static picture showing a person with it's arm up encompassing ambiguity whether the subject is involved in a dance or rumble. Hence looking at the data in this way gives evidence how individual features contribute more or less but when we consider all of the individual ratings in our result we end up with the established methodology.

In essence the results suggest the **Breakdancers**' movement is interpreted more as guided by a prescribed algorithm determining the repetitive machine-like movement pattern as more *predictable* and *automatic*. While the **Dancer**'s movement, correspondingly determined by choreography, embodying intentional as well as involuntary qualities in its behaviour, leads to an altogether much subtler decrease of human and machine-typicality. This is indicated by feature ratings of the dynamic as less *synthetic* (d: -0.49, s: -0.06) and *productive* (d: -0.4, s: 0.04), both for the most part applicable to machines (synthetic: 0.46, productive: 0.56), but also slightly less *instrumental* (d: -0.18, s: 0.13), tending towards animals

(-0.26) for a feature that is most applicable to machines (0.49). The shift could be inferred from the dancer's particular style, here a five second appearance of Kate Bush. Hence the subtle decrease of *intentional* and *autonomic* qualities away from human-typicality but also away from machine, together with the minor approximation to animals could be ascribed to her distinct dance style which is said to be influenced by her karate training, giving rise to a behaviour that is less *predictable* and more *complex*.

Both results indicate that predictable movements lead to a decrease of human inferences which corresponds to findings of Eyssel et al. [52]. Even though in the case of the **Dancer** the effect is less than half the size in comparison to the **Breakdancer's**. Kate Bush's dance is rhythmic rather than metronomic, thus being interpreted as more spontaneous and following a more random principle makes her behaviour still predictable but to a lesser degree while the repetitive mechanical movements of the **Breakdancer** also affects its interpretation as more machine-like.

Animal entities

Looking at entities within the animal categories, the **Worm's** interpretation demonstrates a drift away (-0.47) from the regions co-opted by *humans* and fairly nominal shifts in relation to machine (-0.09) and animal-typicality (0.1). For the **Fly** the numbers indicate the dynamic representation obtains a strong tendency towards human-typicality (0.8) and animal-typicality (0.75) and slight decrease in machine-typicality (-0.22).

The **Worm's** displacement could be inferred from observers impulsive reaction to the **Worm's** slimy appearance similar to spiders and other angst-inducing creatures. This is indicated by a slight increase of *creepiness*. In addition the helplessness expressed in the tossing and turning shown in the dynamic representation. The apparent inability to find a way into the ground decreases the *autonomy* and increases the *automatic* qualities in the movement, which is supported by driving features being rated less applicable to the dynamic representation like *caring* (d: -0.59, s: -0.15) or *productive* (d: -0.25, s: 0.31) and *instrumental* (d: -0.57, s: -0.01). The vain movement dwindles the intentional behaviour to leave the daylight, hence having only a certain control over the action diminishes its *autonomy*.

The interpretation of the **Fly's** behaviour was not in line with the expectations. Due to its discreet movement the anticipation was the attribution of *automatic* and *predictable* qualities designated by a typicality-displacement towards the region of machines. However, as the numbers indicate its interpretation approaches humans and animals. This is sustained by individual features indicating the dynamic being interpreted more *sensitive* (d: 0.18, s: -0.24) and *aware* (d: 0.38, s: -0.02), both generally more human and animal features. Moreover a minor decrease towards machines, which could be attributed to the rhythmic movement virtually suggesting a dance pattern, manifest for example in the dynamic being interpreted more *goal driven*.

This result, contrary to our expectations, indicates the second most substantial shift in the affective relationship of our dataset. The solid interpretation of the **Fly** towards humans and animals in contrast to the **Worm's** is supported by insights provided by Kiesler et al. [36]. Their work indicate

that animals like pets who are closer to humans evoke a higher emotional attachment. Thus the **House-Fly's** increase in human and animal typicality in relation to the **Worm's** could be attributed to it being more familiar that the alien behaviour of the **Worm**.

Machine entities

The interpretation of a jiggling **Washing-machine** shifts towards machines when presented with movement, as suggested by the displacement of typicality: Here the difference between static and dynamic mean-interpretations becomes negative (-0.19) in respect to animals and more than double in relation to (-0.45) humans, while strongly positive (0.96) in relation to machines. Correspondingly, even though half the effect size of the **Washing-machine**, the **Roomba-robot's** dynamic interpretation has a stronger typicality-displacement of 0.57 towards the machine realm but at the same time an increasing displacement of -0.65 towards animals and -0.85 towards humans.

