AFFINITY WITH ARTEFACTS

Humans' perception of movement in technological objects

PhD in Media and Arts Technology

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Dedicated to our position in the universe.

ABSTRACT

It is commonly accepted that our relation to inanimate objects is different than to biological entities. When movement comes into play, however, this relation can bring about ambiguities and transfigure familiar relationships between the animate and the world of things. This thesis investigates this relationship and the role of movement. The main focus is on humans' perception of movement, in particular how this affects the relationship to technological objects.

It is a known phenomenon that humans tend to focus on life and life-like processes. This propensity affects the creation as well as the observation of things. As social and emotional beings, humans experience a living presence of objects, and tend to not treat them as dead matter. Apparent for example in emotional attachments to devices like the computer, cell phones or robots. We have a long-standing practice of projecting social roles onto our surrounding as a way to relate and interact with things in the world. Differences in these relationships are affected by the appearance as well as movement of things, a phenomenon that is well-established, for instance, in cognitive psychology and gestalt/animation theory, where it has been demonstrated that abstract objects and shapes, when they move, tend to be interpreted less object-like and more as social and animate beings. Equally, in human-robot interaction, studies with real robots illustrate that people tend to 'anthropomorphise,' and attribute life-like properties to these technological objects with certain human or animal characteristics. The affinity towards the living affects not only the experience and observation but also the creation of technologically animated things. For a long time artists and inventors have been trying to mimic nature and develop technology simulating life-like qualities. These creations, as reported in this thesis, manifest for instance through animated creatures, artistic sculptures and artefacts, the creation of artificial systems, and robotics.

The aim of this thesis is to learn more about the role of movement for human perception of the animate/inanimate by presenting movement as the common denominator on three levels. First, this thesis contributes to the understanding of the phenomena by bringing together work from various contexts and as such presenting an interdisciplinary approach to the topic. Second, as a result, a novel methodology is presented that provides a relational approach to examine move-

ment as a determinant of variances in the interpretation of an entity. Based on a feature-space, used to compare peoples' interpretative relationship to entities, the method allows to evaluate how an entity's movement characteristic affect the way thoughts and actions are directed to them. Third, results are obtained from the application of the methodology in an empirical study, assessing peoples' interpretation of a ready-made object, a technologically modified hairbrush moving autonomously. These show that the movement of an everyday object motivates an interpretation closer to humans and animals.

The results correspond to the findings mentioned above. However, as the empirical work brings together people and an autonomously acting robotic object, which lacks anthropomorphic/zoomorphic or mechanoid morphology, in a real world scenario, it transfers these findings from cognitive psychology and computer graphic animation to the field of human-robot interaction.

PUBLICATIONS

Some ideas and figures have appeared previously in the following publications:

Wolf, Oliver Olsen and Geraint Wiggins (2017). "Dawn of the living hairbrushes: humans affective responses to movement in artefacts". In: Proceedings of HRI 2017 workshop on "The Role of Intentions in Human-Robot Interaction".

— (2018). "Look! It's moving! Is it alive? How movement affects humans' affinity to living and non-living entities". In: *IEEE Transactions on Affective Computing*. ISSN: 1949-3045. DOI: 10.1109/TAFFC.2018.2820707.

Because the things are the way they are,
things will not stay the way they are.

— Bertolt Brecht

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DECLARATION

I confirm that the research included within this thesis is my own work or that where it has been carried out in collaboration with, or supported by others, that this is duly acknowledged. Previously published material is also acknowledged.

I attest that I have exercised reasonable care to ensure that the work is original and does not to the best of my knowledge break any UK law, infringe any third party copyright or other Intellectual Property Right, or contain any confidential material.

I accept that the College has the right to use plagiarism detection software to check the electronic version of the thesis.

I confirm that this thesis has not been previously submitted for the award of a degree by this or any other university.

London, April 2018

Oliver 'Olsen' Wolf

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PREFACE

Robert Musil's (1943) novel *The Man Without Qualities*, a book that I read before starting my career as a PhD student provides a literary approach to several topics related to this thesis. At certain points in this thesis I cite shorts abstracts from the novel. Here for instance one of his remarks on technological objects.

> Wenn es die Verwirklichung von Urträumen ist, fliegen zu können und mit den Fischen zu reisen, sich unter den Leibern von Bergriesen durchzubohren, mit göttlicher Geschwindigkeit Botschaften zu senden, das Unsichtbare und Ferne zu sehen und sprechen zu hören, Tote sprechen zu hören . . . alle diese Urträume nach Meinungen der Nichtmathematiker mit einem mal in einer ganz anderen Weise verwirklicht waren, als man sich das ursprünglich vorgestellt hatte. Münchhausens Posthorn war schöner als die fabriksmässige Stimmkonserve, der Siebenmeilenstiefel schöner als ein Kraftwagen, Laurins Reich schöner als ein Eisenbahntunnel, die Zauberwurzel schöner als ein Bildtelegramm, vom Herzen seiner Mutter zu essen und die Vögel zu verstehen, schöner als eine tierpsychologische Studie über die Ausdrucksbewegungen der Vogelstimme. Man hat Wirklichkeit gewonnen und Traum verloren. Man liegt nicht mehr unter einem Baum und guckt zwischen der großen und der zweiten Zehe hindurch in den Himmel, sondern man schafft; man darf auch nicht hungrig und verträumt sein, wenn man tüchtig sein will, sondern muß Beefsteak essen und sich rühren.
>
> — Robert Musil (1943, p. 39)

If it is the fulfillment of man's primordial dreams to be able to fly, travel with the fish, drill our way beneath the bodies of towering mountains, send messages with godlike speed, see the invisible and hear the distant speak, hear the voices of the dead, be miraculously cured while asleep; see with our own eyes how we will look twenty years after our death, learn in flickering nights thousands of things above and below this earth no one ever knew before; . . . Of course there is no denying that all these primordial dreams appear, in the opinion of nonmathematicians, to have been suddenly realized in a form quite different from the original fantasy. Baron Munchhausen's post horn was more beautiful than our canned music, the Seven-League Boots more beautiful than a car, Oberon's kingdom lovelier than a railway tunnel, the magic root of the mandrake better than a telegraphed image, eating of one's mother's heart and then understanding birds more beautiful than an ethologic study of a bird's vocalizing. We have gained reality and lost dream. No more lounging under a tree and peering at the sky between one's big and second toes; there's work to be done. To be efficient, one cannot be hungry and dreamy but must eat steak and keep moving.

— Robert Musil (1996, p.35)

1 INTRODUCTION

In this thesis, I explore the relationship between humans and technological objects from an artistic perspective, drawing on methods from cognitive science and design research. I look at robots and computational artefacts in action and interaction with its environment. The focus is on the perception of movement, in particular how this affects the relationship to technological objects.

The research presented here is based on my personal interest in the relation between technological objects and people. The work is motivated by the exploration of this relationship in my artistic practice through the creation of responsive/life-like objects, and the observation of how people react to them. The driving question of the resulting research is how artefacts which exhibit some apparent behaviour or 'life of its own' elicit and attract people's attention, and how people's perception of such artefacts is dependent on their style of movement or behaviour.

In this chapter, I introduce these topics in four sections. In the first section, I ground this work through examples from my artistic practice based on the mechanisation and animation of artefacts. Analogously to the Dadaists' concept of the readymade – the idea of creating boundary objects by situating them between object and art – these works move between the familiar borders of inanimate objects and animate creatures. In the second section, I describe how observations made during an exhibition of one of my works instigated my research interests and lead me to formulate the research question of this thesis: namely, how does movement affect people's perception of technological objects? The third section outlines the structure of this thesis, while the fourth specifies the key contributions.

Ultimately, this thesis investigates the action and interaction with artefacts from an artist's/designer's perspective complemented by a scientific angle to study how people's perceptions of objects is linked to the style of their movement or behaviour using scientific methods. The general aim is to provide a better understanding of how movement affects humans' affinity to technological objects. Combining scientific research and artistic methods situates this work in the research fields of cognitive science and design research.

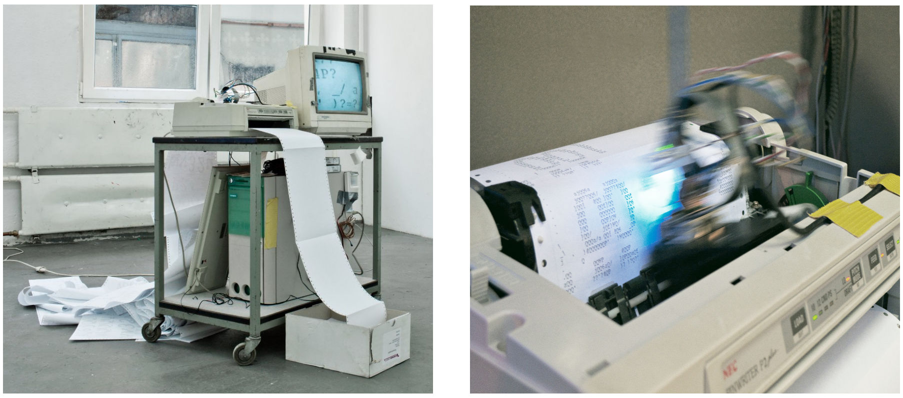
1.1 MOTIVATION: MECHANISATION AND ANIMATION

Over the past 15 years I have developed an artistic practice exploring 'technology as antennas for the imagination.' My practice focuses on deploying machines and technology in creative contexts, and the majority of the resulting works are situated in the field of mechanisation and animation of objects. In particular, setups where apparatuses are left to their own devices and moving autonomously. In such scenarios, once initiated, the dynamics of the process are self-created and automatised by the machines trapped within their own functionality, simulating a self-sufficient existence and suggesting the presence of an identity.

This is exemplified by the following three works from my artistic practice.

(§)"=$" (2003)

The closed-circuit installation *(§)"=$"* (2003) represents an *Écriture automatique* performed by a machine based on an autopoietical[1] loop between a camera and a printer. The set-up shown in Figure 1.1 is made



(a) View of the installation at the V8 Gallery in Karlsruhe, Germany.

(b) Close up of the feedback mechanism at the Museum of Design in Zürich, Switzerland.

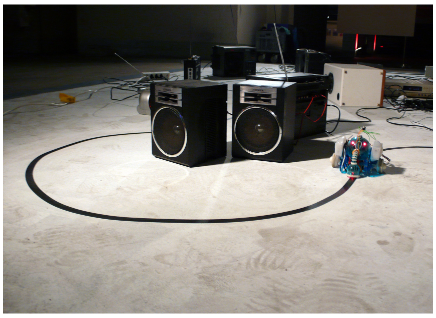
Figure 1.1: The closed-circuit installation *(§)"=$"* (2003) involving a feedback loop between a camera and a printer. Image 1.1a courtesy of Thorsten Strohmeier, Image 1.1b courtesy of Birk Weiberg, both published with their permission.

out components from electronic trash and comprises a feedback mechanism: a camera on a printer's head sends the visual data of the printout as ascii-data to the printer. The printout in turn is fed back to the camera as optical data which again generates ascii-data sent to the printer.

1 Autopoietic organisation as self-creation, self-preservation of a system (Varela et al., 1974)

Accompanying measures in rail replacement bus service (2009)

The robotic-sound installation *Accompanying measures in rail replacement bus service* (2009) consists of a robot equipped with a microphone and a radio transmitter that is set out in a landscape of radios as shown in Figures 1.2. Therein the robot's movement perpetually generates a



(a) View of the installation at Skaftfell in Seyðisfjörður, Island.

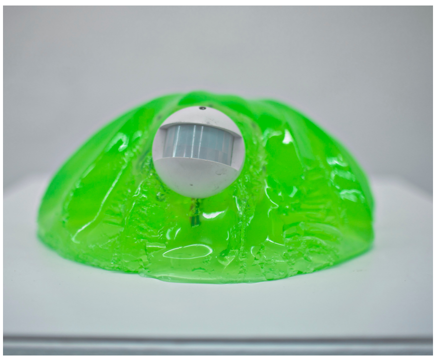
(b) Performance presentation at xxx micro research lab in Berlin, Germany.

Figure 1.2: The robotic-sound installation *accompanying measures in rail replacement bus service* (2009). Both images by the author.

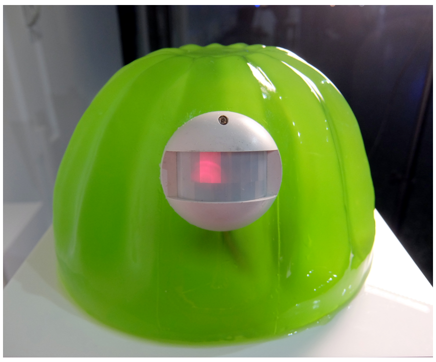
composition of feedback noises of various kinds, depending on its position and movement relative to the radios which are receiving on the transmitter's frequency.

Retortenheber, der (2011)

The interactive sculpture *Retortenheber, der* (2011) consists of a jelly pudding with a motion detector mounted on top of it as shown in Figure 1.3. The behaviour is generated by an instrumental feedback



(a) View of the installation towards the end of the exhibition at the V8 Gallery in Karlsruhe, Germany.



(b) View of the installation during the *Intersections* event at the Arts Pavillion in London, UK.

Figure 1.3: The interactive sculpture *Retortenheber, der* (2011). Image 1.3a courtesy of Thorsten Strohmeier, published with his permission. Image 1.3b by the author.

of a large jelly pudding with a motion detector tracking movement mounted on the pudding. Detected motion triggers the eccentric motor placed within the pudding and the jelly starts to wobble, which in turn activates the motion detector.

IN CONCLUSION, these works exemplify my artistic practice, exploring movement in artefacts which, as a result of their mechanisation and animation, exhibit some apparent behaviour or 'life of its own'. In this sense, they provide the motivation for this research, which is and has been established in the artistic works I create.

The particular aims for the research stem from the creation and the observation of how people reacted to the next piece I will describe, a technologically modified hairbrush, presented as a case study in the following.

1.2 AIMS: CREATION AND OBSERVATION

The hairbrush and the observations made during one of its exhibtions both gave rise to the objective for this research: the creation of this work provide the practical basis, and the observations form the theoretical interest for the work presented in the upcoming chapters.

Creation

The case study features a technologically modified hairbrush named *Uruca Caliandrum*, a hairbrush that metamorphoses from an everyday hairbrush into a robotic creature.

Figure 1.4: The technologically modified hairbrush *Uruca Caliandrum*. Image courtesy of Thorsten Strohmeier, published with his permission.

Uruca Caliandrum is based on an everyday object, a ready-made hairbrush technically modified becoming a bio-inspired robot that is designed to feature aspects of apparent behaviour. The hairbrush is programmed to morph between the state of a regular hairbrush and an animal-like autonomous robot. It is designed to 'wake up' with the light of dawn and uses little motors hidden within the corpus to move with its brushes, similarly to a caterpillar. The subsequent observations were made using an early prototype of the hairbrush as shown in Figure 1.4. A detailed development history and further prototypes used in the empirical work of this thesis are described in Section 5.1.

Observations

The following observations were made during an invited exhibition that took place in February 2014 at the Hardy Tree gallery, a small gallery in the inner city area of Kings Cross in London, UK. The exhibition showed works by four different artists and lasted for three days. Within the exhibition space the hairbrush was sitting on a plinth as shown in Picture 1.5. Every now and then, triggered by different levels of light, the brush became active – it started to crawl around on the plinth and had to be placed back by an attendant to avoid dropping onto the floor.

Figure 1.5: The robotic hairbrush *Uruca Caliandrum* on a plinth at the exhibition in the Hardy Tree gallery. Image by the author.

Over the three days, the exhibition had around 100 visitors, with over half of them attending the private viewing on the first evening. Due to a limited budget, the participating artists were asked to watch over their pieces during the days of the exhibition. During this duty, I collected the following observations, typically positioned nearby the plinth with the hairbrush.

Most visitors approached the exhibition without reading the text describing the different pieces provided at the entrance or nearby the exhibits.[2] Hence, they approached the hairbrush without any background knowledge about the object's functionality.

Typically, visitors were surprised as soon as the hairbrush started moving. Interestingly, more than two-thirds identified something or-

2 The description that came along with the hairbrush is specified in Section 5.1.2.

ganic. This was expressed in cries of astonishment and comments like "creepy', "eerie", "almost like an animal", or "I get goosebumps watching this". Some people expressed discomfort by stepping back one or two steps. At least three people refused to touch the object. The majority, though, came closer to the object. Two audience members even came to the rescue to prevent the hairbrush from "committing suicide" as it crawled closer to the abyss at edge of the plinth.

Additionally, the work instigated various discussions with visitors about their relation to objects and machines, and elicited personal stories.

IN THE PERSONAL STORIES, one of the visitors revealed the she was the owner of a Roomba^{TM} vacuum cleaner robot. She explained that she quite enjoys watching the robot not only because it is doing the job, but also because the "robot seems so lively, as it is doing something or other all the time."

Another visitor showed a YouTube video of a scene from the film *American Beauty*: a 3min excerpt showing a plastic bag floating in the wind accompanied by music.[3] The video has about 1.6 million viewers, and scrolling through the comments bore witness how people empathise with the movement of this bag. She cited some of them like user 'greenbrae7' who was thankful for "bringing this plastic bag to life", or 'wegotonelove', who commented that"the dance is beautiful, warm but distant. It's effortless. It's saying 'I'm here', 'I'm alive"'.

Another audience member stated that the hairbrush brought back memories of fictitious puppets like *Pinochio*. He remarked in respect to the attentiveness of the plastic bag's movement, that we have a natural attraction to movement. For instance, a couple of days earlier, he had found himself observing an empty tin floating around in a pond driven by the wind. He also commented that the omnipresent lucky-cat waving its paw in the air still managed to catch his attention every time he walked past the corner shop.

OVERALL, the observation of people's experience of the hairbrush could be summarised as follows:

- The movement of the object was attracting attention.
- Two-thirds expressed perceiving something organic.
- Some people expressed discomfort.

3 https://www.youtube.com/watch?v=gHxi-HSgNPc (accessed October, 2017).

1.2.1 *Objective and Research Question*

Taking the question "What is fascinating about robots?" as a starting point, the particular interest outlined here is in the relation between life-like objects and people, and how their experience and perception is influenced by the objects' movements.

The work presented here is motivated by both my artistic practice and the observed reactions, discussions and shared experiences from people when showing these artefacts. Both gave rise to the objective for the work presented here which is to explore the role of movement in the relationship between technological objects and their observation by people. The interest in this relationship engendered the following research question:

How does movement affect people's perception of technological objects?

The exploration of this question is addressed in this thesis based on the following structure.

1.3 STRUCTURE OF THE REPORT

This chapter introduced the topic, the aims and the research question guiding this thesis. It illustrates how the work is motivated by my artistic practice, in particular the experiences and observations made during a public exhibition of one of these artefacts, the robotic hairbrush *Uruca Caliandrum*, which provides the practical base, as well as the theoretical interest and background for the empirical studies described in the upcoming chapters.

The subsequent chapter provides background to the work, it presents related work from an artistic context that have been inspiring together with concepts referring to literature that has been influential predominantly from philosophy of arts and technology, literature and film studies. The aim here is twofold. On the one hand, to present movement as one of the primary factors that provokes affection, as well as a stylistic device used by artists e.g. in sculptures and installations or cartoons to bring something to life and suggest the presence of an entity. On the other hand, to demonstrate how linguistic phenomena, in particular metaphor, can be used as devices to express, evoke and indicate emotions as for example found in prose and poetry.

The follow up chapter provides a survey of related work stemming from cognitive psychology, computer graphic animation and human-robot interaction (HRI) presenting key empirical works on this topic.

The aim here is one the one hand to amend concepts like animacy and agency elucidated in the previous chapter 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 videos or physical interaction to elicit different interpretations in observers. On the other it provides the rationale underpinning the use of the sociolinguistic device of the metaphor as an indicator for differences in the way an entity is perceived.

As a result of this, in the methodology chapter a quantitative method is developed that uses language as an instrument of measurement to illustrate how the movement of an entity motivates changes in people's affinity. The method centers around humans' intuitive process of categorising and attributing characteristics to things, as found in the concept of metaphor. Drawing on the linguistic concepts of animacy and agency, indicating how sentient or alive an entity is perceived to be, the method uses a set of features that are characteristic of human and non-human behaviour. Inviting participants to attribute these features in form of degrees to entities and to represent their subjective responses in a geometrical feature-space allows to compare and contrast individual attributions to different entities under different conditions. The resulting metric provides a measurement tool that enables to measure and describe effects and changes in the interpretation of entities by means of shifts in the metric's feature-space.

In the application chapter, the outlined methodology is applied and validated in an empirical study presenting a HRI-like scenario. For this study an enhanced version of the hairbrush is used, the iterative development of which is described at the beginning of the chapter. This version's morphology is improved by hiding all the electronics inside to remove marks of its morpho-functionality and make it appear like an everyday object. Thus the transformative capacity of this non-anthropomorphic object, which lacks resemblances e.g. of faces or body structure similar to animals and humans, allows to study differences in its interpretation as an effect of movement. Additional improvements are made in the locomotion mechanism able to move it with two different patterns (biological, mechanical and no-movement) that provide three different conditions for the study.

Applying the methodology in an empirical study, in which subjects had to interpret the hairbrush's movements in different movement patterns, led to results indicating differences in the feature attribution as an effect of movement. In particular, it showed that the applied biological and mechanical movement led to a significant increase of the attribution of features representative for animate creatures. Furthermore, it showed that both movements are conceived significantly more with features representative for the uncanniness and eeriness of the experience with a slight increase for the mechanical movement.

In the evaluation chapter the methodology and the results are validated through a second research instrument. This is carried out using verbal data analysis on short descriptions given by the participants as part of the empirical study. The result obtained here equally reveals that movement has an effect on the way an object is described. The results correspond to the findings in the feature-space and are apparent as predominantly social descriptions of the object in the movement conditions in contrast to the no-movement condition.