The result of the typicality-displacement suggests in both cases the dynamic representation is interpreted as more *automatic* and less *intentional*. However, in the case of the **Washing-machine** the displacement is nearly double towards its machine-typicality while the **Roomba** decreases with similar significance in terms of human and animal-typicality. In case of the **Washing-machine** this is supported by the dynamic representation recorded with a higher rating for *goal driven* (d: 0.22, s: -0.12), a feature principally attributed to machines (0.54). Furthermore the dynamic's increment for *clunky* (d: 0.47, s: 0.08), a feature in general rather undecided for machines (0.08) and not very characteristic of humans (-0.47) and animals (-0.31), which could be imputed to the machine's severity of the movement almost falling apart. Interesting is the shift in the mean rating in terms of *lonely* a feature indicating how social an entity is interpreted. Related Heider and Simmel's [38] findings showing that movement is generally interpreted in rather social terminology, the static is rated quite *lonely* (0.54), appropriate to the solitary placement in the backyard while the dynamic is rated less *lonely* (0.11), suggesting it is interpreted more social as an effect of movement.

The **Roomba** result did not match our expectation. We expected an inferior attenuation or even increment of *intentional agency*, as implied for example in the dynamic's rating as more *aware* (d: 0.17, s: -0.33). We anticipated this due to the robots' movement: while the **Washing-machine** stays put, moving regardless of the situation, the **Roomba-robot** does not just move straight forward, it moves in respect to the carpet in front of it's trajectory and nestles around the backpack next to it. Subsequently suggesting its action is interpreted more autonomic, moving in regard to the situation, thereto leading to a lesser degree of automatic movement qualities. However the inapplicability of driving features like *spontaneous* (d: -0.21, s: -0.54) reflected in the negative values and the more *logical* (d: 0.43, s: 0.06) and less *creepy* (d: -0.33, s: -0.65) rating of the *dynamic's* representation indicate the result determining the movement as less *autonomic* and *intentional*.

For both the result could be attributed to a purposeful and deterministic interpretation of the movement, potentially expressed in the machines' rhythmic motion. Similar to the

human entity's dancing, the depicted movement in both cases is quite predictable which is reflected in the increase of machine-typicality. Additionally both dynamic instances are interpreted with less human and animal typicality. This could be understood in terms of humans' need to interact effectively as a motivational factor [70]. Thus suggests that when the conceivable ambiguity of an objects' movement is obviously predictable, we get on with it and interpret it as less *autonomic* and *intentional*, for example in the case of the **Washing-machine's** fierceness and the threat of breakdown, or the **Roomba-robot's** potential for spontaneous lively behaviour.

Natural entities

The natural entities result in the **Clouds'** dynamic interpretation with a decrease in machine-typicality (-0.31) in relation to the static interpretation, almost equal in regard to animal (-0.36) and with a double effect size (-0.64) in respect human-typicality. The **Leaves'** interpretation also decreases firmly in human-typicality (-0.58) in its dynamic interpretation in contrast to its static counterpart similarly but less significant (-0.21) for the machine-typicality while the animal-typicality increases marginally (0.08).

The motivation for employing both entities was their ambiguity: Either are commonly considered as part of the natural environment, while the cause of their motion could be attributed to an external force, hence interpreted in a similar way to inanimate objects characterised by a transfer from one object to another [39], [54].

The typicality shift of the **Clouds** represented dynamically could be expounded in terms of the causality and conformity to physical constraints condensing in a degrade of animate qualities as reflected in ratings of salient features like *sentient* (d: -0.43, s: -0.2), *aware* (d: -0.5, s: -0.24) and *lonely* (d: -0.57, s: -0.09) as less applicable. Similar effect but lesser for the **Leaves**, to whose static representation features like *lonely* (d: -0.63, s: -0.33) and *spiritless* (d: -0.61, s: -0.33) are less attributable. However in contrast, the **Leaves** are interpreted more animal and slightly less machinic in the dynamic representation. The dynamic **Clouds** are for instance rated as less *instrumental* (d: -0.57, s: -0.31) consequently less *automatic* as they not only move in regard to the environment, their plasticity is affected by the environment. Likewise the **Leaves's** movement is causally effected by the environment exposing a movement subjugated by the wind however they stay put which is reflected in the rating as less *creative* (d: -0.24, s: 0.25) and *complex* (d: 0.1, s: 0.39).

7 FINDINGS

7.1 Overview

In a controlled environment, an online study having people interpret entities represented either static or dynamic, differences in the affective relationship as an effect of movement could be shown and measured.