Furthermore, in terms of differences between the two movement conditions, the results suggest that mechanical movement leads to an increase of negative emotions while biological movement is positively correlated with positive emotions.

In summary, the following key contributions are provided by the work and research outlined in this thesis.

1.4 CONTRIBUTIONS

- This thesis provides an understanding of the affinity of humans to the movement of technological objects by bringing together work from various contexts. The work presented here integrates artist, designer and scientist's approaches to the topic together with concepts from philosophy, literature and film studies, and empirical work from cognitive psychology, computer graphic animation and human-robot interaction.

- The developed methodology and its application in a human-robot interaction-like scenario demonstrates its use and validity. It provides a measurement tool using a feature-space to evaluate differences in subjective interpretations based on the attribution of different degrees of features to entities. As such it presents a quantitative method that provides a relational approach on two levels. First, instead of using nouns which determine an entity as belonging to one or another category or species, e. g. this is an animal or not, it utilises adjectives and verbs, which places focus on the way people experience and relate to an entity, e. g. ascribing emotions and intentions. Second, it enables a measurement that allows a relationship rather than just attributing properties on a simple black/white or either/or ratio.

- The results from the application of the methodology indicate movement as a determinant of variances in the interpretation of the object. The findings reveal that the movement of an everyday object motivates an interpretation closer to humans and animals, apparent in increased attribution of animate and intentional features. Furthermore, in terms of differences between the two movement conditions, evidence suggests that mechanical movement leads to an increase of uncanniness and eeriness, while biological movement raises positive emotions.

These results extend a well documented phenomenon. They correspond to findings of screen-based work on animated abstract shapes or Wizard of Oz scenarios, where the behaviour of objects is remotely controlled by a human. These works show that the movement of abstract shapes or non-anthropomorphic objects are interpreted more in social terminology and as animate, and less in factual and impersonal language (surveyed in the related work Chapter 3). However as the empirical work brings together people and an autonomously acting robotic object, which lacks anthropomorphic/zoomorphic or mechanoid morphology, in a real world scenario, it transfers these findings from cognitive psychology and computer graphic animation to the field of human-robot interaction.

2 BACKGROUND

Nach glaubwürdigen Überlieferungen hat das im sechzehnten Jahrhundert einem Zeitalter stärkster seelischer Bewegtheit, damit begonnen, dass man nicht länger in die Geheimnisse der Natur einzudringen versuchte, sondern sich in einer Weise, die nichts anderes als oberflächlich genannt werden kann, mit der Erforschung ihrer Oberfläche begnügte. Der grosse Galileo Galilei, der dabei immer als erster genannt wird, räumte zum Beispiel mit der Frage auf, aus welchem in ihrem Wesen liegenden Grund die Natur eine Scheu vor leeren Räumen habe, so dass sie einem fallenden Körper solang Raum um Raum durchdringen und ausfüllen lassen, bis er endlich auf festem Boden anlange und begnügte sich mit einer viel gemeineren Feststellung: er ergründete einfach, wie schnell ein solcher Körper fällt, welche Wege er zurücklegt, Zeiten verbraucht und welche Geschwindigkeitszuwächse er erfährt.

— Robert Musil (1943, pp. 301-2)

Credible received wisdom indicates that it all began in the sixteenth century, a time of the greatest spiritual turbulence, when people ceased trying to penetrate the deep mysteries of nature as they had done through two millennia of religious and philosophical speculation, but were instead satisfied with exploring the surface of nature in a manner that can only be called superficial. For instance the great Galileo Galilei, always the first to be mentioned in this connection, eliminated the question of what were nature's deep intrinsic reasons for abhorring a vacuum and consequently letting a falling body penetrate space after space until it finally comes to rest on solid ground, and settled for something more common: he simply established how quickly such a body falls, the course it takes, the time it takes, and what is its rate of downward acceleration.

— Robert Musil (1996, p. 326)

The aim of this thesis is to learn more about the role of movement for human perception. In particular how movement motivates changes in peoples' relationship towards things. In this chapter I look at this relationship through related work from an artistic context that have been inspiring together with concepts referring to literature that has been influential predominantly from philosophy of arts and technology, literature and film studies.

This chapter elaborates and assembles examples in the fashion of an annotated portfolio along with key concepts in a way that has an indexical, mutually informing relationship similar to an exhibition on the topic of this thesis. Bowers (2012), drawing the parallel to a genealogical tree, points out an annotated portfolio creates family resemblances amongst artefacts similar to a curated exhibition. Thus the subsequent assemblage provides a personal access to my affinity to movement and technological objects and could be considered as curated assembly of works that have been of interest for this PhD. Some of them stem from direct encounter during the time working on this thesis in London, visiting various museums, galleries and performance spaces. Others are older, originating from my ongoing interest in art and design.

The rationale shows that the body of works motivate this thesis by making transparent the context, ideas and theories that have taken part and formed during the production of the methods (Chapter 4) and application (Chapter 5), this is approached through examples that could be considered as a tour through an exhibition on the topic of movement. This chapter consist of three parts that all present different perspectives on the overarching research question on how movement changes the perception of artefacts. In the first part I illustrate how movement is one of the primary elements in founding humans' relationship to artefacts. Therein I argue that movement provides the basis for the living and that there are differences in the perception of movement of artefacts ranging from living or intentional action to non-living or involuntary movement. In the second part I present linguistic conceptualizations to look at how we talk about our relationship to artefacts. Here I present humans' intuitive process of categorizing and attributing characteristics to things as found in the concept of metaphors. Ultimately, I argue for a relational approach focusing on adjectives and verbs instead of excluding nouns, e. g. I'm human but not animal or machine, to express and indicate emotions and feelings towards things. The third part considers movement as a stylistic device used to design an affective relationship. Here I discuss movement as a device using an artefact's ambiguity between inanimate and animate object to create an affective relationship ranging from repulsion to attraction.

This guided tour contributes two goals. Firstly to present movement as one of the primary factors that provokes affection, as well as a stylistic device used by artists.[1] The other goal is to demonstrate how linguistic phenomena, in particular metaphors, can be devices to express and evoke emotions, as, for example, found in prose and poetry. Ultimately, this chapter provides an interdisciplinary synthesis of literature as a contribution to knowledge. The following sections bring together work from various fields to provide an understanding of our affinity to the movement of technological objects.

2.1 MOVEMENT FORMING THE BASIS FOR OUR RELATIONSHIP TO ARTEFACTS

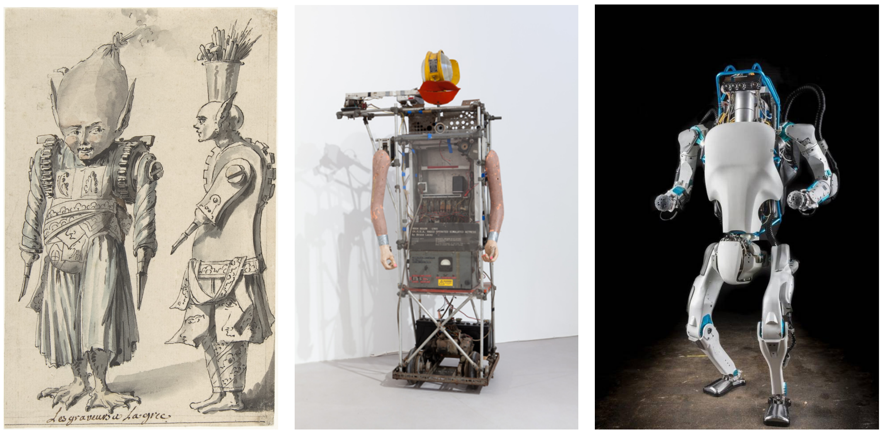
> I was cleaning and, meandering about, approached the divan and couldn't remember whether or not I had dusted it. Since these movements are habitual and unconscious I could not remember and felt that it was impossible to remember – so that if I had dusted it and forgot – that is, had acted unconsciously, then it was the same as if I had not. If some conscious person had been watching, then the fact could be established. If, however, no one was looking, or looking on unconsciously, if the whole complex lives of many people go on unconsciously, then such lives are as if they had never been.
>
> — From Leo Tolstoy's Diary (1897) cited by Shklovsky (1917, p. 12)

As Tolstoy's words in the Quote 2.1 above indicate, movement is something that happens in the background. The quote expresses that we humans are not always particularly aware of movement but at the same time it is part of our lived experience, for instance how we use things and relate to our surrounding. In the following section the aim is to give priority to movement and look at the way it affects the perception of things. This includes technological objects and animated artefacts like robots but also everyday objects and humans.

Dautenhahn points out that "[t]he concept of robot is a moving target, we constantly reinvent what we consider to be 'robot' ... Robots are designed artefacts, and they are a moving target; what we consider to be a typical 'robot' today will probably be very different from what

1 E. g. in cartoons, bringing a drawing to life or animating technological objects

people in 200 years consider to be a robot" (Dautenhahn, 2013, Section 38.2).



(a) *Caricature of Engravers* (1771) by Ennemond Alexandre Petitot.

(b) *R.O.S.A. B.O.S.O.M.* (1968) by Bruce Lacey.

(c) *Atlas* (2016) developed and distributed by Boston Dynamics.

Figure 2.1: Different concepts of a robot. Image 2.1a by The Metropolitan Museum of Art published in the public domain. Image 2.1b by Angus Mill courtesy of Camden Arts Center. Image 2.1c by Boston Dynamics published on wikimedia under CC BY-NC-SA 4.0.

Artist and inventors have been working with movement, trying to mimic nature and develop technology simulating lifelike qualities not only since the invention of character animation on screen (Bates, 1994). Stacey and Suchman (2012), with reference to Riskin (2003a,b), list early animations and automatons recorded to convincingly simulate life processes from the 17th century, for instance Jacques de Vaucason's defecating Duck or Wolfgang von Kempelen's Chess player through to 21st century modern robots from the MIT-lab such as those developed by Rodney Brooks. Further examples of automata are presented in Cohen (1967) and Reichardt (1978) from art, science and mythology; Ernst (2003) examines automatons and mechanisms depicted in narrative prose from the middle ages to the early modern period; Giedion (1955) contributes an historical overview and investigation of human inventions and mechanisation's reach and appeal; Al-Jazari (2012) lists 12th century work of Arabic engineering and technology, including mechanised figures and simulations of the planetary system; and seminal exhibitions like Hultén (1968) and Reichardt (1968) or more recent publications like Broeckmann (2016) and Kries (2017) reassemble artistic and design approaches to technological objects, machines and automatons that go beyond their utilitarian use.

Whether or not the concept of technological objects like the robot has changed, what has not changed is *movement* within theses works.

From this perspective this section aims to provide answers to the question *what is movement?* I start with presenting movement as forming the basis for the living. I then conceptualize humans' attraction to the dynamic form of things (expressivity) and present movement as one of the primary elements in founding our relationship to artefacts. Depicting the intuitive accessibility of an industrial robot's movement, I argue that movement is an immediate experience as the design of the behaviour of this non-biological entity encourages engagement with people. Furthermore that there are differences in the perception of movement ranging from the living or intentional action to involuntary movement commonly associated with the non-living.

Condensation Tube by Hans Haacke (1963)

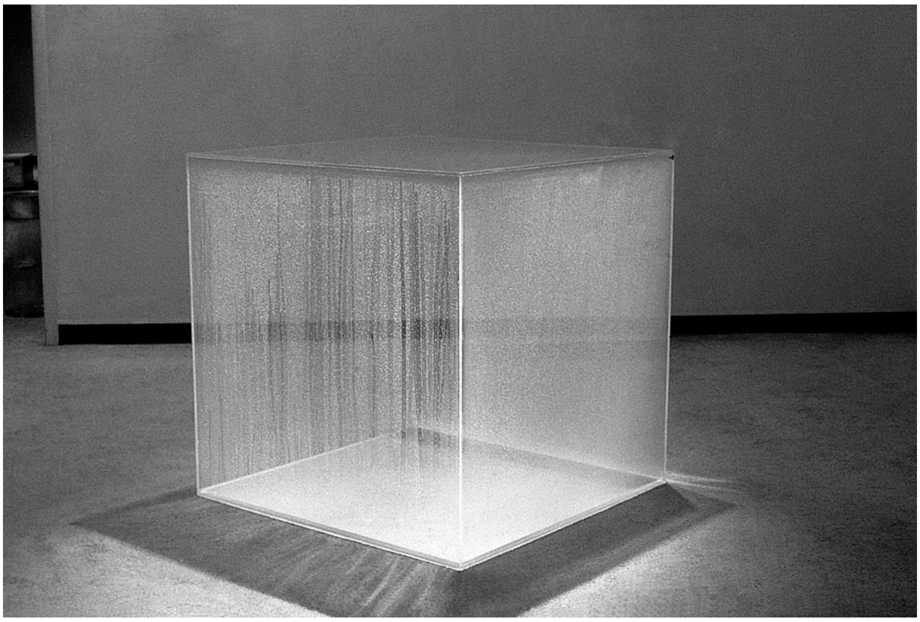


Figure 2.2: *Condensation tube* by Hans Haacke (1963) – movement as a dynamic form. ©Hans Haacke/VG Bild-Kunst, published with permission by the artist.

At the beginning of my PhD, during one of my first visits to the Tate modern gallery in London, Hans Haacke's (1963) *Condensation cube*[2] was on display. Haacke is an artist who seeks to continually reveal that an artwork is not merely an object but is also its context (Haacke, 2016, p.181 ff.). This early piece from his œuvre, going back to his interests in biology, ecology and the exposure to systems theory (Haacke, 2016, p.106), consists of a sealed acrylic glass cube with water inside as shown in Figure 2.2. The water condensates in respect to changes in

2 Original title: *Kondensationswürfel* (Haacke, 1963)

its environment challenges the perception of movement. Nothing dramatic happens whilst you are standing in front of it — if you are lucky a drop of water is moving. It brings to mind that the planet and our atmosphere is in constant movement which is forming the base for the living.

2.1.1 *The Dynamic Form of Things*

Langer's (1957) remarks on *expressiveness* outline beautifully the perception of changing intensity of qualities in the eye of the beholder associated with movement. In her book *Problems of art: Ten Philosophical Lectures* she describes anything that exists only for perception, something that is only visible, not tangible, and plays no part in nature as common objects do, as a virtual entity. She goes on to characterise expressiveness as the dynamic form that is apparent in the eye of the beholder as the changing intensity of qualities through motion, like a funnel of water, a dance or the momentary efflorescence of a bursting rocket. The dynamic form, the "virtual thing," disappears as soon as the motion stops or slows beyond a certain degree (Langer, 1957, p.18). For Langer, 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 movements and the expressive form of things are intimately related (Johnson, 2008). We learn though 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 (Piaget, 1997). Within this relationship, movement is considered as an immediate experience. This is elucidated with the following example illustrating an artistic approach of playing with the dynamic form of things.

Mimus by Madeline Gannon (2016)

Humans' affinity towards the expressiveness of things was apparent to me for instance when I was visiting the *Fear and Love: Reactions to a Complex World* exhibition[3] at the Design Museum in London. One of the works on display that gained a lot of attention was an *ABB IRB 6700* industrial robot. This work, entitled *Mimus* (2016), by the interaction designer Madeline Gannon, consists of a robot, locked behind a glass cage as shown in Figure 2.3. The robot was programmed to re-

3 From 24 November 2016–23 April 2017, http://designmuseum.org/exhibitions/fear-and-love (accessed August 2017)

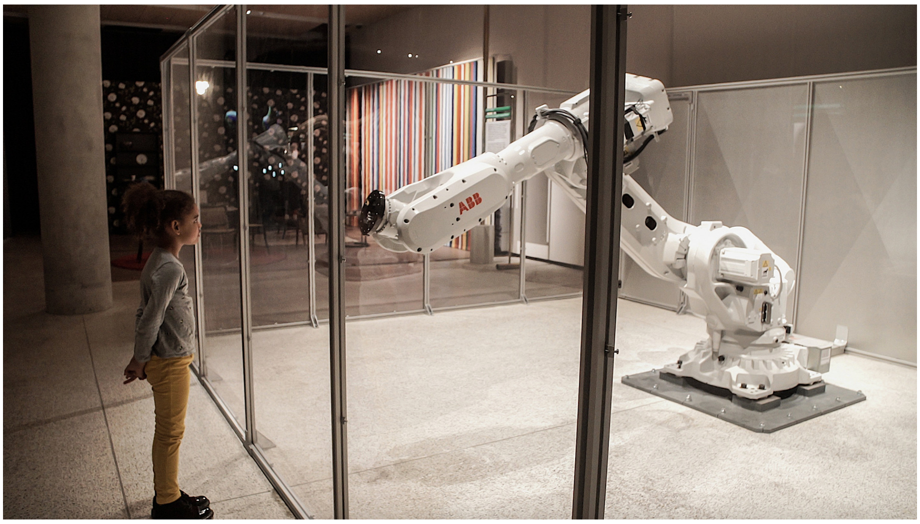


Figure 2.3: *Mimus* by Madeline Gannon (2016) – affinity towards movement. Image by Madeline Gannon, published with her permission.

act to the surroundings using the input of motion sensors and formed a zoo-like environment for people to interact with a giant industrial robot.[4] A clear affinity to the work could be observed in viewers of all ages as they playfully interacted with the robot. As such they provide evidence to match the designers' intention "that the behavior and design are intuitive in a way that people who have never even seen a robot before will be able to immediately understand how to interact with Mimus" (Gannon, 2016).

2.1.2 *The Primacy of Movement in the Perception of Artefacts*

In the book *Being alive*, the anthropologist Tim Ingold (2011) provides various essays on movement and animacy. He acknowledges the primacy of movement, conceiving it as ontological prior to the properties projected onto things (Ingold, 2011, p.68). In this way, movement, the dynamic form of things, is an immediate experience that happens before we even start thinking conceptually about things. This is also indicated for instance in Carey's work in the field of developmental psychology and cognitive development. In her book *The Origin of Concepts*, she recognises movement, the "knowledge of spatio-temporal continuity and cohesion" (Carey, 2009, p.96) as a core cognition that is not conceptual. Similarly, the film maker Sergej Eisenstein (2013, p.19) per-

4 Similar attraction is reported from the phonotactic behaviour of Edward Ihnatowicz's cybernetic sculptures e. g. *SAM* or *The Senster*, the latter is a huge hydraulic robot reacting to visitors movement commissioned by the electronics company Philips shown in Eindhoven, Netherlands in the late 1960's (Penny, 2011; Reichardt, 1978; Zivanovic, 2005).

ceives the attraction to the dynamic form of things as pre-logical and for instance determines the attraction of fire due to its limitless power to create plastic forms and appearances.

Both artworks, Haacke's *Condensation Cube* (1963) and Gannon's *Mimus* (2016), mentioned above provide pointers to movement as an immediate experience. In Haacke's work, the primacy of movement is expressed in its ubiquitousness as relational changes within an environment which form the foundation for the basis of life.[5] In addition, intimately related to the *Condensation Cube* but more important for the work presented here, in the expressivity of the industrial robot. In an interview Gannon acknowledges that due to the "very raw experience with this animal like machine responding to your every move, all the technical aspects melt into the background" (Nordstrom, 2016, 3:30min). The intuitive accessibility incorporated in the work and apparent in the playful interaction of the people accentuates how the robotic and potentially threatening nature of the robot fades into the background and becomes secondary, while at the same time foregrounding movement as a primary experience. In that light our affinity to the expressivity of the robot suggests movement as an immediate experience, a protagonist that enters the 'stage' very early. Thus the robot's behaviour is a play with humans intuition. It illustrates the pre-conceptual (Carey, 2009), pre-ontological (Ingold, 2011) or pre-logical (Eisenstein, 2013) experience of the movement as taking place before we even start thinking conceptually about the nature of an artefacts behaviour.

2.1.3 *The Perception of Involuntary Movement and Intentional Action*

A personal experience of becoming aware of own actions and agency losing the control over my own, goes back to an artist talk of the performance artist Stelarc at Zurich's University of the Arts. I can't forget the smile on his face during one of his demonstrations. In the demonstration, he used a transcutaneous electrical nerve stimulation device, a technology normally used for pain management [6] to control the action of my, and others' arms. Stelarc attaches the device himself for the "Event for Invaded and Involuntary Body" (Stelarc, 1997) performances as shown in Figure 2.4a. Feeding spikes of electronic impulses into his body, his objective is to build a "more complex and interesting body – not simply a single entity with one agency but one that would be a host

5 Interesting in that respect is also the *Photosynthesis Robot* by Futurefarmers (2003).
6 Device similar to this one: `http://amzn.com/B00NCRE4GO` (accessed August, 2017)

for a multiplicity of remote and alien agents" (Stelarc, 1997). However, the spikes injected into my muscles made my arm move without my intention. In addition to his grin, I also can't forget the perplexing and irritating feeling which accompanied the puzzling experience of this action happening without my authorisation and without me having agency of the motion.

From this perspective, agency provides information about the perception of movement along the lines of intentional action or involuntary movement and thus can be perceived to be originating from an either biological or non-biological sources. As Mutsumi Yamamoto (2006, p.29) points out, agency is a matter of gradient rather than a simple animate and inanimate binary. 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.*[7] moving organically or mechanically, or as if moved by an internal agency, shed light on whether it is perceived to be animate or inanimate as shown in Figure 2.4.

(a) Remote controlled performance artist Stelarc

(b) Animated desktop lamp *Luxo Jr.*

involuntary movement — intentional action

Figure 2.4: Scope of agency: different degrees of ownership and authorship of an action indicate whether the apparent action is involuntary movement or intentional action. Image 2.4a published by user Davepape on Wikipedia under CC BY 2.5. Image 2.4b by Rosenfeld Media published on flickr under CC BY-NC-SA 2.0.

Rakison and Poulin-Dubois (2001) characterises the degree of an entity's agency as likely to being more the recipient or more the agent

7 See Shedroff and Noessel (2012, p. 189) and https://en.wikipedia.org/wiki/Luxo_Jr. (accessed October, 2017).

of an action.[8] Gell (1998, p.133) discriminates between 'happenings,' caused by physical laws and resulting from material causation, and 'actions,' caused by prior intentions and stemming from agency. Gallagher and Zahavi (2012, 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. The experience of action belongs to the person who is causally involved in the production of that action, and thus is 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 (Jackendoff, 1978, p. 222, cited by Szewczyk and Schriefers, 2011).

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, an animated desktop lamp moving by itself has more agency, characterised by author and ownership both seeming to reside within the entity, while if the lamp is involuntary moved by someone, its agency is reduced, characterised by the divergence of authorship and ownership of the action.

The examples in this section section aim to to provide answers to the question: *what is the role of movement in our relationship to artefacts?* I reported different artistic uses of movement and foregrounded movement and the dynamic form of things as an intuitive and immediate experience. This was done by describing peoples' affinity to the expressivity of an industrial robot matching the artist's intention to design the behaviour of the robot in a way that is intuitively accessible and familiar. I argued that movement forms the basis for engagement between humans and artefacts by providing examples exemplifying people's affection for those artefacts. Furthermore, I argued that movement provides the basis for aliveness and that there are differences in the perception of movement ranging from involuntary movement to intentional action.

In respect to the next sections, focusing on the linguistic conceptualization of our relationship to things, the aim here was to illustrate

8 The Self-Moving Oil Droplets by Takashi Ikegami (2007) are interesting in that respect. He is using oil-droplets in an aqueous environment to investigate "the chemical-molecular origins of movement" (Ikegami, 2010) and illustrates movement as an activity that happens in the relation between the entity and the environment rather than something that is determined by forces inside or outside an entity.

that we make 'sense' through the primordial experience of movement, which provides the basis for abstract conceptualization and reasoning.

2.2 LINGUISTIC CONCEPTUALISATIONS OF OUR RELATIONSHIP TO ARTEFACTS

> Who does the lamp communicate with? The mountain? The fox? But here the answer is: to man. This is not anthropomorphism. The truth of this answer is shown in knowledge and perhaps also in art. Furthermore, if the lamp and the mountain and the fox did not communicate themselves to man, how should he be able to name them? And he names them; he communicates himself by naming them. To whom does he communicate himself?
>
> — Walter Benjamin (1986, p. 317) referred in Steyerl (2006)

Human beings are metaphorical creatures (Johnson, 2008, p. 279). The concept of the metaphor reflects the intuitive process of categorising and attributing characteristics as a dialog and understanding of things. Human propensity to infer meaning and language offers us a way to interpret "the intensity of our connections to the world of things, and for discovering the similarities in how we relate to the animate and inanimate" (Turkle, 2007, p. 10).

In this section I look at how we communicate our relationship to our surrounding artefacts and things in general. I present our propensity to attribute characteristics to things to describe and communicate a relationship. I argue for a relational approach focusing on adjectives and verbs instead of excluding nouns to give way to an interpretative relationship that pays attention to the way people interact, experience and relate to things. Furthermore, I illustrate how language indicates differences in our relationship along the lines of interpreting an entity as animate or inanimate (animacy).

56 kleine Helicopter by Roman Signer (2008)

The artist Roman Signer considers his works simply as actions. The installations and performances reassemble, for example rockets, catapults, staged explosion and combustion events (see Mack et al., 2006). The 3:10min video *56 kleine Helicopter* (Signer, 2008) (stills are presented in Figure 2.5) is described in a press release of the Smith College Museum of Art as:

> This video [*56 kleine Helicopter*], purchased with funds from the Contemporary Associates of the Museum, shows a squadron of 56 remote-controlled toy helicopters. They rise into the air, collide with each other, carom off the ceiling and walls, and finally die in mechanical spasms on the floor. The effect is both humorous and disturbing, as the toys seem to transform into a swarm of gigantic insects intent on their own self-destruction.
>
> — Smith College Museum of Art (2011).

Figure 2.5: Stills from the video *56 kleine Helicopter* by Roman Signer (2008) showing a congregation of helicopters taking off and mutually destroying themselves. Image courtesy of the artist, published with permission of Barbara Signer.

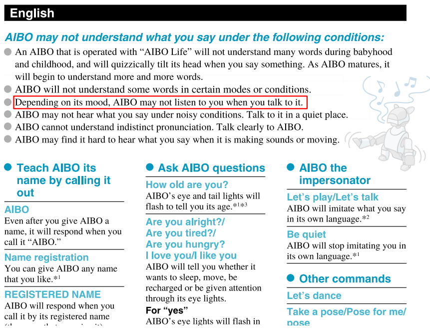
As in a lot of Signer's work the video comes with a slapstick simplicity. I found it fascinating to watch the almost military order of the helicopters transforming into a lifelike chaos and ultimately staging the end of life or death of the machine. The movement in the work could be considered a metaphor for life. This is reflected in the words of the press release which likens the motion to a "swarm of insects".

2.2.1 *Interpretative Relationship to our Surrounding*

Langer (1957, p.23) explains that if we want to name something that is too new to have a name, like a gadget we haven't 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 (1980) 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 press release of Signer's work in the Quote 2.2 above or reactions to the hairbrush, presented in Section 1.2, 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 a hairbrush as intending to commit suicide embodies attributing human form or a human mind to the entity. Similarly, understanding the mind as a machine that "is not *operating* today" (Lakoff and Johnson, 1980, p.26, emphasis in original) or describing the robot Aibo as being mood dependent as in the manual by the Sony Corporation (2001) shown in Figure 2.6b, involves metaphoric mapping from the human domain (Carston, 2002, p.95).

(a) Animism: seeing lifelike forms.



English

AIBO may not understand what you say under the following conditions:

- An AIBO that is operated with "AIBO Life" will not understand many words during babyhood and childhood, and will quizzically tilt its head when you say something. As AIBO matures, it will begin to understand more and more words.
- AIBO will not understand some words in certain modes or conditions.
- Depending on its mood, AIBO may not listen to you when you talk to it.
- AIBO may not hear what you say under noisy conditions. Talk to it in a quiet place.
- AIBO cannot understand indistinct pronunciation. Talk clearly to AIBO.
- AIBO may find it hard to hear what you say when it is making sounds or moving.

Teach AIBO its name by calling it out

AIBO
Even after you give AIBO a name, it will respond when you call it "AIBO."

Name registration
You can give AIBO any name that you like.*1

REGISTERED NAME
AIBO will respond when you call it by its registered name

Ask AIBO questions

How old are you?
AIBO's eye and tail lights will flash to tell you its age.*1*3

Are you alright?/ Are you tired?/ Are you hungry? I love you/I like you
AIBO will tell you whether it wants to sleep, move, be recharged or be given attention through its eye lights.

For "yes"
AIBO's eye lights will flash in

AIBO the impersonator

Let's play/Let's talk
AIBO will imitate what you say in its own language.*2

Be quiet
AIBO will stop imitating you in its own language.*1

Other commands

Let's dance

Take a pose/Pose for me/ pose

(b) Anthropomorphism: attributing humanlike properties.

Figure 2.6: Animism and anthropomorphism: examples for social perception in the environment. Both images by the author, image 2.6b screen shot from Aibo manual (Sony Corporation, 2001, emphasis added).

Attributing human-like properties to entities is described in the concept of *anthropomorphism*, which can be distinguished from *animism* (see Figure 2.6a) as the latter refers to the tendency of seeing animal forms in clouds, faces in trees – seeing human-like agents in the environment (Guthrie, 1995).[9] The former is characterised by the creation of human-like agents out of non-humans (Epley et al., 2008a), as a special form of metaphor. Vidal (2007) considers anthropomorphism

9 A different take on animism is provided by the artist Lars Laumann who is exploring unusual biographies in his work. In the video *Berlinmuren* (Laumann, 2008), he builds a portrait of Eija-Riita Eklöf Berlinermauer who describes the belief that all objects are living and having a soul as animism. This provides the basis for her being emotionally and sexually attracted to objects and the substrate for her love affair with and subsequent marriage to the Berlin Wall. The video reports in a quite convincing way her and other peoples' outing as objecto-sexual. See also Steyerl (2017, p. 49), speaking of apophenia as the perception of patterns within random data.

as the most spontaneous register through which humans' establish – consciously or not – a strong relationship with artefacts or other non-human living beings. In this process, Epley et al. (2007) identify three major key determinants: *Sociality*, *Effectance*, and *Elicited Knowledge*. At the core of their model is a process of induction of elicited knowledge, that is using existing knowledge about ourself or from conversing with others to guide inferences about properties, characteristics and mental states of non-human agents. This induction is influenced by two motivational factors: sociality, the need and desire to establish social connections with others, and effectance, the need to interact effectively.

Seibt (2015) 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 (1990), 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 surroundings as a way to socialise the world and not to anthropomorphise it. Correspondingly Attfield (2000) and Turkle (2007) foster an interpretative account of cultural objects by emphasising the importance of social history of everyday life in our relation to objects and things. As Turkle (2007, p. 5) remarks, objects can serve as markers of relationship and emotional connection, they accompany us through our lives, as we accumulate memories, thoughts and feelings and become part of us. We give things names and relationships (Pickering, 2011), for instance soldiers are reported to give names to the bomb-disposal robots they've been working with and when a broken robots had to be sent back to the repair unit the soldiers would ask to get "the one" back instead of acquiring a new one as they did not want the original to "die" (Carpenter, 2013, cited by Knight, 2014). Similarly, Sung et al. (2007) report 21 of 30 households interviewed by them gave names and nicknames to their Roomba™[10] vacuum cleaner robots.

However, in as far as anthropomorphism is an inductive process or an interpretative process 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" (Lakoff and Johnson, 1980, p.5), as demonstrated in the attribution of the hairbrush's alleged suicidal tendencies (see in Section 1.2). Moreover, Langer (1957, p.20) remarks that this understanding of one thing through another is a deeply intuitive process. Carey (2009, p.3) similarly states that humans' capacity

10 https://en.wikipedia.org/wiki/Roomba (accessed April, 2018).

for conceptual representation involves conceptual changes as an intuitive process. Within this process of interpretation, language has the potential to capture ontological commitments (Carey, 2009, p.35). This is illustrated in the divergence in the attribution of *agency* ranging from living or intentional action to non-living or involuntary movement.

2.2.2 *Relational Approach to Bridge the Gap between Humans and Things*

Ingold (2011) and likewise Coeckelbergh (2014), take a relational approach and consider agency not something that is sprinkled on things to make them come to life, but rather something that resides within the activity – what happens between – such as the experience, interaction and relation between a human and a robot.

From this vantage point things are in life rather than there being life in things (Ingold, 2011, p. 29). As a consequence, "if we follow active materials, rather than reducing them to dead matter, then we do not have to invoke an extraneous 'agency' to liven them up again. The wind, for example, is not an object, nor does it tear at the trees because it is endowed with agency. It is an air current, materials-in-motion. We say 'the wind blows', because the subject-verb structure of the English language makes it difficult to express it otherwise. But in truth, we know that the wind is its blowing. Similarly, the stream is the running of water. And so, too, I am what I am doing. I am not an agent but a hive of activity" (Ingold, 2011, p. 18).

In respect to the activities of nonhuman entities like animals and robots, Coeckelbergh (2014) observes a gap between reasoning about and experiencing these entities. Based on the observation that humans tend to anthropomorphise or zoomorphise, for instance treating a robot as if it has human or animal properties, he criticises the 'standard approach', which is based on the assumption that the presence of an entity depends on having particular properties and rests on the "Cartesian mechanism of exclusion" (Coeckelbergh, 2014, p. 72).

Built upon a negative anthropology this approach is trying to define the humans in terms of what they are not: as non-gods, non-animals, non-machines, and indeed as non-beast-machines or at least more-than beast-machines. In this respect robots are used as "purification tools, instruments that keep open the divide, that guard the borders between human and nonhuman, defining humans in terms of what they are not" (Coeckelbergh, 2014, p. 72). This perspective brings us to think of robots as "mere machines" and assumes a gap between the entity. For instance , a gap between the robot as a Ding-an-sich[11] and its appearance. For Coeckelberg this dualistic approach stands in contrast with how people interact, experience and relate to robots when we ascribe emotions and intentions, and love or take care of the machine so as not to hurt it.

As a solution he proposes a relational approach focusing on people's experiences and subjective realities emerging from human-robot relations. Rather than assuming two atomistic, unrelated entities prioritising particular 'properties' he makes the case to focus on the relation. Ingold (2011, p. 166) correspondingly finds it problematic to identify things as belonging to one or another category or species, each known by an appellative or 'common' noun. For instance, saying 'I'm not an animal,' infers a separation between humans and animals that is artificially maintained. Using adjectives or verbs instead of just excluding nouns, e. g. animal or machine, places focus on the 'appearance' and 'perception' of the entity-in-relation. It allows us to shed light on the tacit knowledge in play while engaging with machines. For Coeckelberg focusing on this knowledge-in-relation with other entities that is already there rather than the Cartesian mechanism of exclusion (using other entities to distinguish ourselves as humans), closes "the gap between reasoning and experience, between thinking and action, between belief and feeling" (Coeckelbergh, 2014, p. 63). It also allows multisubjectivity and plurality of truths situating the machine as naturally, materially, socially, and culturally embedded and constituted.

Related Sørensen and Ziemke (2007) propose a dynamic conception of agency to avoid that agency becomes a capacity a system either has or has not. The dynamic conception of agency understands agency as a 'degree' of possibilities an organism is capable of managing and thus allows us to explain the evidently high 'agency factor' of humans without isolating mankind in nature or reducing other animals to mere automata.

2.2.3 *Differences in How Alive Something is Interpreted*

Animacy as a semantic principle and linguistic concept provides indications of how sentient or alive the referent of a word is interpreted. It is a matter of gradient rather than a simple animate and inanimate binary and is intimately related to agency (Yamamoto, 2006, p.27). Differences

11 Translated as thing in itself, referring to the controversial view of objects as they are independent of observation commonly associated with Kant's cognitive dualism. See for instance Thielke and Melamed (2015).

in the use of words describing an entity's animacy indicate differences in its interpretation, and they can also be considered as a stylistic device to express and evoke emotions or attitudes through language. It is of interest for example in poetic writing to find smiling or dancing flowers, angry or cruel winds (Encyclopædia Britannica, 2017) or jumping rainbows (Eisenstein, 2013, p.53). John Ruskin (1866), in opposition to anthropomorphism, termed this pathetic fallacy. Correspondingly, writing "[t]he lamp was *staring* at him" (Ziegler, 2010, p.57, emphasis added) 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 characterisation of a referent ranging from human, animate to inanimate (Dahl and Fraurud, 1996, p.47), apparent as such for instance by referring to the wind as "[h]e closed the door", "[t]he wind closed the door", "[t]he door was closed by the wind" (Dahl and Fraurud, 1996, p.49). Thus, in contrast to the previous example of the lamp, describing it in a more factual language, as 'shining at him' instead of 'staring' or 'the mind is stray' instead of 'operating', embodies differences along the lines of portraying an entity, here a lamp or a person/mind, more as animate or inanimate.

In this section the focus was on linguistic conceptualisation of our relationship to artefacts and how it reveals differences in our perception. I started with an example displaying the expressivity, the dynamic form of a non-living object being predominantly described in language used to describe the living. I argued that we generally tend to categorize and attribute characteristics as dialog and understanding of things. Differences in these interpretations are apparent in the use of language as divergence in animate or inanimate descriptions. Furthermore I reasoned for a relational approach focusing on adjectives and verbs instead of excluding nouns to stress its possibility to communicate our feelings and emotions towards artefacts.

Language and words are not only a way to describe and communicate a relationship, they are similar to movement, a metaphor, a stylistic device to express and evoke differences in the relationship to things. The artistic use of movement in artefacts employing the technological animation of objects as a stylistic device is the focus in the next section.

2.3 MOVEMENT AS A STYLISTIC DEVICE TO DESIGN AN AFFECTIVE RELATIONSHIP

> Art, which results in physical objects, is the only activity that represents the half-way house between the regimentation of technology and the pure fantasy of films and literature; and only in the name of art is a robot likely to made which is neither just a costume worn by an actor, nor an experimental artificial intelligence machine, nor one of the many identical working units in an unmanned factory.
>
> — Jasia Reichardt (1978, p. 56)

In the citation at the beginning of this chapter on page 11, Musil (1996) describes the movement of a rock in two ways. On the one hand, in rather factual terms, reassembling Galileo's viewpoint, using physical parameters describing it as getting to the bottom by determining it in terms of physical conditions (e. g. speed, path, time and velocity), he portrays the stone more as an inanimate object. On the other hand, the rock is described as more animate and poetical — as a falling object that has a fear of the void. This game with animacy, which Eisenstein (2013) determines the principle of poetry, is even more apparent and affective when things are animated on screen, the affect towards movement, the expressive form of things, on the one hand can be considered as part of our survival kit to distinguish animate from inanimate (Blythe et al., 1999, p.257), on the other, hand in hand with the latter, as exemplified above with the rock, it is the survival kit of poetry.

The particular focus of this section is to look at how movement is used as a stylistic device in the arts to contribute and challenge relationships to artefacts. To address this I first look at the principle of poetry as a technique of art playing with ambiguity of familiar relations, as found in the readymade[12] creating boundary objects by placing them between objects and art. I argue that ambiguities between the familiar borders of non-living object and living creature are employed to design affective relationships to artefacts apparent as repulsion or attraction.

2.3.1 *Playing with Ambiguities as a Technique of the Arts*

It is commonly accepted that our relation to inanimate objects is different than to biological entities. However this relation comprises con-

12 Marcel Duchamp defined the readymade as "Objet usuel promu à la dignité d'objet d'art par le simple choix de l'artiste" (Breton and Eluard, 1938, p. 35).

(a) *Supermarket* (1997) (b) *Having meals just like refueling* (1994)

Figure 2.7: Portraying ambiguity between humans and machines. Dark surrealism by painter Tetsuya Ishida (1973-2005) challenging the notion of being human (Ishida, 2010). Both images ©Tetsuya Ishida, published with permission of Michiaki Ishida.

ceptual ambiguities. Things can be experienced as technological and biological at the same time. The ambiguity therein could be that each of us is both subject and object (De Beauvoir, 1976, p. 10) or sandwiched in between (Ingold, 2011, p. 166). A similar contradiction can be found between the concept of human and machine. For instance my heart pumping without my intent makes me feel ambiguous in determining whether I'm a machine or human. Maybe I'm both at the same time. Riskin gives an example. She writes, the neologism 'wetware', used as a metaphor for humans' logical and computational capabilities, expresses an organising ambivalence between machine and life. "We believe that the processes of life and consciousness are essentially mechanistic and can therefore be simulated, and yet we are equally firmly persuaded that the essences of life and consciousness will ultimately be beyond the reach of mechanical reproduction" (Riskin, 2003a, line 97).

Comparable conceptual tentativeness can also be found in the relation to the world of things. Things can be experienced as technological and biological at the same time. Simondon for instance diagnosed two conflicting attitudes towards technological objects. On one side, they are considered as assemblages of matter devoid of true meaning and merely utilitarian. On the other, objects are considered robots that are animated with hostile intentions towards humans (Simondon, 2012, p. 10). To that effect, Turkle (2007) says that "[w]e find it familiar to consider objects as useful . . . [but] [w]e are on less familiar ground when we consider objects as companions to our emotional lives or as provocations to thought" (Turkle, 2007, p. 5) to underscore that in our relationship to things, thought and feeling are inseparable. She points out that technological objects are more than an inanimate collection of atoms and molecules. They can, and often are, capable of evoking emotional responses and relationships.

A rather dark approach to these ambiguities and their use as a stylistic device is portrayed in the pictures of the painter Tetsuya Ishida (1973-2005). Shown in Figure 2.7, the painting evoke a grim mood in the way they challenge the notion of being human (Ishida, 2010). Similar stylistic devices are found in Kafka's stories, sketching hybrid beings (Baer et al., 2010), e. g. the character Gregor Samsa being a salesman and a gigantic insect at the same time (Kafka, 1984). Amongst other examples, Nelson (2002, pp. 12-13) refers to Kafka's story *The Burrow* as an analogy to the grotesque, which in resemblance to ambiguity, is composed of a tension between what is familiar and what is unknown. She introduces her notion of grotesque and its fascination by citing Da Vinci standing at the entry of a grotto and experiencing the paradox between "two, contrary emotions ..., fear and desire – fear of the threatening dark grotto, desire to see whether there were any marvelous thing within it" (Miller, 1982, p. 5, cited by Nelson, 2002, p. 1).

This tentativeness as a stylistic device to make things appealing can also be found in readymades employing the ambiguity between the familiar and the new, this is exemplified in the following work.

+ ∞ − by Roman Stańczak (1996)

The artist Roman Stańczak works with everyday objects and materials. In an interview conducted by Żmijewski, Stańczak refers to the readymade tradition and his use of ordinary objects in his work as follows:

> As my medium I chose commonly used, everyday objects present in many houses. By using these objects I activate people's imaginations about these things. I use objects as carriers of information. I express my opinion about the world through interfering with objects, which can take the form of, for instance, deforming. After I'm done with an object it starts to create a new situation. A person who uses a kettle, chair or bathtub encounters in a completely new reality an object he or she has been familiar with for many years, which I hope is surprising. That split second of surprise is a doorway through which I can access a person's subconsciousness.
>
> — Roman Stańczak (1994)

Figure 2.8: The sculpture + ∞ − by Roman Stańczak (1996) at the Frieze art fair in London 2015. Image courtesy of Saatchi Gallery, published with their permission.

His use of familiar objects and his playful venture to put them into a new context that makes them imaginative appealing and surprising was demonstrated by one of his pieces exhibited at the Frieze Artfair[13] in London in 2015. The sculpture + ∞ − (Stańczak, 1996) consists of five vacuum cleaners soaking up each other in circles as shown on Figure 2.8. Even though the vacuum cleaners were not running and the setup staging the redundancy of the artefacts interacting with themselves was not moving it moved my mind with its imaginary qualities. This self-driven system of vacuum cleaners cleaning themselves and thus vacuuming their alleged function to facilitate life and Daseins-comfort[14] leaves behind uselessness and aesthetic functions.[15]

13 `https://frieze.com/fairs/frieze-london` (accessed April, 2018).