Our results relate to findings from previous works on two levels: On the one hand using traits to assess people's interpretation like the ones mention in the Related Work 3.1 on *anthropomorphism*, on the other indicating ontological shifts in the interpretation elicited by movement as in the *agency* investigations discussed in 3.2. However, our methodology reassembles findings from both and therefore differs in the following ways: The awareness of the controversial use of words, as potentially influencing and priming people made us use an indirect method of displaying images e.g., of animals instead of using the word animal, as discussed in 3.3. Furthermore we examine participants' interpretation of traits in response to the pictures on a Likert scale from 0-6 rather than a go/no-go, black/white or either/or level, to facilitate an relational approach of understanding 'others' [57].

7.2 Limitations of the study

We did not measure the cultural background nor the effect of solitude of our participants. Carey [4, p.33], citing Quine [71], [72], [73], argues that concepts that articulate common sense ontological commitments are innate but also a cultural construction. That an observers' culture has an effect on the perception of movement is shown for example by Morris [55]. Additionally loneliness has an effect on anthropomorphism as shown by Epley [7].

The static images used in **Study B** are not from the UN picture fund used in **Study A** as there are only stills available. Yet for our measurements we had to have static and dynamic representations of the same entities. Video sequences longer than 4-5s would have been preferable, but the Qualtrics framework at the time of the study did not allow buffering or embedding of videos in a practicable way. Additionally, representations of zoomorphic or anthropomorphic robots (e.g., [47], [49]) have not been tested in the framework.

7.3 Future work

For further studies, we will test the framework presented in a complex environment e.g., a setup similar to the one described in the introduction featuring physical objects, or in a human robot interaction. In addition collaborating with computer graphic animators to apply screen displays to measure the effect of the same entity performing different movements, e.g., comparing an entity's mechanical with its biological movement.

8 SUMMARY AND CONCLUSION

We reported a quantitative method measuring the relation between human observers and various human and non-human entities. Our particular focus was to show that the affective relationship significantly changes with degrees of *animacy* and *agency* when movement comes into play.

First, we conceptualized an entity's *expressivity* emanating from its dynamic form as involuntary movement or intentional action along with its *animacy* interpretation as inanimate or animate. Second, we ground our work in previous research following similar methodologies asking people to ascribe traits under different conditions to evaluate the effect of *anthropomorphism*. Furthermore, work looking at movement perception as causal or intentional leading to different forms of *agency* attribution. As a key contribution we provide an *agency-framework* to illustrate differences in participants' interpretation in form of movement qualities and descriptions, as degrees of *agency* and *animacy*.

Our methodology reassembles findings from both and we present a metric using an indirect method not asking people directly about humans, animals and machines but using images instead of words. Moreover, our method permits a measurement deploying a relationship rather than just attributing properties on a simple black/white or either/or ratio. Additionally, the *agency-framework* illustrates on the one hand our metric assessing participants' interpretation of entities in analogy to the linguistic device of metaphors, and on the other our evaluation method by first establishing ontological categories for humans, animals and machines, and second, using the categories to assess changes in the affective relationship as displacements in ontological commitments evoked by movement.

Subsequently, our methodology comprised two steps, both carried out and informed by two online studies. In the first study we used 70 words to obtain a measurement tool, a feature-space. We asked people to interpret depictions of entities of humans, animals and machines by asking them to attribute traits on a scale. As a result we obtained a measurement tool with particular regions comprising a distribution of the features typicality along the three ontological categories of humans, animals, and machines in a geometrical structures. The feature-space's application as a measurement tool is additionally facilitated by a feature reduction, removing redundant features and determining the mean-interpretation for each region. As a consequence the processing and geometrical representation of the individual interpretations provided a measurement tool for the second part, **Study B**, analysing the influence of movement on this classification by having people interpret entities displayed either static or dynamic. By using the same set of traits we could project these results into our previously obtained feature-space and show changes in participants' interpretation of various entities as an effect of movement, for example the interpretation of a breakdancer represented with movement as less intentional and more mechanical. Or a lesser degree of anthropomorphism in a Roomba robot's dynamic representation.

Along these lines our methodology and studies provide a quantitative method to assess and illustrate changes in observers affective relationship to entities based on subjective responses to different types, and under different conditions, with and without movement. The processing and geometrical representation of the individual interpretations in a feature-space provides a measurement tool that enables one to look and talk about effects and changes of the conceptions of entities by means of shifts of typicality, represented graphically as well as arithmetically by vector distance measurements, in regard to humans, animals and machines.

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