14 Daseins-comfort here refers to Ortega y Gassets' notion of "technology as the effort to save effort" translated by the author from "Technik [ist] die Anstrengung . . . , Anstrengung zu ersparen" (Gasset, 1949, p. 42).

15 Jean Tinguely in his work, e. g. *Rotozaza No. 2* (Tinguely, 1967), correspondingly aimed to contrast the useful, productive industrial machinery with machine-sculptures that produce nothing but artistic meaning. "From a machine one demands order and precision, reliability and regularity, Tinguely's point of departure is mechanical disorder" (Hultén, 1968, p. 165). His machines, the "meta-mechanics" (Hultén, 1968, p. 165), fulfil their function for the sake of function and therefore oscillate between utilitarian and aesthetic demands. See also works by Andreas Fischer, e. g. as part of his show *Your time is my Rolex* (Merz, 2012).

Stańczak's work conveys the Dadaist's concept of the readymade – creating boundary objects by situating them between object and art. One of the ideas behind the readymade was to free everyday objects from their utilitarian function and meaning (Parkinson, 2008, p. 32). This kind of play with the familiarity of objects can be found in a well known example given by Marcel Duchamp. *Fountain* (Duchamp, 1917) consist of an everyday object of a urinal placed in the context of art. This arrangement challenges familiar relations between the maker and the object and the provocation therein is the source of its power (Gaver et al., 2003; Parkinson, 2008, p. 47). Correspondingly, Turkle (2005) delineates the evocativeness of boundary objects[16] as featuring the experience of a double vision. In the look back and the look forward, the familiar is made new and somehow unfamiliar as in the Freudian uncanny: "Seen from one angle, [they] seem familiar, extensions of what came before. They play out (and take to a higher power) the themes of connection with and animation of the machine . . . yet they are also new in ways that are challenging and evocative" (Turkle, 2005, p. 291). Thus people become attached, experience and feel a new level of connection to objects, "a shift from projection onto an object to engagement with a subject" (Turkle, 2005, p. 293). In this sense defamiliarisation and providing multiple interpretations can be considered as a stylistic device to question the perception of that which is familiar, and seems natural and unquestionable.

Shklovsky (1917) referring to Tolstoy (see Quote 2.1), explains that perception generally becomes habitual and automatic and "[s]uch habituation explains the principles by which, in ordinary speech, we leave phrases unfinished and words half expressed" (Shklovsky, 1917, p. 11). Analysing prose and poetry of Tolstoy and others he determines the technique of defamiliarisation in art as a form of transferring and deautomatising perception from the habitual and automatic. Emphasising the aesthetic experience, which is the sensation of things as they are perceived and not as they are known, Shklovsky (1917, p. 17) states the purpose of art is to defamiliarise and deautomatise perception of objects. Or to use Nelson's (2002) analogy to the grotto, standing in front of the dark entrance evokes grotesque or ambiguous sentiments (Nelson, 2002, p. 22). The ambiguity between what is familiar and what is novel, provoked by the unexpected recombination of events, objects, or species waiting inside the grotto.

16 In contrast to the psychologist perspective provided by Turkle (2005), the sociologist's Star and Griesemer (1989, p. 393) delineates boundary objects as objects that have different meanings in different social worlds and cultures.

2.3.2 *Ambiguity as a Principle of Poetry to Design Affective Relationships*

The film maker Eisenstein writes about the principle of poetry in reference to Walt Disney's early animation films e.g. animating a line. The principle of poetry lies in the potential to transfigure, to transform, comprising an inversion of familiar relations between the animate and the world of things (Eisenstein, 2013, p.30).

Ambiguity as a powerful resource that can promote personal relationships fuelled by curiosity and engagement is underlined by Gaver et al. (2003). In respect to the design of objects, they differentiate ambiguity, 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" (Gaver et al., 2003, p. 235).

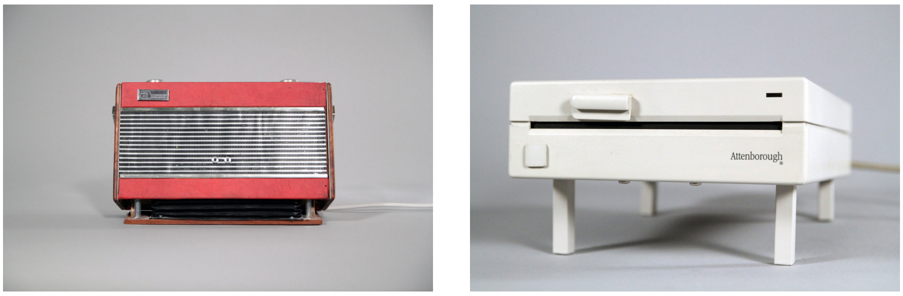
In correspondence to the boundary objects of the readymade creating a tension and attention between the familiar and the new, technological animation involves a suspense between the non-living object and living creature. Stacey and Suchman (2012) put this tension and its appeal at the heart of technological animation as found in the cinema, animating life on the screen, or in autonomous machines giving life-like characteristics to objects. Cinema, per se based on animation, is a transformative deception requiring belief in the illusion of movement (Stacey and Suchman, 2012, p. 6). Autonomous machines in turn are compelling because they enact what the cinema promises, making the inorganic feel live.

This is exemplified in the following two projects. Both apply life-like behaviour to objects, the first to create an emotive connection and friendly affection to the object, and in the second movement is employed to contribute to the uncanniness of the scene.

Artificial Defence Mechanisms by James Chambers (2010)

As part of a fictional technological history the designer James Chambers is a member of a hypothetical research group running under the name Attenborough Design Group (ADG). The ADG is ostensibly led by the famous natural historian, cultural icon, and filmmaker David Attenborough and is set up as being part of the electronics company Texas Instruments. Consequently they design "products that protect themselves from threats in their environment the way animals do in nature" (Chambers, 2010).

The Gesundheits Radio (Chambers, 2010) shown in Figure 2.9a is a transistor radio from the sixties that sporadically 'sneezes' to expel dust.



(a) *The Gesundheit Radio* (2010) sneezes when dusty.

(b) *Floppy Legs* (2010) stands up upon liquid's approaching.

Figure 2.9: Design works by the Attenborough Design Group (Chambers, 2010) applying behaviour inspired by the survival instinct, as found in the animal kingdom, to products. Images incl. Figure 2.10 courtesy of James Chambers, published with his permission.

The *Floppy Legs* (Chambers, 2010), shown in Figure 2.9b, is a portable floppy drive that stands up when it detects liquid nearby. Both, *The Gesundheits Radio* and the *Floppy Legs* "investigate the use of behaviours found in nature to defend emerging technologies" (Chambers, 2013). The concomitant ambiguity, could be considered as an enactment of the animate vs. inanimate contradiction (Ghedini and Bergamasco, 2010). The object's behaviour designed to be experienced as alive and intelligent suspends the familiar notion of the everyday objects. In correspondence to "the principle of poetry" (Eisenstein, 2013, p. 30) here applied to an object.

Chambers is playing with and transfiguring the familiarity of objects and survival behaviour found in nature. This is further emphasised by the imaginary history around the objects. This play with ambiguity is carried out not only through the comprehensive fictional story coming along with the devices but also the design of the specific movements resulting from iteratively prototyping of sneezing behaviours as shown in Figure 2.10. Thus by the use of "live action" (Thomas and Johnston, 1995, p. 319) copying the behaviour from humans and animals to create a purportedly familiar behaviour, the projects question the familiarity of a consumable product and gathers peoples' sympathy by "anthropomorphising the various movements" (Auger, 2014, p. 35).

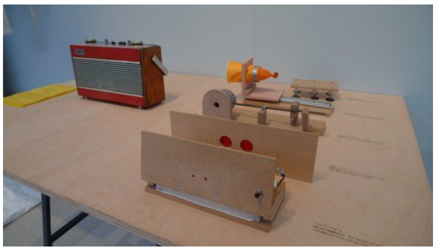


Figure 2.10: Iterative designs of the sneezing mechanisms.

The design of the behaviour, here consisting of a living being like sneezing or knee-jerk reaction, applied to an object could be considered as a stylistic device to create attention and a sweet-natured affection to the object. However similar ambiguity in human behaviour applied to an object could also serve as a stylistic device to create a rather threatening and uncanny sentiment as in the following example.

Voight-Kampff Machine by Syd Mead (1980)

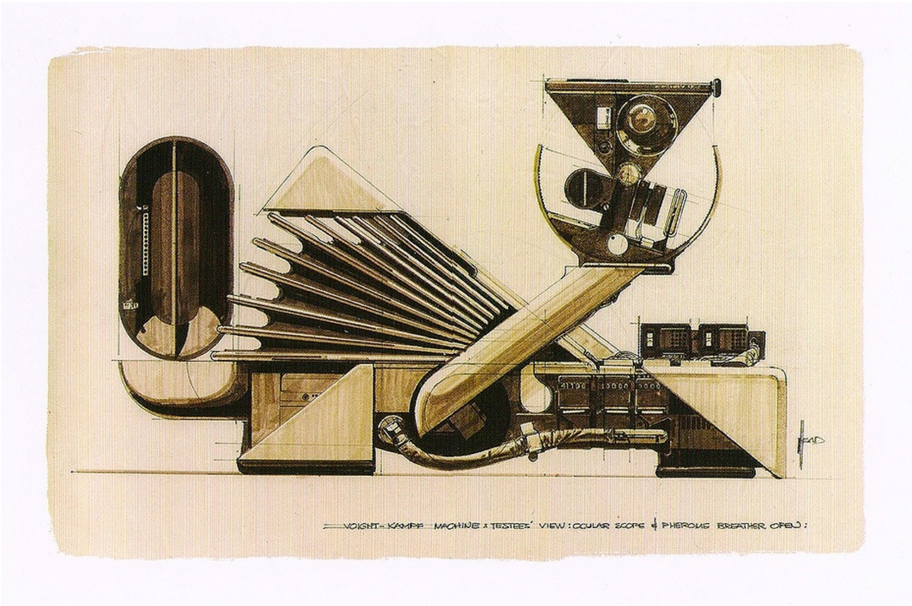


Figure 2.11: Sketch of the breathing *Voight-Kampff machine* contrived by the industrial designer Syd Mead. It is used as a device in the film Blade Runner to determine whether a person is real or a replicant. Image courtesy of Syd Mead, published with his authorisation.

The polygraph-like machine, shown in Figure 2.11, is a device deployed in the film Blade Runner designed by the industrial designer Syd Mead. In an interrogation scene (Scott, 1980, 0:05h) it measures subjects' bodily functions such as respiration, heart rate, blushing and eye movement in response to emotionally provocative questions (Scroggy, 1982, p. 52). Comparable to the imitation game set-up found in a Turing test it can be used to determine whether the counterpart is an replicant (android robot) or not.

However, in my eyes the important part here is not only the behaviour of the tested subject but the behaviour of the technological object itself, which resembles, in contrast to the nervous subject under investigation a relaxed breathing movement analogous to mammals. The ambiguity in the designed behaviour is less to increase an "emotive connection" (Auger, 2014, p. 35) to the device as in Chambers' objects but rather to give the machine a menacing air. During the design process Meads reports he realised "that what could give this sophisticated lie detector a definitely threatening air was to suggest that it was alive" (Sammon, 1996, p. 107).

2.3.3 *Repulsion and Attraction Towards Artefacts*

Humans' drive to imitate nature and simulate human and animal beings lies at the very heart of Western culture (Penny, 1995). The resulting technological objects blur the lines between animate and inanimate, between human and machine. Providing multiple interpretations that play with and transfigure familiar relations to things and ambiguities therein can be considered as a stylistic device employed in arts, as in poetry and figurative art, but also in art forms and design principles involving technological animation.

Ambiguities can create attraction and repulsion, as the examples above and the reaction to the hairbrush reported in Section 1.2 indicated. The technological animation of an object could be considered to represent a particular ontological uncertainty (Vidal, 2007): the enactment of the animate vs. inanimate contradiction found in a puppet-as-object or a puppet-as-person (Ghedini and Bergamasco, 2010). Similarly a Roomba robot's behaviour perceived as lively (see Section 1.2), or the attraction to a breakdancer moving in a mechanical way (covered in the upcoming study in Section 4.3), could be taken as examples for ambiguity and its appeal. Interpreting a stimulus belonging to multiple ontological categories (object/live) and playing with uncertainty in terms of its liveliness 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 (Burleigh et al., 2013). The automaton, with the human/machine distinction at stake, can be uncanny as it is "[n]ot quite alive yet mechanically propelled into the semblance of life, it exemplifies the alienating excess of the uncanny. This excess matches up with Freud's assertion that the uncanny is fundamentally a deferred repression that eats away at the surface of the familiar" (Pranolo, 2011, line 485, cited by Stacey and Suchman, 2012). Eisenstein (2013, p.65) in turn considers more the attraction, as a secret of the "comic mechanism", as "the comical it to be found in the incompatibility of the one with the other" (Eisenstein, 2013, p.37). For instance Charlie Chaplin's movement can be comical because of the mechanical elements evoked "through repetition, timing and use of pause and pose" (Leslie, 2002, pp. 17-18, cited by Stacey and Suchman, 2012, p. 14).

2.4 SUMMARY AND CONCLUSION

This chapter explored an approach to movement and the perception of movement from the perspective of the arts. I presented a personal approach listing related inspirational works from an artistic context together with concepts referring to influential literature. The aim was to learn more about the role of movement for human perception. This was carried out in three different parts presenting different perspectives on how movement affects people's perception of technological artefacts. The first part focused on the perception of movement. Therein I provided artistic examples to illustrate that movement not only forms the base for the living but also the basis for our relationship to artefacts and things in general. I discussed differences in how we experience and perceive movement ranging from involuntary movement associated with non-living objects to intentional action of living creatures. The focus of the second part was on the language we use to communicate our relationship to artefacts emphasising metaphors and how they reflect humans' intuitive process of categorising and attributing characteristics as a dialog and understanding of things. The particular focus was on differences apparent in the use of language ranging from animate to inanimate descriptions of things. I reasoned for a relational approach, focusing on verbs and adjectives instead of excluding nouns, to give way to an interpretative relationship that pays attention to the way people interact, experience and relate to entities. The focus of the third and last part was on movement as a stylistic device used in the arts to design an affective relationship. Therein I argued that ambiguity, as a principle of poetry, is affective through its play with familiar relationships, for instance the technological animation of artefacts making the inorganic feel live. This was supported by examples using movement as a stylistic device to design an affective relationship which can range from repulsion to attraction.

I conclude that humans as social creatures have a tendency to being attracted to the movement of things. Attributing agency and establishing an affective relationship is part of being human. It can be considered as part of our survival kit to distinguish animate from inanimate. It is also the survival kit of poetry aiming to establish an affective relationship by playing with our familiar relationship to things.

Ultimately, changes in our affective relationship generally could be attributed to our individual's pursuit of meaning (Cantril, 1941, 53 ff.). Our "innate tendency to focus on life and lifelike processes" (Wilson, 1984, 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 different perceptions of animacy and agency are central to the methods and applications presented in the subsequent chapters.

As a result, this background chapter provides a personal perspective to what was salient, topical and important for the work presented, and at the same time provides the rationale to use the sociolinguistic device of the metaphor as an indicator for differences in the way an entity is perceived.

3

RELATED WORK

In the previous Chapter 2 I elaborated and assembled examples from the arts along with key concepts in a way that has an indexical, mutually informing relationship to the topic of this thesis. I presented different perspectives on the same state of affairs, the overarching research question on how movement changes the perception of artefacts. The aim was firstly, to present movement as one of the primary factors that provokes affection and forms the basis for our relationship to things. Secondly, the objective was to show with examples how language can reveal differences in the way we communicate that relationship, ranging from animate to inanimate descriptions apparent as degrees of animacy and agency. I reasoned for a relational approach, focusing on verbs and adjectives instead of excluding nouns, to give way to an interpretative relationship that places focus on the way people interact, experience and relate to entities. Thirdly, I illustrated that movement can be used as a stylistic device to evoke differences in the affective relationship to things ranging from repulsion to attraction.

In this chapter, with resemblance to the previous one, related work with a focus on movement and language is surveyed. These are empirical works, mainly from cognitive science, assessing differences in peoples' relation to human and non-human entities presented in language, or on video screens as well as in laboratory or real-world scenarios. This is presented in two sections, the first is looking 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. These works primarily use traits or descriptions to determine differences in observers attribution of characteristics to human and non-human agents. Subsequently, these are put alongside a body of work looking at differences in attributions as an effect of movement. Specifically in respect to robots and objects and how they affect people's interpretation. The aim of both is to extend concepts like animacy and agency elucidated in the previous chapter 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 videos or physical interaction to elicit different interpretations in observers.

The insights from this chapter and the previous chapter provide the conclusion for a method, reassembling a relational approach, using language to assess subjective interpretations. The key concepts and findings from both are transferred into an *agency-framework* to highlight observed movements, structures and kinematics as potentially being interpreted as animate or inanimate. This *animacy-framework* is used as a conceptual structure to frame and evaluate the resulting empirical work.

3.1 language to assess differences in interpretations

In correspondence to Section 2.2 in the previous chapter which looked at linguistic conceptualisations of our relationship to things, the focus in this section is on humans propensity to attribute characteristics to things and how the language used to describe this relationship can give indications of whether entities are being interpreted more as animate or inanimate.

Accordingly, this section starts with empirical work looking at differences in how humans attribute human characteristics to various non-human entities, and subsequently works focusing on human and non-human appearance, and how this affects the way animate and inanimate characteristics are directed towards them.

3.1.1 *Differences in the Attribution of Human and Non-Human Characteristics to Entities*

One of the motivations behind the design of the methods and studies presented in the subsequent chapters was an unpublished technical report by Kiesler and Goetz (2002). To evaluate inanimate and mechanistic elements of "mental models" (Kiesler and Goetz, 2002), 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. (2010) 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 described in a short story. They concluded that individual differences in anthropomorphism exist and matter for creating an empathic connection with non-human agents. Using equal measures, Epley et al. (2008a) investigated differences in peoples' interpretation of descriptions 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 dehumanisation, when people characterise human agents as non-human.

The denial of human attributes to other people and likening them to non-humans (dehumanisation) as a subtle and everyday phenomena is supported by the research and findings of Haslam et al. (2005). By prompting people to complete go/no-go association tasks of traits they assess differences among social categories of humans, 'other humans' and non-humans. Traits are either uniquely human (e. g. higher cognition, moral sensibility, sophistication) or of human nature, involving for example emotionality, interpersonal warmth and flexibility. The results indicate effects of *infrahumanisation* and *self-humanising*: 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. They conclude that in our perception of social beings dehumanising and infrahumanising is fundamental.

That people's intimacy to animals and objects similarly affect the relationship is shown by Kiesler et al. (2006). In a study comparing people's explanation of behaviours of dogs, fish or animated artefacts, they provide evidence that being an owner (of) prompts stronger psychological explanation, e. g. a higher degree of attributing intentionality to the animals' behaviour and increasing emotional attachment.

3.1.2 *The Effect of Human and Non-Human Appearance*

The effect of appearance to the relationship with human and non-human entities is accentuated by Riek et al. (2009). They have people watching a video clip featuring protagonists of varying degrees of appearance, starting from mechanical to human: a Roomba robot, a robotic lamp, a humanoid, an android and a human boy as shown in Figure 3.1. They measure responses based on rating of how sorry they felt for the protagonist on a Likert scale. Their results indicate strong support for their hypothesis that human-looking robots receive more empathy of people than mechanical looking robots.

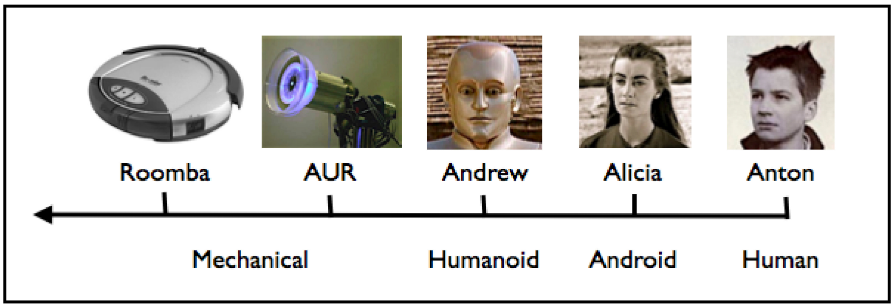


Figure 3.1: The protagonists used in the experiment by Riek et al. (2009) to assess the effect of appearance to anthropomorphism. Image courtesy of Riek et al., published with permission of Laurel Riek.

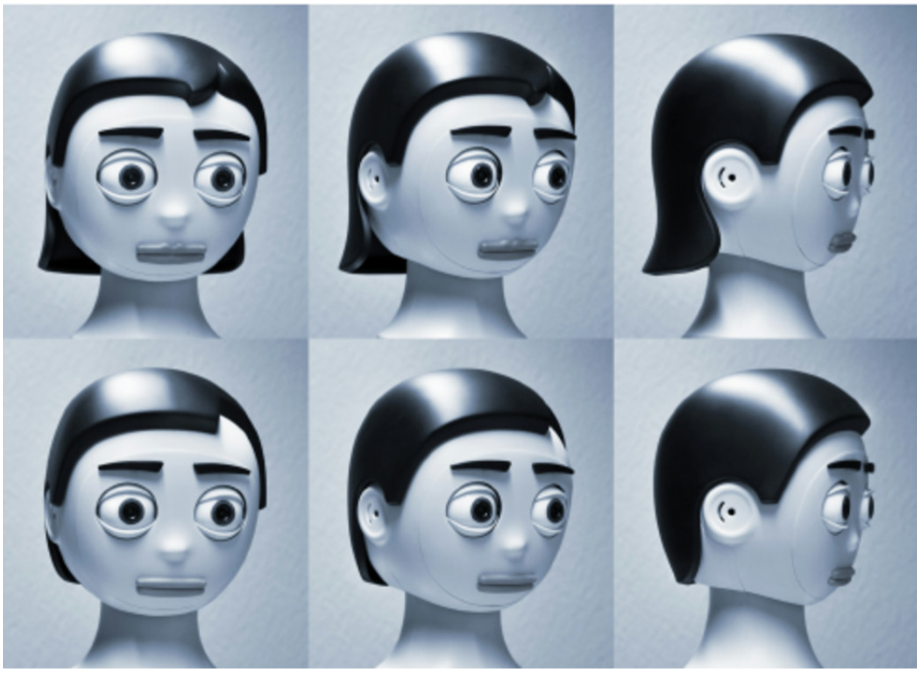


Figure 3.2: Stills from videos representing either a female or male instances of a *FloBi* robot used by Eyssel and Hegel (2012) to assess gender stereotypes. Images courtesy of Eyssel and Hegel, published with their permission.

How dimensions of human social cognition are applied to non-human objects is demonstrated by Eyssel and Hegel (2012). Having people infer certain traits to different designs of a *FloBi* robot (Hegel, 2010) as shown in Figure 3.2, their results indicate that participants applied gender stereotypes that typically characterise human-human social cognitive processes to robots.

3.1.3 *Controversies Using Language for Evaluation*

The use of language for evaluation is controversial though. The problematic use of words was pointed out in Section 2.2.2 of the previous chapter looking at process and moral philosophy to reason for a relational approach focusing on adjectives and verbs instead of excluding nouns to give way to an interpretative relationship that pays attention to the way people interact, experience and relate to things.

Similarly controversial issues are found in empirical work. As pointed out by Gelman et al. (1995, p. 159), in one of Stewart's studies (Stewart, 1982) subjects responded by choosing between the attributions of 'alive creature,' 'non-alive object,' and '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. Equally, Coeckelbergh and Gunkel (2014) indicate the very term "the animal", as used for instance in Kiesler and Goetz's (2002) study mentioned above, is not morally neutral but already makes a decision about the status of the animal. They refer to Derrida (2008, p.41), denoting it "l'animot", 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. Coeckelbergh 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 it is a matter of degree.

In this section the focus was on humans and non-human entities, like animals and robots, looking at empirical work assessing differences in their interpretation by drawing a line between human and non-human characteristics applied to them. In correspondence to differences in the linguistic conceptualizations of our relationship to artefacts presented in the previous chapter in Section 2.2, these works provide empirical evidence for differences in the interpretation of various entities. In these works the entities were either manifest in language, described in short stories or portrayed static focusing on their appearance. In contrast, in the following section movement comes into play. Therein I look first at a body of work using the stimuli of movement on video screens followed by real-world scenarios featuring robots to assess differences in peoples' interpretation.

3.2 MEASURING THE EFFECTS OF MOVEMENT

The concept of agency delineated in the previous chapter in Section 2.1.3 illustrated differences in the interpretation of an entity's behaviour along the lines of intentional action or involuntary movement. Accordingly, this section focuses on empirical work assessing entities' movement characteristic and how it affects the way thoughts and actions are directed to them. It starts with looking at how different stimuli of movement in non-figurative displays or objects are interpreted as inanimate or animate motion. It then considers different movements applied to more figurative entities like robots. Variations of the movement of these entities are displayed on video screens to assess differences in their interpretation, while the final section is looking at physical robots and objects interacting with people in a real world scenario to determine differences in people's perception.

3.2.1 *Differentiating Animate and Inanimate Motion Cues*

Gelman and Spelke (1981) recognise that the fundamental difference between whether events are identified along the lines of living and non-living is that the former involve animate entities, like people or animals, while the latter refers to non-living things. Early exploration of conceptions and meaning attributed to the stimuli of movement originate from Heider and Simmel (1944), Johansson (1973), and Michotte (1963). These works experimentally uncovered people's tendency to interpret observed action of simple objects or non-figurative unitary movement of dots displayed on screens as apparent behaviour. Analogous to the concepts of animacy, illustrated in Section 2.2.3, 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. (1999) 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 and causal movement into the domain of *animate* intentions and desires. Scholl and Tremoulet (2000) demonstrate that an entities' simple motion cues like changes in velocity and direction in absence of any reference background can produce an impression of animate behaviour. The work of Blythe et al. (1999)

focuses not only on differences of animate and inanimate motion but distinguishes different types of animate motion. Humans and other animals' categorizing behaviour based on motion cues could make the difference between life and death. For instance when encountering a mountain lion, cues like turning your back on the animal or running away both trigger the lion's predatory chase behaviour. Thus avoiding these behaviours "deny the lion's perceptual system that normally accompany being a mealtime animal" (Blythe et al., 1999, p. 257). Taking this example as a starting point they examine some basic goals of animate motion and provide motion cues that may be general across species and ecologies to categorize behaviour into biologically important classes like aggressive intentions (pursuit, evasion, fighting, chasing), passive intentions such as being courted, and playing as different types of animate motion.

In correspondence to the primacy of movement delineated in Section 2.1.2, Rakison and Poulin-Dubois (2001) determine motion as prime in infant perception almost from birth. Following Mascalzoni et al. (2010) humans' sensitivity to self-propelled objects is apparent in infants from around the fifth month of age, which leaves undetermined whether this sensitivity is acquired by experience with animate objects or whether it is innately predisposed in the brain. The results of the experiments with infants by Mascalzoni et al. (2013) support the hypothesis that the human system possesses an early available, possibly innate basic mechanism to compute causal motion apparent in the temporal continuity between events. They conclude that infants' sensitivity and preference to causal events, independent of any prior visual experience, determines the perception of physical causality in adults. Similarly, using point-light displays Simion et al. (2013) 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. (2010), 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. Likewise, Mark Johnson (2006) illustrates in his work that the motion stimulus of light points on a screen can function as a general "life detector" and therefore is potentially interpreted as animate.

Vaughan (1996) evaluated peoples' response to simple movement of typographical items on the computer screen. Her findings revealed that organic movement conveyed more emotion than geometric, and emotional responses increased with complexity of the patterns (Vaughan, 1996, cited in Vaughan, 1997). Correspondingly, Arnheim (1954) conducted research on abstract animations using simple square blocks' movement to communicate different relationships between them. He observed that people project human emotion and values on the animation of abstract shapes with no identity, and with increasing complexity of the behaviour the association of human qualities increased. Furthermore that mechanical movements are prone to elicit less emotional responses than organic movements (Arnheim, 1954, p. 396, cited in Vaughan, 1997).

Cook et al. (2009) examined differences between biological and non-biological motion. The former, natural motion is exemplified by a minimum-jerk movement (MJ), featuring a characteristic velocity profile that minimises jerkiness over a movement trajectory, here a moving arm; while gravitational movement of a falling tennis ball with a constant velocity is taken as a representation for non-biological movement. In the study presented they investigate whether a biological motion deficit is found in adults with autism spectrum condition (ASC) in comparison to the normal control group (NC). Both groups were watching a series of visual stimuli constituting two conditions. One was a reference animation composed of 85% natural and 15% gravitational movement, and in the target animation the ratio between those two varied. The participant's task was to pick the less natural. The aim of this set-up was to find and measure a threshold for detection of perturbances in biological and non-biological motion. Their findings indicate that the NC group was particularly sensitive to changes in the velocity profile of biological relative to non-biological motion, in contrast to the ASC group where this relative sensitivity to biological motion could not be observed.

Perceptual and Conceptual Information Work Together

Scholl and Tremoulet (2000) point out that interpretations of movement seem to be largely perceptual in nature but also involve higher-level cognitive processing. Causal and social structure of the world can be recovered by inferring properties such as causality and animacy. In equal measures, Carey (2009) mentions that we are sensitive to multiple sources of information. Perceptual information can work together with conceptual information when interpreting an entities' action. She remarks that "spatio-temporal information is sometimes sufficient input to the mechanism that computes teleological descriptions of these events, representations of goals and means, agents, helping, hindering, chasing, fleeing, and computations of rationality go beyond the spatio-temporal description of the scene, and they cannot be reduced to a spatio-temporal vocabulary" (Carey, 2009, p.172). Thus perceptual information is integrated with what is just learned and what is known already. She explains that the interpretation of observed action to differentiate intentional and causal agents is informed by learned concepts, for example "infants integrate their representations of the spatio-temporal parameters of events with information about the ontological status and stable causal dispositions of the interacting entities" (Carey, 2009, p.243).

Caruso et al. (2010) provide examples and studies suggesting that the perceived intentionality of an agent's streak may be a unifying determinant of people's belief. For instance when an ostensibly random agent like the stock market was described in animate, goal-directed terms, people's tendency to report that a trend continued to increase, compared to when the random agent was described as an object. iPod users who tended to notice orderly patterns in shuffle mode started to describe the devices as psychic, telepathic, moody, temperamental and empathic. Thus characterising an agent as intentional has presumed controls over observed actions. Similarly, Gelman et al.'s (1995) work supports the view that categorising an agent based on motion information is determined not only by perceptual causal principles but also conceptual information. They notice the perception of something as inanimate implies the cause of an agents' motion comes from an external source, honouring principles of inanimate causation. Correspondingly, an animate object's motion is informed by causal principles but the cause of the agents motion and change is internal, hence comprising characteristics of biological entities. However, the ontological categorisation as either animated or inanimated is not determined by causal principles alone and can be highly ambiguous. When interpreting an object in motion, conceptions and perceptions of animate and inanimate objects work together. When perceptual information is ambiguous, one way to disambiguate it is to interpret it within a conceptual framework. For instance perceiving something like an abstract object that accelerates in the absence of a source does not guarantee identification of the unknown object as animate. Gelman et al. illustrate this with an experiment providing participants either animate or inanimate conceptual information to an object moving on a computer screen. The former comes with the information that the motion is generated by a person, while the latter instances the motion as originating from a ball. As a result, even though the motion pattern is identical, subjects described them correspondingly as inanimate or animate depending on the conceptual information given.

Interpreting action and the concomitant ontological commitments can vary across cultures, as shown by Morris and Peng (1994). They had people from two cultures (Chinese and American) respond to events they are familiar with, one representing a physical event the other a social event, both shown on a screen. In the case of the physical event, the display of an object moving across a soccer field, they found no cultural differences, both groups attributed the object's trajectory to external, situational forces and conforming to physical constraints. In the case of the social event, simulated by a group of swimming fish deviating from the physical constraints they found differences. Chinese subjects interpreted those more socially, e. g. joining the group, as the result of resembling familiar social dynamics, while Americans in contrast, whose culture is considered to be individualistic, considered the behaviour less a social dynamic, e. g. separating from the group.

3.2.2 *Social and Non-social Behaviour of Robots on Screen*

Mori (2012, published 1970 in Japanese) hypothesised 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, since then, well-known uncanny valley. The hypothesised effect as deepening the uncanny valley is illustrated in his publication through the graphic shown in Figure 3.3. Empirical evidence for Mori's valley is provided by MacDorman (2006). He assesses participants' ratings in terms of parameters determined to ressemble 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. (2013) point out for the most part the morphed images are not realistic hence the result being rated as unfamiliar by participants is not surprising.

Equivalently to Mori's hypotheses of the primacy of movement, Vidal (2007) identifies movement rather than any specific detail of the appearance as the main channel for the dialogue between an entity and a human. This is experimentally supported by Lehmann et al. (2015),

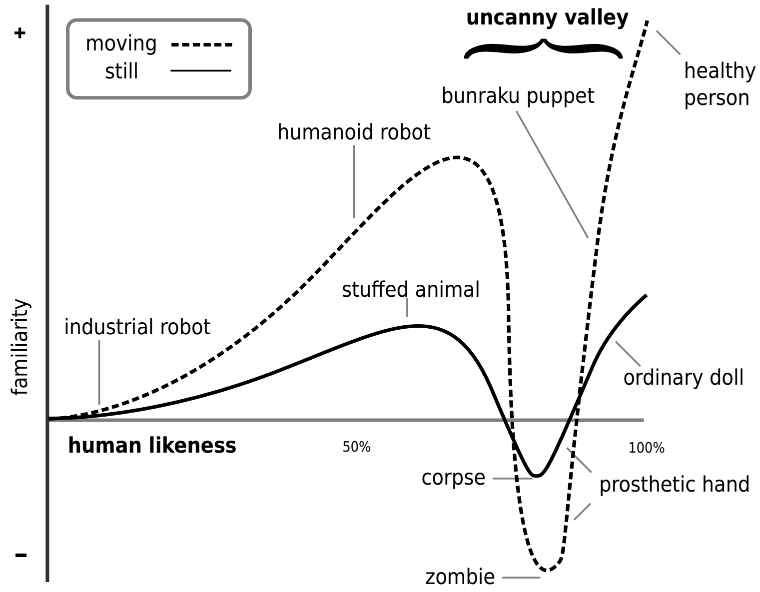


Figure 3.3: Graphic depicting Mori's uncanny valley and illustrating his hypothesis that the presence of movement steepens the slopes of the valley. Image by user Smurrayinchester published on Wikimedia under CC BY-SA 3.0.

Figure 3.4: Still from the video showing a human-robot interaction scenario used in Lehmann et al. (2015) to assess peoples' interpretation of the video showing either social or nonsocial engaging behaviour of the *Care-O-bot*® 3 robot with the human. Image courtesy of Lehmann et al., published under CC BY 4.0.

having people rating semantic pairs of traits in regard to a non-anthropomorphic robot, a *Care-O-bot®3*[1], interacting with a human shown on a video screen (see Figure 3.4). Their results illustrate that movement, even if it is not socially engaging behaviour, facilitates the propensity of humans to ascribe intentions to robotic objects.

Similarly, Hendriks et al. (2011) 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. These five personality characteristics were determined prior to the study, from ratings of 30 traits like calm, boring, careful, systematic, etc. The five personalities were then reenacted by a human and subsequently abstractly translated to the robots' behaviour which was recorded on video. For their study they invited participants to rate the traits in respect to the five different robot behaviours in the videos. Their results revealed that the perceived personality matched with the intended product personality.

The predictability of a movement is a focal point in the work of Eyssel et al. (2011). They assess differences in participants' anthropomorphic interference in terms of attributions of traits to a short video showing a *FloBi* robot (see Figure 3.2). 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 inferences increase for predictable and unpredictable behaving robots, while unpredictable behaviour doesn't increase anthropomorphism when there is 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 Section 2.3 of the background chapter.

3.2.3 *Real-World Human Robot Interaction Scenarios*

The work of Bartneck et al. (2009b) supports the findings above from Hendriks et al. (2011) showing that participants were able to recognize different movement of objects. However, in contrast they do not use a video presentation, instead having participants interacting with real

1 Developed by Fraunhofer Institute for Manufacturing Engineering and Automation `https://www.care-o-bot.de/en/care-o-bot-3.html` (accessed October, 2017)

(a) *Robovie II* (2009) developed by Advanced Telecommunications Research Institute International (ATR).

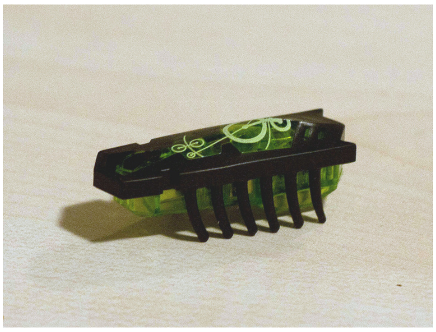
(b) *iCat* (2009) developed by Philips Research.

Figure 3.5: The two robots used in Bartneck et al. (2009a) to examine participants responses to the same interaction protocol applied to two different appearances of a robot. Both images courtesy of Christoph Bartneck, published with his permission.

robots. In their study they assess peoples' responses to the embodiment of two robots, the *iCat* and the *Robovie II* as shown in Figure 3.5. The same protocol for the verbal utterances and the "intention of the behaviour" where applied to the two different robots. Participants were asked to play *Mastermind* with the robot and afterwards participants' facial expressions, hesitation to turn them off, and rating of traits (given at the end of the game) were evaluated. Their results suggest that for the perception of a robot's animacy the behaviour is more important than its embodiment. Likewise, Saerbeck and Bartneck (2010) findings, assessing participant's written responses to different type of motions applied to two different robots, indicate that the same motion parameters applied to different robots are interpreted in the same emotional categories. For example, all participants used emotional adjectives to describe the robots' behaviour, independent of the difference in the physical appearance/setup. To generate the different type of motion they systematically varied the two motion parameters acceleration and curvature and applied them in equal measures to both robots, either an *iCat* (see Figure 3.5b) or a *Roomba*™ robot (shown in Figure 3.6a).

Differences in movement characteristics are considered by Darling et al. (2015). They examined participants affect towards no movement

(a) *Roomba*™ 400 robot (2004) developed by iRobot Corporation.



(b) *Hexbug Nano* (2007) developed and distributed by Innovation First.

Figure 3.6: *Roomba*™ robot deployed by Saerbeck and Bartneck, 2010; Sung et al., 2007, and *Hexbug Nano* robot used by Darling et al., 2015 to study human-robot interaction. Image 3.6a by user Mike1024 published in Wikipedia in the public domain. Image 3.6b by user Martin Linkov published on flickr under CC BY-NC-SA 2.0

and lifelike movements of little *Hexbug Nano* robot toys as shown in Figure 3.6b. 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.

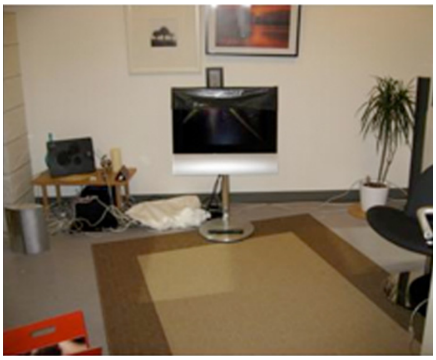
The Wizard of Oz is in the House

The preceding works comprised screen based animations and laboratory or real-world scenarios to assess humans' interpretation of entities. Common to each experiment was that the behaviour of the robots was programmed into the robot to perform autonomously. However, there is a body of work using a human remote operator to simulate autonomic behaviour of technological objects. By addressing the difficulty of programming specific behaviours, they are able to put emphasis on the design of the behaviour and its application to a diverse set of domestic items found in the house.

The following works comprise household items like a door, sofa, TV and trash can which movements are controlled using the Wizard of Oz technique. The Wizard of Oz technique (WoZ) is used to remote control object's behaviour by a human. It is considered "a rapid-prototyping method enabling unimplemented technology to be evaluated by using a human to simulate intelligent responses of an agent" (Maulsby et al., 1993). It is widely used in human-computer interaction experiments to explore man-machine interaction. In an experimental setup, subjects interact with an agent or computer system allegedly being autonomous but is actually fully or partially operated by a 'wizard', an unseen human being placed nearby or in a separate room, observing the user's action and simulating an entity's response in real time. In human-robot interaction research, WoZ is often used to test the hardware of a robot whose sensorimotor capabilities are still limited. Thus it is used to provide a testbed to simulate higher-level decision-making progress of the robot, for instance, in care, therapy or educational contexts (Dautenhahn, 2013).

(a) Sofa by Spadafora et al. (2016)

(b) Door by Ju and Takayama (2009)



(c) TV by Mortensen et al. (2012)

(d) Trash Barrel by Yang et al. (2015)

Figure 3.7: Examples of domestic objects aroused by the Wizard of Oz technique. Image 3.7a courtesy of Spadafora et al., 3.7b by Ju and Takayama, 3.7c by Mortensen et al., 3.7d by Yang et al., all published with their permission.

THE RISK TAKER SOFA-BOT is a robotic sofa developed and studied by Spadafora et al. (2016) at the Design Department, Politecnico di Milano. It is part of a research project with the overarching goal to understand how people interact with everyday objects that move expressively. Peoples' interaction and understanding of the sofa is assessed using a 'personality design method'. The method employs human stereotypes of personality based on metaphors by using five traits to characterise a personality. For instance "The Big Boss/The Strict Regulator" is characterised by "Openness to Experience", "Conscientiousness", "Agreeableness", "Extroversion", "Neuroticism" (Spadafora et al., 2016, referring to Goldberg, 1990; Norman, 1963). Spadafora et al. use this method to assess whether personalities 'programmed' into an interactive object are recognised, here by virtue of a moving sofa. This is demonstrated in a qualitative study using a WoZ technique to evaluate whether the designed and remote controlled behaviour of the sofa-bot can be recognised by participants interacting with the sofa as illustrated in Figure 3.7a. The authors come to the conclusion that participants ability to recognise different behaviours, designed accordingly to different stereotypes of personalities, was consistent.

DOORS movement and it's interpretation is the focus of a collaboration between California College of the Arts and the robotics company Willow Garage. In the associated paper, Ju and Takayama (2009) examine different gestural motions, 'door gestures' resulting from the alleged automatic movement of a physical door simulated by a WoZ. In their study they examine peoples' interaction with the different behaviours of the door while walking towards it. Particularly how the different physical gestures, resulting from altering speed and trajectory, create different levels of approachability to people. Peoples' experiences and how their responses change in respect to different door gestures are measured using ratings of traits on a Likert-scale and open-ended responses. Their results indicate that the interactive doors were able to elicit social responses and convey different gestures and messages, such as engagement and avoidance, in a highly constrained design space with only one degree of freedom. Furthermore they accentuate that emotional responses towards movement of things can have a functional role as well as an aesthetic one.

AN EXPERIMENT involving amorous televisions stems from a collaboration of psychologists, computer scientists and designers from Denmark. The protagonist of the 'nookery', set up by Mortensen et al. (2012), is a TV falling or moving in love by rotating with the help of a remotely controlled motorized floor stand. Using WoZ, the TV responds to participants movement and inputs on the remote-control placed in front of the TV. The question Mortensen et al. are answering through an experiment is whether the TV's behaviour can convey social statuses and communicate various patterns. These patterns include: 'greeting', performed by a number of small movements upon someone's entering the room; 'following', by choosing and following a favourite person, to mimic the seeking of eye contact; and 'touching', by lighting up the screen when the favourite person touched the remote-control, to imitate attention seeking. In the experiment participants were invited to enter the room shown in Figure 3.7c, either alone or in groups of two, and explore and interact with the things for five minutes. Subsequently, they had to fill out a questionnaire and participate in a semi-structured interview.

As part of their results they report the TV's behaviour being described as "It's in love", hence interpreting it as a social agent and attributing a 'high status' of agency. Overall, the results indicate that simple product movement provokes attention and it is possible to communicate behaviours non-verbally by adapting to the participant's movements – but only under some circumstances. When participants interacted with the TV in pairs the TV's behaviour obtained less attention. The movement was just a factor to determine the TV's preference for which person to follow, but not enough to convey either of the patterns to the participants. They come to the conclusion that participants' reaction to the TV as a social agent is an automatic reaction outside of their conscious focus.

TRASH BARREL'S gestures are examined in a study by Yang et al. (2015) aiming to understand and improve public interaction with autonomous objects. In particular how an objects' gestures, in this case the actions and interactions of a trash barrel in a public space, can influences peoples' perception of the robot. This is carried out with the help of a WoZ setup to control the movement of the trash barrel in two frequently visited dining locations at Stanford University as depicted in Figure 3.7d. After the remote controlled robots' engagement with a person or group, the participants were approached by an interviewee asking a series of open-ended question that were recorded on tape. Participants' interactions were evaluated with the help of an ethnographically inspired approach using qualitative analysis with an open coding scheme. They identify and report four common themes of interaction: first, people ascribed desires and motivation to the robot; second, poor navigation was interpreted as not socially adaptable; third, struggling behaviour created polarisation between encouraging individuals to help or to ignore the robot; and fourth, people engaged with the robot mostly when they need its service and it was actively advertising its intent through movement.

This section focused on empirical works measuring differences in the perception of movement of entities ranging from simple dots and abstract objects displayed on screen to robots and technologically animated objects in real world setups. First, I specified works assessing peoples' ability to discern animate from inanimate visual motion cues and peoples' tendency to describe the apparent behaviour of non-figurative entities and simple objects in social and animate terms. Additionally, I described works demonstrating how perceptual and conceptual information work together when interpreting an entity. Subsequently, I looked at work assessing different social behaviours applied to robots on screens as well as in real world scenarios, showing that even if it is not socially engaging behaviour, it facilitates the propensity of humans to ascribe intentions to robotic objects. Furthermore, a body of works reproducing social interaction of people with domestic objects using a WoZ setup were reported which simulated autonomous interaction of objects via a human. Peoples' interaction with the animated presence of these objects, not treating them as dead matter, bring to light that an object's autonomous movements provoke social responses and enable domestic objects to be treated as social agents. This corresponds to the on-screen animations mentioned at the beginning of this section, which indicated that people have this tendency to interpret observed action of simple objects or non-figurative unitary dots movements as social behaviour. However, the non-screen-based works comprise objects and people in a real-world setting, thus provide more ecological validity to these findings.

3.3 summary and conclusion

This chapter provided a body of work exploring the research question of this thesis: how does movement affect people's perception of technological objects? In correspondence to the previous chapter, this chapter provided related work with a focus on language and movement. These were empirical works predominantly using language to assess differences in peoples' relation to human and non-human entities presented on screens, as well as, in laboratory or real-world scenarios. This was set out above in two parts. The first part provided works focusing on peoples' interpretations of entities in terms of anthropomorphism and primarily using traits or descriptions to determine observers attribution of characteristics to human and non-human agents. This is evident in how human characteristics are assigned to non-human entities (anthropomorphism) or vice versa through dehumanising humans. This can be seen as relational mapping from a source domain to a target domain, analogously with the sociolinguistic device of metaphor described in Section 2.2 of the previous chapter. In the second part, these observations are complemented with considerations of different forms of movement and how they affect peoples' interpretation of an entity as animate or inanimate in correspondence to differences in the interpretation of an entity's agency depicted in Section 2.1. The works here 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 summarised in Figure 3.8.

In respect to the research question, the insights from both chapters on the one hand give rise to a relational approach for the methodology developed and described in the subsequent Chapter 4, and on the other hand the investigation of differences in peoples' relationship to an object moving autonomously carried out in the application Chapter 5.

In connection to the methodology the insights are based on the recognition that the use of words is controversial, as pointed out in Section 3.1.3 and Section 2.2.2. The reasoning in both sections affords a relational approach, on the one hand to permit a measurement deploying a relationship rather than just attributing properties on a simple black/white, or either/or ratio. On the other focusing on adjectives and verbs instead of excluding nouns to facilitate a relational approach of understanding 'others'. Thus paying attention to the appearance and perception of the robot, the emotions and feeling towards the entity-in-relation. With this in mind, the methodology established in the following chapter combines insights from the two and therefore differs from others by providing a relational approach on two levels. First, a relationship between subjects and their interpretation of various entities using various features used to describe movement and behaviour is established. Features, such as verbs and adjectives, are used instead of excluding nouns to reflect the way people interact, experience and relate to entities. Second, participants' interpretation is not just a rating of the feature as true or false but rather a scope of attribution ranging from "not at all" to "very much."

In regard to the application, Section 3.1 provided indications on peoples' tendency to interpret movement of non-anthropomorphic shapes and objects shown on screen in social and animate terms. Section 3.2 reported works and results with objects like the Wizard of Oz scenarios simulating autonomous interaction of objects via a human in a real world setting and which correspondingly brought to light that an object's autonomous movements provoke social responses and enabled an interaction with domestic objects similar to social agents. Insights from both gave rise to a study design (see Chapter 5) that brings together people with an autonomously acting robotic object, which lacks anthropomorphic/ zoomorphic or mechanoid morphology, in a real world scenario which to my knowledge hasn't been investigated so far and therefore transfers the finding from cognitive psychology and computer graphic animation to the field of human-robot interaction.

INANIMATE		ANIMATE
simple ←	movement qualities	→ **complex**
Qualified by specified, causal, rigid, rotary or translatory movements, passive continuous transfer of motion from A to B (launch effect), e. g. Johansson (1973) and Michotte (1963)		Qualified by spontaneous, active, relative to others, streaky movements, motion of B not caused by A, discontinuation in causal rules and structures, e. g. Heider and Simmel (1944) and Saerbeck and Bartneck (2010)
predictable		**unpredictable**
Characterized by structured, planned and repetitive movements, the entity (e. g. robot) seems to follow a regular principle, e. g. Eyssel et al. (2011) and Scholl and Tremoulet (2000)		Characterized by contingently spontaneous and streaky behaviour, the entity's behaviour seems to follow a sort of random principle, e. g. Sung et al. (2007) and Waytz et al. (2010)
involuntary		**intentional**
Extrinsic motive to act, entity is perceived as having no control, being the recipient and experiencer of an action, playing a receptive/ mechanical role, e. g. Jackendoff (1978) and Rakison and Poulin-Dubois (2001)		Intrinsic motive to act, entity is interpreted as being the author and owner of action, playing an agentive role in an action/events, e. g. Gallagher and Zahavi (2012) and Simion et al. (2013)
automatic		**autonomic**
Cause and effect relationship, entities cannot respond with independent action and seem to act on external situational forces and conform to physical constraints, e. g. Blythe et al. (1999) and Gelman et al. (1995)		Responsive to cause and effect, entities seem to resist and respond to forces and physical constraints acting upon it, able to violate energy principles, e. g. Gelman and Spelke (1981) and Morris and Peng (1994)
physically ←	movement descriptions	→ **psychologically**
Interpretation of events using vocabulary mainly from the domain of naive physics, as unintentional, mechanical, automatic or causal, e. g. Gelman and Spelke (1981) and Szewczyk and Schriefers (2011)		Interpretation of events using psychological vocabulary, entities are primarily described as intentional, being autonomous or having reasons, e. g. Carey (2009) and Kiesler et al. (2006)
factually		**socially**
The event is delineated with instrumental, non-social and factual features, using an impersonal language describing entities as fulfilling a function and serving a purpose, e. g. Carey (2009) and Michotte (1963)		The apparent behaviour is described with features of intentional action and social interaction using personal language describing living beings, e. g. Cantril (1941) and Heider and Simmel (1944)
"controllable", "efficient", "instrumental", "logical"	examples from study feature-set	"aware", "caring", "devious", "sensitive", "sociable"

Figure 3.8: Agency-framework concluding 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.

4

A METHODOLOGY FOR MEASURING HOW PEOPLE RELATE TO ARTEFACTS

Wissenschaft ist nur dort möglich, wo sich die Geschehnisse wiederholen oder doch kontrollieren lassen, und wo gäbe es mehr Wiederholung und Kontrolle als beim Militär? Ein Würfel wäre kein Würfel, wenn er nicht um neun Uhr so rechteckig wäre wie um sieben. Die Gesetze der Planetenbahnen sind ein Art Schiessvorschrift. Und wir könnten uns überhaupt von nichts einen Begriff oder ein Urteil machen, wenn alles nur einmal vorüber huschte. Was etwas gelten soll und einen Namen tragen, das muss sich wiederholen lassen, muss in vielen Exemplaren vorhanden sein, und wen du noch nie den Mond gesehen hättest, würdest du ihn für ein Taschenlampe halten; nebenbei bemerkt, die grosse Verlegenheit, die Gott der Wissenschaft bereitet, besteht darin, dass er nur ein einzigesmal gesehen worden ist, und das bei Erschaffung der Welt, ehe noch geschulte Beobachter da waren.

— Robert Musil (1943, p. 377)

Science is possible only where situations repeat themselves, or where you have some control over them, and where do you have more repetition and control than in the army? A cube would not be a cube if it were not just as rectangular at nine o'clock as at seven. The same kind of rules work for keeping the planets in orbit as in ballistics. We'd have no way of understanding or judging anything if things flitted past us only once. Anything that has to be valid and have a name must be repeatable, it must be represented by many specimens, and if you had never seen the moon before, you'd think it was a flashlight. Incidentally, the reason God is such an embarrassment to science is that he was seen only once, at the Creation, before there were any trained observers around.

— Robert Musil (1996, p. 409)

The work presented in this thesis is about the relationship between human observers and various human or non-human entities. The focus is on how humans perceive movement and how it affects this relationship. This chapter reports the development of a novel methodology based on a quantitative method to measure how the observation of movement – the dynamic form of things as described in Section 2.1.1 – affects the way people relate to entities.

Chapter 2 provided the background to explore the way the movement of natural entities (locomoting animals and robots or the expressivity of dancers) plays a vital part in our perception of these things. In congruence, Chapter 3 surveyed empirical work with a focus on movement and the use of language to assess difference in the way people relate to things. Insights from both chapters gave rise to a relational approach using language to understand the relationship between humans and things. As a consequence, this chapter describes a methodology based on the use of language in order to measure this relationship. Humans' intuitive process of categorising and attributing characteristics as a way of understanding things, as found in the concept of metaphor described in Section 2.2.1, is central to the outlined method. Section 2.2.3 outlined the linguistic concept of animacy and concomitant agency, expressing how sentient or alive an entity is interpreted as being. Drawing from these concepts, this chapter develops a set of metrics to investigate whether conceptual boundaries of entities, like those between human and non-human, change when movement comes into play.

I start with a section reasoning about the methodology assessing subjective interpretations. The methodology presented is developed and informed by empirical work and is deployed by means of two parts. The first part lays the foundation for using language as an instrument of measurement. It contrasts subjective interpretations and the attribution of features in relation to entities like humans, animals and machines.This results in a measurement tool, a geometrical feature-space with three designated regions containing features representative for humans, animals and machines. The second part investigates whether these regions change when entities are represented with movement. By gathering subjects' responses to various pictures of entities represented with and without movement the study provides measures for the effect of movement as displacement of the interpretations in the feature-space. This is shown graphically through principal component analysis (PCA), and numerically by typicality displacement in relation to the three regions.

In all, this chapter provides a quantitative method for measuring how movement motivates changes in observers' interpretation affect towards an entity. The methodology together with its application in the following Chapter 5 provide a key contribution of this thesis. As a conclusion of the background and related work discussed in Chapter 2 and 3, the metric provides a computational approach to evaluate how observers perceive various instances of entities. This is measured via the attribution of qualities or traits to these entities. Moreover it allows representation of processed information in geometrical structures, to talk about distances between them and make similarity judgements. As such it presents a quantitative method that provides a relational approach on two levels. First, instead of using nouns which determine an entity as belonging to one or another category or species, e. g. this is an animal or not, it utilises adjectives and verbs, which pay attention to the way people experience and relate to an entity, e. g. ascribing emotions and intentions. Second, it enables a measurement that allows a relationship rather than just attributing properties on a simple black/white or either/or ratio.

The methodology outlined here can be used to analyse differences in subjective experiences of art installations, performances, or sculptural artworks, as well as in human-robot interaction scenarios as carried out in the subsequent Chapter 5.

4.1 ASSESSING SUBJECTIVE INTERPRETATIONS

In general the work and the methodology presented here is about subjective interpretations. In particular, it concerns metaphorical attribution of features to entities presented either with or without movement. The attempt is to assess to what degree an observer views an entity as having features of *agency* and *animacy* as outlined in the previous Chapters 2 and 3. The concept of metaphor is used in accordance with Duffy (2003) who disagrees with Nass and Moon (2000), I do not think humans "mindlessly apply social rules and expectations to computers"Nass and Moon (2000, p. 81) that provide an explanation of (a system's) behaviour, such as the claim that people impart intrinsic intentionality to the device. To my mind, the observer's interpretation is not analysable in terms of any explanatory system of functional or intentional states of the object.[1] Rather, it can only be interpreted as what it

1 Duffy (2003) refers to Searle (1983) who makes this subtle but important difference between as-if intentionality and intrinsic intentionality. Duffy says that the latter is a form of anthropomorphism that is incorrect as it is trying to provide an explanation of a system's behaviour which is difficult or even impossible to prove, while the former,

is like (Nagel, 1974), because "nothing is metaphysically hidden. However ignorant we are of octopuses, aliens, and robots, nothing about them is truly hidden from us, that is to say the other side of a metaphysical veil" (Shanahan, 2010, p.26).

These interpretations, methodologically grounded in "folk phenomenology [provide] description of experiences stemming from subjective or first person analysis, which feels can be exported, with limited modification, to other experiencers of the same or similar phenomena" (Hayler, 2015, p. 3, referring to Metzinger, 2004). The methodology reported here takes inspiration from this approach; subjective responses to various entities with or without movement are computed and compared using the developed measurement tool. This results in intersubjective or shared features attributed to the representation of the entity under the specific condition. The relationships between these shared features are subsequently calculated, compared and discussed.

To that effect the following sections report a methodology informed by two empirical studies and based on quantitative methods to measure participants' relation to entities, and potential perceptual shifts elicited by movement and behaviour of these entities.

In the fashion of Gärdenfors' theory of phenomenal conceptual spaces (Gärdenfors, 2004), 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 to serve as a tool to define regions and specify relations among the dimensions. Gärdenfors draws a tight connection between distances in a conceptual space and similarity judgements: "the smaller the distances is between the representations of two objects, the more similar they are. In this way, the similarity of two objects can be defined via the distance between their representing points in the space. Consequently, conceptual spaces provide us with a natural way of representing similarities" (Gärdenfors, 2004, p. 4). Correspondingly, participants' responses are represented in geometrical structures, computed using PCA and vector displacement. As a consequence, this method establishes a relational approach with the objective of obtaining a spatial representation. Hence it facilitates the illustration and assessment of differences between participants' re-

as-if intentionality, is a metaphorical interpretation indicating how something appears. This problem is expressed in "the other minds problem", stating that we cannot "climb into the heads of others to get the full story from the inside" (Haraway, 2008, p. 228, cited by Coeckelbergh and Gunkel, 2014). See also the point of views quoted in Section 2.2.1.

lationship to entities. This is measured as distances between the 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 (see Sections 2.1.3 and 2.2.3). The first study, *Study A*, constituting the first part, 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 (entities without movement). The result provides a measurement tool for the second part, *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.

Both studies and the resulting metric use subjective interpretations to measure peoples' relation to entities and potential perceptual shifts elicited by movement and behaviour are reported in the following sections. 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.

4.2 Construction and Calibration of the Feature Space

This part was motivated by the aim to build 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 of either humans, animals or machines. The choice of the categories of machines and humans emanated from work by Kiesler and Goetz (2002) and was extended with animals following an email conversation with Sarah Kiesler. Processing the responses in respect to the categories resulted 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 are described next.

4.2.1 *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 a randomly selected picture set from the available three. Each set was based on 20 randomised 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 an independent variable.

THE CATEGORIES are humans, animals and machines. Each picture set is a slide show of 20 randomised pictures representing exclusively that category. With the problematic terminology of the categories mentioned in the Background Section 2.4 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.[2] With the assistance of the United Nations Photo Library,[3] which kindly gave access to their archive, certain pictures could be replaced with a more recent version (the three picture sets are shown in the Appendix A.1).

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 etc. (The complete list is provided in the Appendix Table A.1). Parts of the items were motivated by the Kiesler and Goetz (2002) study and extended with items

2 *Golden Record* documentation: http://voyager.jpl.nasa.gov/spacecraft/goldenrec.html (accessed October, 2017).

3 http://www.unmultimedia.org/photo/photo_library.jsp (accessed October, 2017).

from Epley et al. (2007) and Waytz et al. (2010) e. g. anthropomorphic traits like thoughtful, considerate, sympathetic; non-anthropomorphic traits or functional features like durable, useful, logical; furthermore false fillers taken from Fussell et al. (2008) e.g. wooden or ceramic. The intention was 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 Carpinella et al., 2017.

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 were 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".

Procedure

Participants were recruited through the network of Queen Mary University using email and social media. Their contributions were collected over three months within a Qualtrics framework[4] which was set to be working on standard computer browsers as well as mobile devices. No prescription was given to the participant in which environment they should engage with the survey. Participants' participation 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 93, the age ranged from 18 to over 65, 49% between 35-54 and 40% in the 26-34 range, with 64% identifying themselves as male, 31% as female, 4% 'prefer not to say' and 1% as 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. The disparity in these numbers results from the removal of respondents with not applicable (NA) values due to their missing out of one or more ratings.

4 https://www.qualtrics.com/ (accessed April, 2018).

4.2.2 *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 (Hotelling, 1933) 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 three regions, corresponding to the category of pictures shown to the participants, are allocated in the geometrical space using individuals' ratings of the features.

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 or machines. PCA is used to represent individuals' responses to the images in the geometrical structure and visualize the distinct regions for the categories. This is illustrated in Figure 4.1, 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 humans, animals or machines. For elucidation of the regions a 'normal probability ellipsoid' with a percentile of 68% is drawn around them for each category.

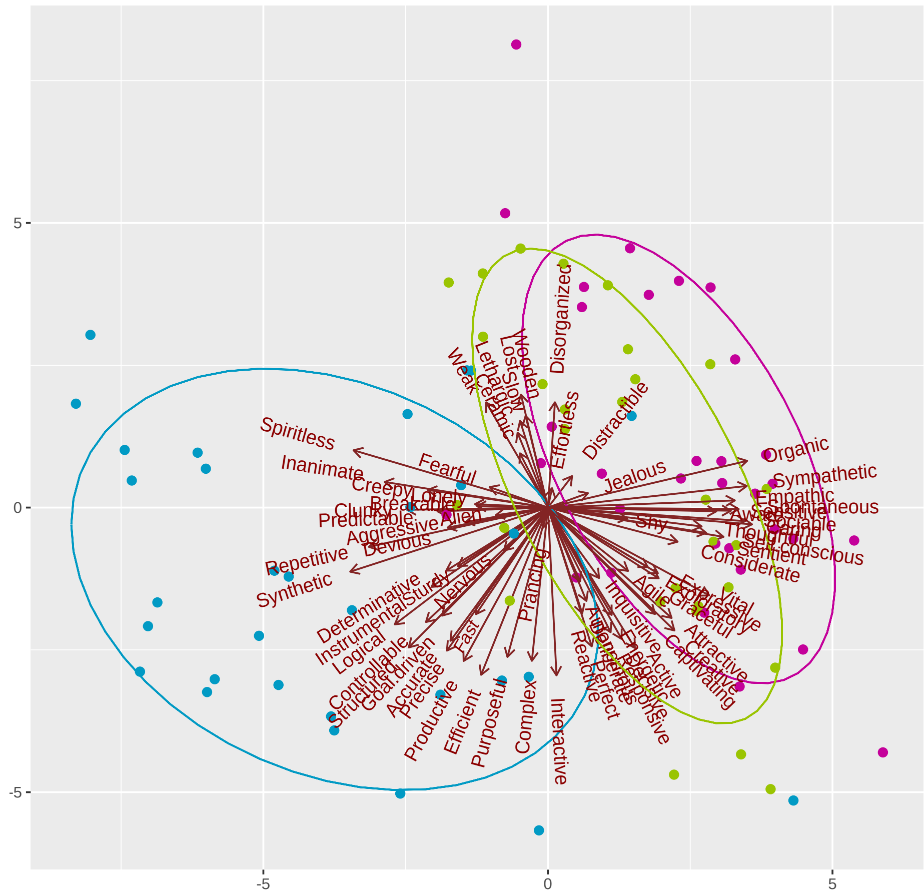


Figure 4.1: The two principal components of the *feature-space* resulting from Study A, showing designated regions with their normal probability ellipsoids for the categories of humans (magenta), animals (green) and machines (blue). The brown vectors denote the eigenvectors for the individual named traits.

4.2.3 *Step III: Optimise the Feature-space*

This step provides instructions how to optimise the feature-space in two forms. First, a feature-reduction removes 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 results 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 optimise 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 (Witten et al., 2016). 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 (Witten et al., 2016, p.327) with a "CFS subset evaluator" (Hall, 1998) 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 = $\hat{H}$, animals mean-interpretation = $\hat{A}$, machines mean-interpretation = $\hat{M}$ can be determined as in Equation 4.1.

$$\hat{H} = \frac{1}{n}\sum_{i=1}^{n} h_i \quad , \quad \hat{A} = \frac{1}{n}\sum_{i=1}^{n} a_i \quad , \quad \hat{M} = \frac{1}{n}\sum_{i=1}^{n} m_i \tag{4.1}$$

$n =$ number of features

Procedure

To optimise 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]

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

mean interpretations are calculated as centroids of each regions' data cluster applying Equation 4.1.

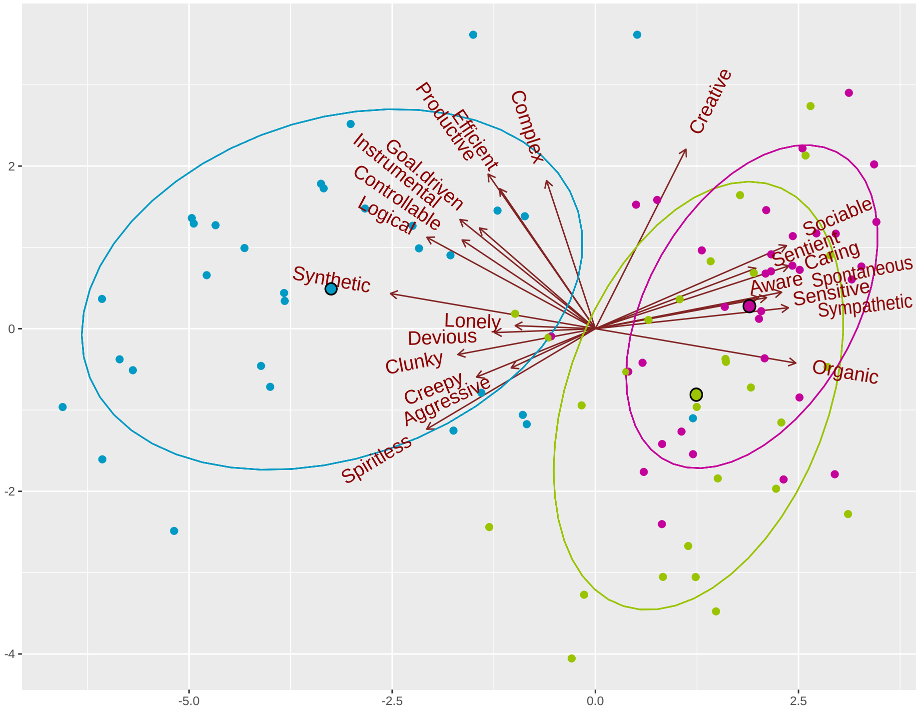


Figure 4.2: The reduced feature-space, as a result of Study A, with designated regions, coloured as before, and centroids (circled in black) representing mean-interpretations.

4.2.4 *Study A: Results*

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 human, animal and machine as shown in Figure 4.1.
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 4.2.

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*.

4.3 USING THE FEATURE-SPACE TO SHOW THE EFFECTS OF MOVEMENT

This part 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' relation 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.

4.3.1 *Step I: Gathering the Data*

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

Method

THE STATIC AND DYNAMIC ENTITIES are 16 in number. These are presented to participants 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 sequences.

The images of the entities are sourced from the author's video archive or Youtube videos, as neither the Voyager record nor the UN photo archive used in the first part provide video 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 4.1).

The choice of images primarily originates from chats during the exhibition of the hairbrush mentioned in Section 1.2, discussions in the research group and to some extent from related works. Some of them were chosen as people reportedly found 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 4 pictures, all of them either of static or dynamic entities. After each instance, participants are asked to rate the reduced feature-set on the same Likert scale as in *Study A* described in Section 4.2.1. 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, implemented in a Qualtrics framework, 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 a distribution (k) of the ratings over the static and dynamic entities as shown in Table 4.1.

4.3.2 *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 4.2.

$$\hat{E^s} = \frac{1}{n}\sum_{i=1}^{n} e_i^s \,, \quad \hat{E^d} = \frac{1}{n}\sum_{i=1}^{n} e_i^d \tag{4.2}$$

$n =$ number of features

THE TYPICALITY of an entity consists of three values resulting from measurements of the entity in relation to the 3 categories of humans, animals and machines. The triple values as determined in Equation 4.3 are calculated by measuring the distance between the entities mean-interpretation E^s or E^d in relation to the 3 mean-interpretations of $\hat{H}$, $\hat{A}$, $\hat{M}$.

$$\text{typicality of } \hat{E} = < \|\hat{E} - \hat{H}\|, \|\hat{E} - \hat{A}\|, \|\hat{E} - \hat{M}\| > \tag{4.3}$$

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 4.2 and the typicality in relation to the means of the regions of humans, animals and machines as given by Equation 4.3.

4.3.3 *Step III: Measure the Effect of Movement*

Method

Differences between entities' interpretations 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 4.3 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 4.4. The displacement of the typicality expressed in a trivalent value of displacement vectors can be used to determine effects within an entity but also to compare across the entities.

$$\begin{aligned} d(\hat{E^s}, \hat{E^d}) = &< \|\hat{E^s} - \hat{H}\|, \|\hat{E^s} - \hat{A}\|, \|\hat{E^s} - \hat{M}\| > \\ &- < \|\hat{E^d} - \hat{H}\|, \|\hat{E^d} - \hat{A}\|, \|\hat{E^d} - \hat{M}\| > \end{aligned} \tag{4.4}$$

Procedure

As a consequence of the entities' data being projected and processed, the effect of movement can be illustrated by plotting the respective static and dynamic interpretation of the entity as shown in Figure 4.3. Additionally, the numbers expressed by the divergence resulting from subtracting the typicality of the dynamic entity from the static (as stated in Equation 4.4) results in a trivalent value of typicality-displacement in relation to the categories of humans, animals and machines.

4.3.4 *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 4.2 are allocated in relation to the regions for the given categories, and a metric of typicality for the entities is implemented using Equation 4.3.

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 4.4. The consequential displacement vector $d(\hat{E^s}, \hat{E^d})$ 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 4.3.

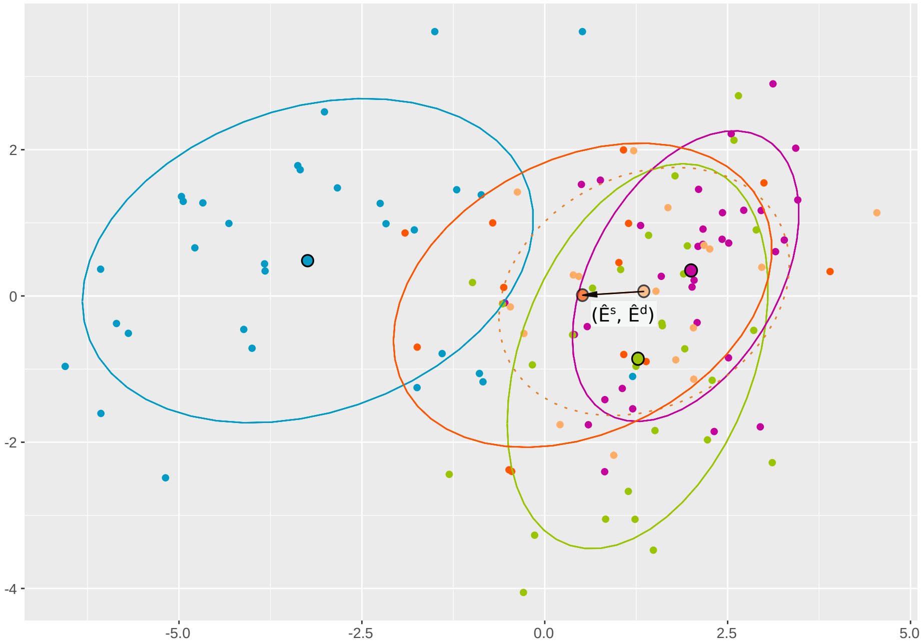


Figure 4.3: Results of Study B, showing shifts in participants' affect towards a breakdancer's (orange) static (pale-dotted) and dynamic (continuous) mean-interpretations within regions coloured as before.

4.3.5 *Results of Study A and B*

The methodology, informed by the result of the studies, provides a way to illustrate differences in participants' interpretative relationship affected by a representation of an entity with movement.

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 visualise 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.

Consider, for example, the observed shift for a static representation of a human in comparison to the dynamic, a video of a human performing breakdancing moves. In this instance, the human is represented with mechanical movement which is shown in the space as a shift toward the region designated to machines. This example of shift in participants' 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 4.3.

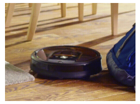
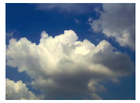
The numerical results of the typicality measurements and concomitant displacement between the static an dynamic entities are listed in Table 4.1. Shifts in the typicality measurement are specified by the results of the displacement of typicality, expressed by $d(\hat{E^s}, \hat{E^d})$ as determined in Equation 4.4.

4.3.6 *Evaluation and Discussion*

The developed agency-framework shown in Figure 3.8, provided as part of the conclusion of the related work, 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 in ontological commitments from human to non-human as specified in Section 3.1, and correspondingly judgements of agency based on an interpretation of an entity as animate or inanimate as presented in Section 3.2.

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 traits, 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,

Table 4.1: Results from both studies specifying the typicality displacement as a result of computing the difference between the static and dynamic interpretations

Study A																
Categories	Human				Animal				Machine				Natural Entities			
$k =$	33				29				31							
Study B	Breakdancer		Dancer		Worm		Fly		Washing-machine		Roomba-robot		Clouds		Leaves	
Entities																
	E^s	E^d	E^s	E^d	E^s	E^d	E^s	E^d	E^s	E^d	E^s	E^d	E^s	E^d	E^s	E^d
$k =$	17	13	18	15	13	17	14	15	16	15	16	18	18	14	17	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	

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 A.2 (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 perception as typicality-displacement are 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 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 as less intentional and has more automatic and involuntary qualities. This is pertinent to the mechanical movement, which in a poetic way transfigures a human through its movement to appearing as 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 the values in the brackets are denoted as 's' for static and 'd' for dynamic. 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 the features' contribution to the overall

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.

result. As an 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 an arm up, encompassing ambiguity over whether the subject is involved in a dance or rumble. Hence looking at the data in this way gives evidence as to how individual features contribute more or less. But considering all of the individual ratings in the result leads to the established methodology.

In essence the results suggest the *Breakdancer's* 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. This 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 5 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. (2011). It should be noted, however, that the effect in case of the *Dancer* is less than half the size in comparison to the *Breakdancer's*. Kate Bush's dance is rhythmic rather than mechanistic, therefore 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* affects its interpretation as more machine-like.

Animal Entities

Looking at entities within the animal category, 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 *dy-*

namic representation obtains a strong tendency towards human-typicality (0.8) and animal-typicality (0.75) and a 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 to 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 wasn't 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 suggestive of a dance pattern, manifest for example in the dynamic being interpreted more *goal driven*.

This result, contrary to the expectations, indicates the second most substantial shift in the affective relationship of the 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. (2006). 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* is (d: 0.47, s: 0.08), in general this feature is rather undecided for machines (0.08) and not very characteristic of *humans* (−0.47) and *animals* (−0.31). This 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 (1944) 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 didn't match the expectation. An small attenuation or even increment of intentional agency was expected, as implied for example in the dynamic's rating as more *aware* (d: 0.17, s: −0.33). This was anticipated 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 its trajectory and nestles around the backpack next to it. Subsequently suggesting its action is interpreted as 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 (Epley et al., 2008b). This 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. Both 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 (Gelman et al., 1995; Michotte, 1963).

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).

Limitations of the methodology

Participants interpretation of the static and dynamic entities were put in relation to static representations of categories. Collecting ratings of dynamic representation of the categories and put them in relation would have been another path to follow. Furthermore collecting participant's ratings from stimuli from across the categories would be another possibility to get and compare participants responses between categories. However, the average time for taking this part of the study was 15 minutes. If participants had to rate 70 stimuli in respect to more than one category it would require a much longer study and more participants, neither of which were possible within the scope of this work.

Furthermore, in respect to the setup, video sequences longer than four to five seconds would have been preferable, but the Qualtrics framework at the time of the study did not allow buffering or embedding videos in a practicable way. Additionally, representations of zoomorphic or anthropomorphic robots (e. g. Bartneck et al. (2009b) and Lehmann et al. (2015)) have not been tested in the framework.

The methodology presented here can be contrasted with alternative methods from experimental psychology, for instance triad tasks and multidimensional scaling. The former, triad tasks, is a method asking participants to judge similarity between three items (which one is different, which two are most similar). It allows to measure judgments of similarities among items in a cultural domain e. g. difference and similarity judgements for type of animals (Rips, 1989, p. 39), plant taxonomy (Ross et al., 2005), semantics domains in language (Burton and Nerlove, 1976). However, following this method with the static and dynamic stimuli used in the methodology presented in this chapter, would make impossible to compare differences between static and dynamic representations of items or entities as in all likelihood this would be the distinguishing mark. The advantage of triad tasks in turn is its simplicity and the possibility to avoid the use of language, thus it can be used cross culturally and with non literates (Burton and Nerlove, 1976). As a consequence, employing triad tasks would allow to overcome the use of language and potential problems therewith as discussed in Section 2.2.2 and 3.1.3.

Similarity measures from triad tests can be used as input to produce multidimensional scaling (MDS) models (Burton and Nerlove, 1976, p. 248). Similar to the PCA visualisation deployed here, MDS can be applied to build a geometric map of stimuli, plotted as points in a space. MDS's historical roots lie in building psychological model of participants' judgements of similarity of objects, but nowadays it is frequently used to visualize data (Borg et al., 2012, p. 7). Thus in contrast the approach presented here, mapping participants ratings as vector distance measurements in a feature space and visualize them using PCA, MDS wouldn't allow to calculate and visualize the relation of the features to the categories as represented in Figure 4.1 and 4.2. However, MDS enables to report a goodness-of-fit statistic between the constructed space, the geometric map and the actual stimuli resulting from the subjectively judged distances (Borg and Groenen, 2005, p. 37).

4.4 SUMMARY AND CONCLUSION

The metric established and validated in the first two parts provides a quantitative method for measuring the perception of various human and non-human entities. The methodology can be used to show that subjects' interpretations significantly change with degrees of animacy and agency when movement comes into play.

This is attributable to the outcomes from the Background and Related Work Chapter in two ways. First, Chapter 2 provided a conceptualisation of 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, the work was grounded in previous research. Related work presented in Chapter 3 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. This was transferred in an agency-framework as shown in Figure 3.8, illustrating differences in participants' interpretation, in form of movement qualities and descriptions, as degrees of agency and animacy.

The methodology reassembles findings from both and presents a metric using an indirect method of not asking people directly about humans, animals and machines but using images instead of words. Moreover, the method permits a measurement deploying a relationship rather than just attributing properties as a simple black/white or either/or ratio. The agency-framework first illustrates the metric assessing participants' interpretation of entities in analogy to the linguistic device of metaphors. Secondly, it shows the evaluation method by establishing ontological categories for humans, animals and machines; then using the categories to assess changes in the interpretative relationship as displacements in ontological commitments evoked by movement.

Consequently, the methodology comprises two steps, both carried out and informed by two online studies. In the first study 70 words were used to obtain a measurement tool, a feature-space. People were asked to interpret depictions of entities of humans, animals and machines by asking them to attribute traits on a scale. As a result a measurement tool was obtained 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 step, 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*. This analyses the influence of movement on this classification by having people interpret entities displayed either static or dynamic. By using the same set of traits these results could be projected into the previously obtained feature-space and changes in participants' interpretation of various entities as an effect of movement could be shown. For example, the interpretation of a breakdancer represented with movement was less intentional and more mechanical. A lesser degree of anthropomorphism in a Roomba robot's dynamic representation can also be shown.

Along these lines the methodology and studies provide a quantitative method to assess and illustrate changes in observers interpretative 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.

Ultimately, the outlined methodology based on feature attribution, assessing how something appears to different participants, can be used to analyse differences in subjective experiences of art installations, performances, or sculptural artworks, as well as in human-robot interaction scenarios. This is carried out in the subsequent Chapter 5.

5

APPLICATION OF THE METHOD

This chapter reports the application of the methodology outlined in the previous Chapter 4 for an empirical study. The study assesses subjects' interpretation of an everyday object, a hairbrush that is animated. Analogously to the Dadaist's concept of the Readymade – creating boundary objects by situating them between object and art described in Section 2.3 – the object of the study is an everyday object transformed into a non-living agent, moving between the familiar borders of inanimate object and animate creature.

This chapter describes the creation and observation of this technologically modified hairbrush named *Uruca Caliandrum*. It first delineates the motivation and iterative development of this artefact, that is designed to feature aspects of apparent behaviour: the hairbrush is programmed to 'wake up' with the dawn and the brushes in the rubber are employed to move similarly to a caterpillar's legs. This transformative capacity of this non-anthropomorphic/zoomorphic/mechanoid object forms the practical base for the second part of this chapter reporting an empirical study. Applying the methodology outlined in Chapter 4, for assessing participants interpretative relationship to an entity, the particular focus of the study is on possible shifts in participants' affiliation triggered by three different conditions of object movement: no movement and two different movement patterns. For the latter, one resembles a continuous minimum-jerk pattern representative of organic or biological movement and one a discrete bang-bang pattern modelling mechanical movement.

The results provided by the application of the methodology indicate differences in the feature attribution as an effect of movement, leading to two key contributions for this thesis. The first is the application of the methodology in an experimental scenario, which shows its validity and in doing so provides a measurement tool to compare differences in participants' interpretation of an entity. The second is the result indicating that the interpretation of a non-anthropomorphic object as more intentional and animate can shift depending on its movement alone. These findings correspond to screen-based work, for instance Heider and Simmel's (1944) seminal work proving that movement of non-anthropomorphic objects like triangles and dots are predominantly interpreted in social terminology as actions of animate beings. However as this study comprises a real-world scenario with a robot and people, it transfers these findings from cognitive psychology and computer graphic animation to the field of human-robot interaction.

5.1 THE SUBJECT OF THE STUDY: URUCA CALIANDRUM

This section outlines the development of a robotic hairbrush named *Uruca Caliandrum*. It describes the conceptual design prototypes of two robots based on the transformation of an everyday hairbrush into a robotic creature. The development of the prototypes is contextualised within the field of biologically-inspired robotics.

Following a section justifying the use of an everyday hairbrush to study the effect of movement on subjects' interpretation, the two prototypes are described. The first section presents the back story and development of the first prototype. The focus for this prototype is how its locomotion and development are influenced by the field of biologically inspired robotics. The first prototype is more than a proof of concept for a technological object that evokes the various interpretations reported in the observations on page 5. These observations also motivated the development of the second prototype used in the subsequent empirical study. The design and development of the second prototype focuses on the morphology of the object as well as its behaviour. The intent is to consider morphology and make the hairbrush look more like an everyday object by incorporating and hiding the electronics and mechanics within the brushes' body. With respect to behaviour, the aim is to enhance the second prototype's movement capabilities by applying two different movement patterns to the locomotion.

Finally, this section provides details about designing the behaviour of an everyday object based on movement alone. The non-anthropomorphic/zoomorphic/mechanoid appearance of the hairbrush is framed as an ideal object to study the effect of movement on people's affinity to artefacts in a real-world scenario.

5.1.1 *Why a Hairbrush?*

As Dautenhahn (2013) pointed out, the appearance of a robot has an effect on how people envisage its function. A robot's design plays an important role on the way people relate to the machine. As set out in Section 2.3, the ambiguous experience of an object moving like a living creature can create tension and attention. On the one hand, a non-humanoid design decreases the expectations of skill people attribute to the robot but on the other increases attention. Non-human robots, lacking semblances e. g. of animal or human face or body structures, instinctively make people act more cautiously as their appearance lacks familiarity. People might not know how to deal with the unknown and unfamiliar behaviour which could lead to dangerous situations (Dautenhahn, 2013, Section 38.10). Ambiguity thwarts easy interpretation as an objects' or robots' appearance doesn't allow people to draw conclusions about its behaviour. From appearance alone it is difficult for people to imagine the robot is capable of 'natural' behaviour and therefore they pay more attention.

The increase in attention concomitant with an intensified need for interpretation is furthermore supported by the Expectancy Violation theory. This theory analyses how individuals respond when they are faced with unexpected events, how it affects and most likely increases not only attention but also changes the way people relate to a stimulus and interpret it. This is apparent for example when an agent's movement violates one's expectations. An agent's infrequent or surprising behaviour captures people's attention to a greater extent than when the agent is moving in an expected manner (Browning and Harmer, 2012).[1] In addition expectancy violation requires people to rethink preexisting beliefs about an agent's behaviour and therefore is likely to stimulate thoughts and ideas about them (Epley et al., 2007). This reflects Shklovsky's (1917) remarks on the principle of poetry and technique of art, as presented in Section 2.3.1, to make objects unfamiliar, which prolongs perception because of the tension between how things are known and how they are experienced.

The ontological uncertainty of the brush's behaviour – a non-living agent that crosses the familiar border between passive object and active agent – uses ambiguity in its design to evoke an interpretation of an object along the axis of living and non-living by movement alone. It provides a way to focus on the aesthetic experience, the sensation of things as they are perceived and not as they are known. Ultimately, using the hairbrush facilitates putting aesthetic and emotional issues in the foreground and practical or material applications in the background. For transgressing the familiar knowledge of an everyday object through its sudden transformation by movement alone, the hairbrush is therefore considered to be an ideal candidate to evaluate variations of interpretations elicited by different movement patterns.

1 Takagi et al.'s (2016) work suggests that this similarly applies to animals' cognition in another experiment showing cat's surprise at physically incongruent events, e. g. the relation between an objects' movement and its sound.

5.1.2 *First Prototype*

This section starts with the backstory of how the hairbrush came into being. This is followed by outlining the process of the development of the first prototype and its description while shown in a gallery where the observations reported in the introduction Chapter 1.2 were made.

Back-story

The work described here goes back to a memorable encounter in my childhood. In my early age I was playing around with a hairbrush lying next to the bathtub. Playing around with the object and pressing the rubber with the brushes back into the brush's body, I was fascinated by the bristles' wondrous and apparent intention to engulf my finger, akin to a sea anemone reaching out to grasp edible items.

Much later, during my time as an artist-in-residence at the Artificial Intelligence Lab at the University of Zurich, I participated in a workshop on 'Bio-inspired robotics' led by Dr. Lijin Aryananda (2010). The workshop was practical as well as theoretical, giving insights into ingenious forms and mechanisms found in nature. The aim of the workshop was twofold, on the one hand by modelling nature, to understand more about nature and on the other to adopt nature's design principles to create novel and effective robots. Ultimately the goal of the workshop was to design and build a robot inspired by nature. During this time I stumbled across a hairbrush while waiting at a till in a supermarket and started playing with it. I purchased the brush and as part of the workshop I took it apart and started to explore its materials to generate forms of locomotion.

This led to the idea/objective of designing a technological object that is leading a double life, morphing between the state of a regular hairbrush and an animal-like autonomous robot. The object exhibits behaviour beyond the intentions of its original design (Papanek and Hennessey, 1977) a functional estrangement that could be considered as "sense-fiction".[2]

The name *Uruca Caliandrum* is derived from vulgar latin *Uruca* and spanish *oruga* standing for caterpillar (insect or vehicle) and *Caliandrum*

2 The object incorporates the principle of Chindogu: individual elements of an apparatus are recognisable, but the reason for combining them is at first bewildering. Therefore the meaning behind the object is derived from "sense-fiction": the object makes functional sense, but is still useless (Dunne, 2006).

standing for high head-dress or bee-hive hairstyle similar to the one of Marge Simpson.[3]

Description

As mentioned in the introduction Section 1.2, the first prototype was shown in the exhibition *Ride the Jud* at the Hard Tree gallery[4] in London from February 12-14, 2014. In the exhibition the hairbrush was placed on a plinth as shown in Figure 1.5 and next to it a description of the work as follows:

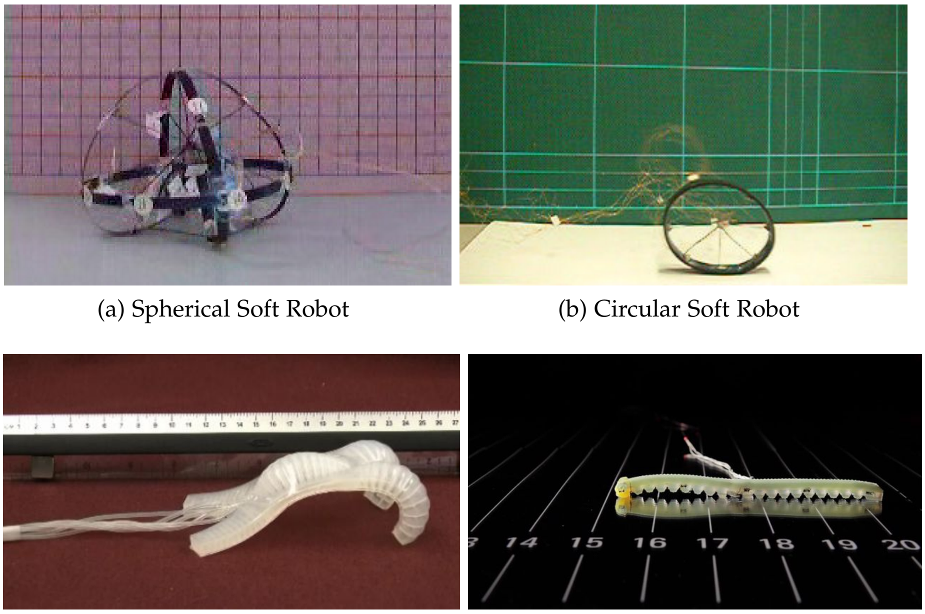
> Uruca Caliandrum — a hairbrush witnessing sunrises
>
> The hairbrush comes with a built-in OrientationAssistance™[1]. This OrientationAssistance™ assists machines in perceiving the sunrise. Here it's built inside the hairbrush, but as an add-on the OrientationAssistance™ can be plugged/mounted on any responsive object/machine.
>
> With the break of dawn the hairbrush wakes up and starts moving in the direction of the sunrise. As soon as it reaches a nice position to gaze at the sunrise, the hairbrush congeals and switches into contemplative mode, watching the sunrise and relaxing from the morning exercise.
>
> In this state and during the day the brush regains the energy lost from the morning exercise with the help of the solar cells on its back. In this time, and also during the night, it then can be used as an everyday hairbrush, before the break of dawn when it will awake again.
>
> [1] OrientationAssistance™ is a trademark of Nicolaus Copernicus & co.

In the following section I describe the process of designing the first prototype, the robot that was shown at this exhibition.

Development

The first version of the hairbrush was developed at the AI-lab in Zurich. The ethos of the lab was following the synthetic methodology as "understanding by building" or "learning by doing" (Pfeifer and Bongart, 2007, p. 77). The challenges faced in designing the robot were on the one hand the movement, designing the locomotion, and, on the other

3 Marge Simpson's hairstyle on the other hand was inspired by the titular Bride in Bride of Frankenstein (Solomon, 2007).
4 http://hardytreegallery.com/ (accessed January 2017).



(a) Spherical Soft Robot (b) Circular Soft Robot

(c) Meshworm (d) GoQbot

Figure 5.1: Crawling and jumping soft robots. Figure 5.1a and 5.1b courtesy of Shinichi Hirai and his lab, Figure 5.1c courtesy of Shepherd et al. (2011), Figure 5.1d courtesy of Huai-Ti Lin, all published with their permission.

hand, including the functionality and autonomy of the robot in the design. Encouraged by bio-inspired robotics, the dynamics and physical properties of materials were explored. This "morphological computation" (Pfeifer et al., 2007)[5] was done by building prototypes based on modifications to conventional hairbrushes to inspect the usage of materials and their properties.

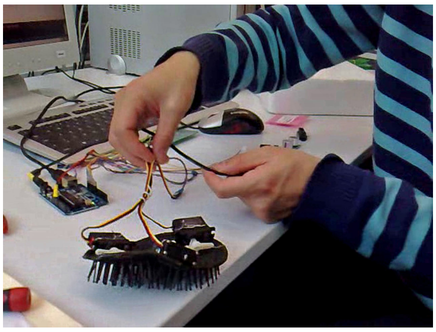
LESSON FROM BIOLOGY: Bio-inspiration is a keyword used in contemporary robotics and is considered as a design principle for intelligent systems (Pfeifer et al., 2005). Drawing analogies between biology and robotics, it describes the use of principles from nature to design simple control methods and locomotion techniques for robots based on the notion that ideas from biology can strongly benefit the design of autonomous robots (Pfeifer et al., 2007).

In the context of this work worms and caterpillars in particular, and their artificial counterparts from the family of soft robots, came into consideration. Figure 5.1 shows examples of robots in which different biologically-inspired approaches to locomotion have been imple-

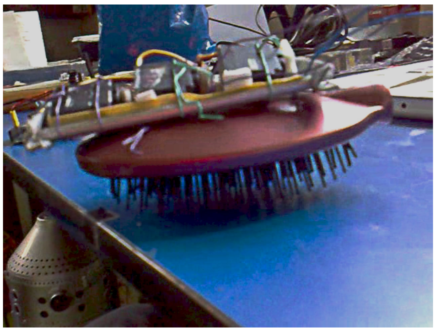
5 Pfeifer et al. (2007) develop the term "morphological computation" to designate the idea that part of the computational task is taken over by the morphology, the mechanical 'intelligence' of the robot found in the physical properties of the materials.

mented. Members of the soft robots family are qualified as mobile machines, animal-like in their capabilities and largely constructed from soft materials (Trimmer, 2013). For instance the worms as shown in Figure 5.1c and 5.1d consist only of soft material and use travelling waves of contraction and expansion to generate locomotion. Caterpillars' locomotion strategy in contrast is based on a so-called "environmental skeleton" (Lin and Trimmer, 2010). To crawl, they use a combination of soft materials and the exertion of compressive forces against a surface to control the release of body tension and generate movement (Kim et al., 2013).

LOCOMOTION MECHANISM: Influenced and fascinated by these bio-inspired robots, the development of the first prototype of the hairbrush explores the combination of a worm's travelling wave with a skeleton, the body, and the soft material of the brush.



(a) Early explorations of the unconstrained structure, attaching three servos to the rubber and the bristles.



(b) Forward-moving locomotion by attaching the rubber to the rigid body and mounting the servos on the top.

Figure 5.2: Video stills showing the process of engineering the movement mechanism of the hairbrush by examining the synergy between the soft and hard materials to produce locomotion. Images by the author.

At the outset three servomotors were attached to the back of a bristled segment of rubber, controlled by a micro-controller as shown in Figure 5.2a.[6] Running a travelling wave with a variety of parameters (speed, acceleration, sinusoidal offset) on the three aligned motors created a wave-like oscillation that was associated similar to a ray's movement. However, in the laboratory on land the resulting forward movement was negligible as the object did not advance very much across the surface it had been placed on. Therefore, in line with the environmental skeleton strategy, the soft structure of the rubber was next attached to

6 Video showing the unconstrained structure with the flexible rubber https://youtu.be/WH2uGUjswCg (accessed November 2017).

the rigid body of the hairbrush as shown in Figure 5.2b.[7] Running the same travelling wave through the flexible rubber while attached to the body of the brush resulted in a forward-moving locomotion, created by the deformation of the rubber and brush's bristles. Furthermore a natural-looking caterpillar gait was produced. Based on these findings, the first prototype was built.

(a) Technologically modified hairbrush. Image courtesy of Thorsten Strohmeier, published with his permission.

(b) Orgyia recens. Image by user Ivengo (RUS) published on Wikimedia under CC BY-SA 3.0.

Figure 5.3: (a) first prototype of the hairbrush and (b) its natural role model.

7 Video of the flexible rubber attached to the rigid body https://youtu.be/49VCbz0sRJs (accessed November 2017).

THE HARDWARE of this prototype consists of three servo motors mounted inside the brush's body and each servo arm attached to the rubber as shown in Figure 5.4. Furthermore, the prototype has a microcontroller (Arduino mini with ATmega 328) and a light sensor (LDR) to measure the 'dawn of the day', both inserted in the brush's handle. A compass module (Honeywell HMC6343) determining direction and a battery for power are mounted on the back of the body as shown in Figure 5.3a. The circuit diagram delineating the connection of the hardware components is shown in Figure 5.5.

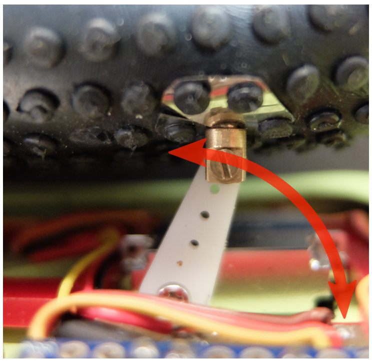


Figure 5.4: Servo arm mounted to the rubber.

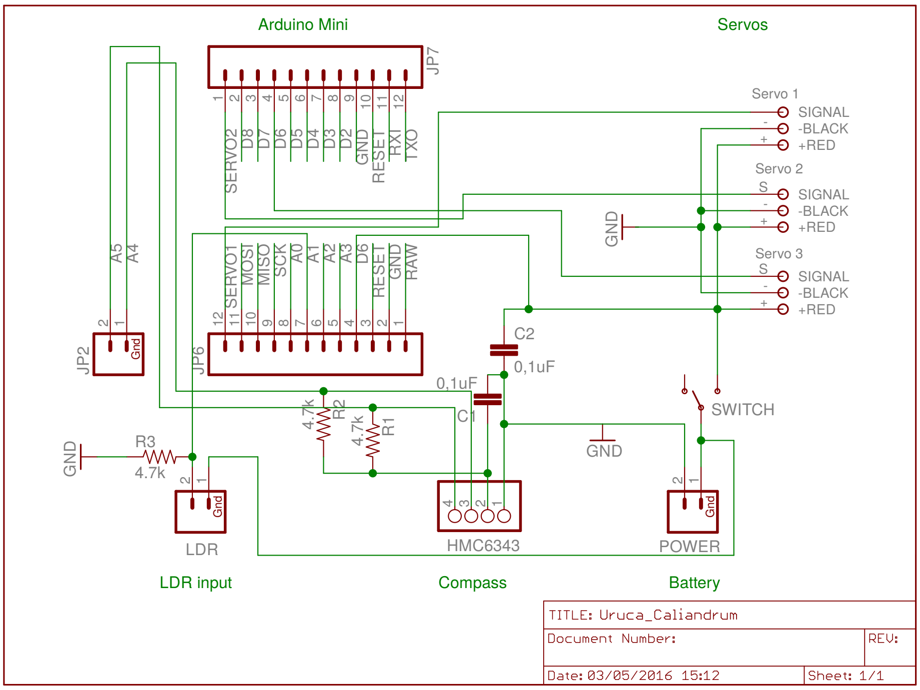


Figure 5.5: Schematic of the electronic parts employed for both prototypes of the hairbrush. Image by the author.

THE SOFTWARE in this electronic device controls the behaviour and provides this everyday object with the ability to swap the functionality between hairbrush and robot. The software is programmed in the Arduino IDE[8] and is set up to manage the object's switch between a regular hairbrush (idle-mode) and a robotic creature (active-mode). The brush switches from idle to active-mode at the dawn of the day (dawn

8 https://www.arduino.cc/en/Main/Software (accessed September 2017).

light measured by the LDE) and vice versa when the brush has placed itself in the correct position orienting towards sunrise (east measured by the compass). Active-mode combines the different functionalities of locomotion, the actuation of the motors, position reading of the compass, and light sensing, as well as a watchdog, the control for sending the micro-controller into sleep or idle-mode to save energy while it is used as a regular hairbrush.

Conclusion

Inspired by biology and the architecture of soft robots, a new form of robot based on an everyday object was developed. One of the key aspects of this first prototype is the combination of the flexible part with the rigid skeleton/structure of the body's hairbrush to generate locomotion in a certain direction. However, the direction is influenced by the imperfection of the whole mechanical system, e. g.the imbalance of the components placed inside and outside the body, and this prototype showed signs of fatigue over the course of its usage.

But ultimately, this first prototype was a proof of concept on two levels. First, the morpho-functionality of switching between a regular hairbrush and a robotic creature: the brush starts crawling and move towards its goal, the sunrise, or, technically speaking, the range of the compass where east is located, and then stops, becoming an everyday object again. Second, people's wide-ranging interpretations of the hairbrush's metamorphosis during the exhibition of this prototype, as reported in the introduction Section 1.2, provided the motivation for this thesis and the development of the second prototype.

5.1.3 *Second Prototype*

In respect to the study described in the next Section 5.2, the aim for the second prototype was to make improvements of the design on two levels. First, in its behaviour, to improve the locomotion system on a mechanical and software level by introducing a pulley system to provide more durability but also a finer control of the movement pattern concomitant with different locomotions. Second, in its morphology, to omit indications of the technological modifications so that the hairbrush appears more like an everyday object.

Behaviour

To overcome the problems of the first version's mechanical fatigue, in particular the problem caused by using servo motors with servo arms, prototyping was carried out to improve the connection between the motors and the rubber. The servo arm applies the power in two directions to the rubber due to its angled position. The arm pulls the rubber as desired up and down (on a vertical y-axis) while at the same time pulling horizontally on the x-axis (see red arrow in Figure 5.4. This resulted in tearing and wearing out of the fixture of the motors to the case as well as the fixture of the servo-arms onto the rubber. Different tests and prototypes resulted in the development of a pulley system using flexible strings instead of rigid servo arms as shown in Figure 5.6). The main advantage of this solution is that the power is applied only in one direction, the prime movement going up and down (see red arrow in Figure 5.6), and thus the wearing out of the material could be reduced significantly. Additionally this solution allows much more stability and finer control of the points of contact on the rubber, which drive the propulsive movement. The solution using the flexible strings and the pulleys provided more durability in terms of stamina but also in terms of fixation to the crucial points in the rubber. Both together allow a finer control of movement pattern concomitant with different locomotions as envisaged for the subsequent study.

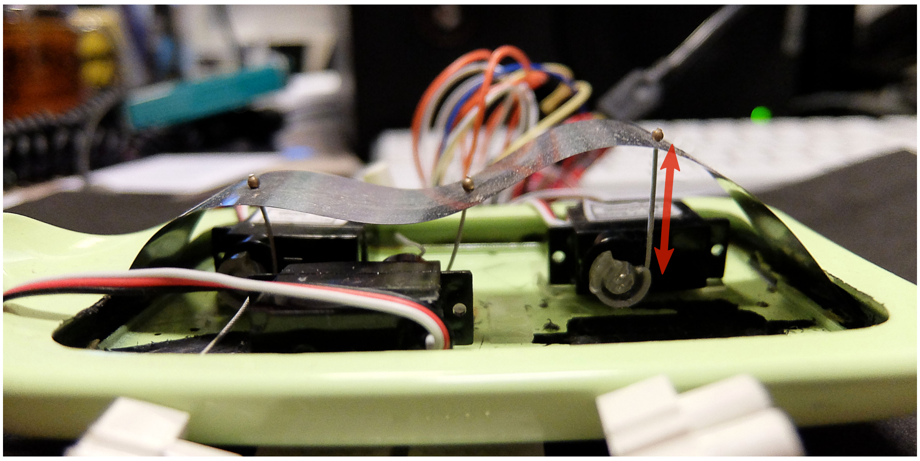
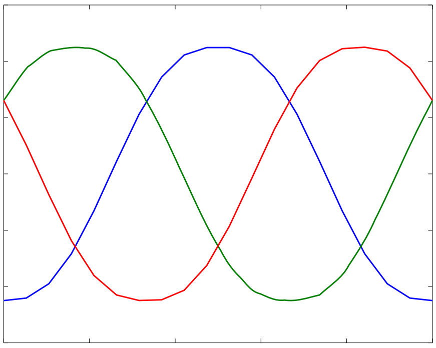
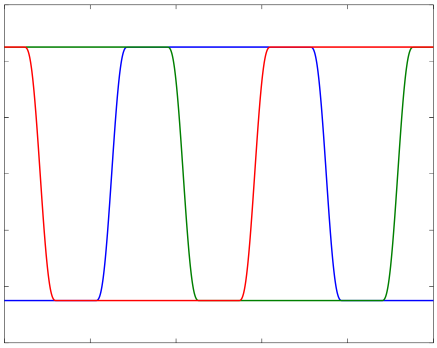


Figure 5.6: Prototyping the pulley system employing three servo motors with strings attached to the rubber (here substituted by sheet metal for an endurance test) to generate the propulsive movement. This locomotion mechanism using pulleys and strings became part of the second prototype. Image by the author.

The aim for the study described below in Section 5.2 was to generate different movements with the same entity. This rationale build on previous work (see Section 4.3) looking at differences between people's interpretation of entities represented with or without movement. Thus the particular focus of the study is on shifts in people's interpretation of an entity evoked by two different forms of movement. To carry this out, the two different movement patterns shown in Figure 5.7 were applied to control the actuators. Each of the three servo motors, controlled by a different phase of the pattern, resulted in the locomotion of the hairbrush in two different ways: a continuous pattern representative for organic and biological movement and a discrete pattern modelling mechanical movement.



(a) Continous minimum-jerk pattern representative for organic or biological movement.



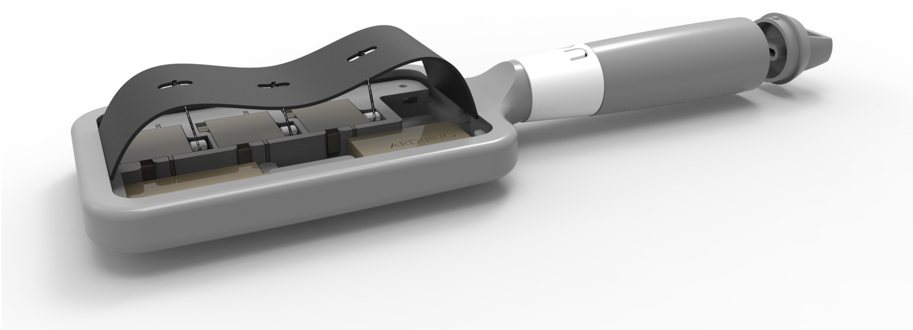
(b) Discreet fixed-stop or bang-bang pattern modelling mechanical movement.

Figure 5.7: Different movement patterns used to control the three different servo motors for the second prototype. The three different colors represent the three servos and show the phase shift between them to generate the locomotion. Both images by the author.

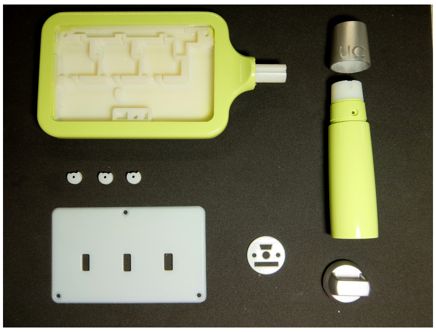
Furthermore the morphology of the hairbrush was altered. In contrast to the first prototype, the aim was to make it appear like a regular hairbrush by removing all signs of technological modification. This was done to facilitate the goal of the subsequent study: to investigate the effect of different movement patterns, applied to the same everyday object, on the way they affect people's interpretations of it.

Morphology

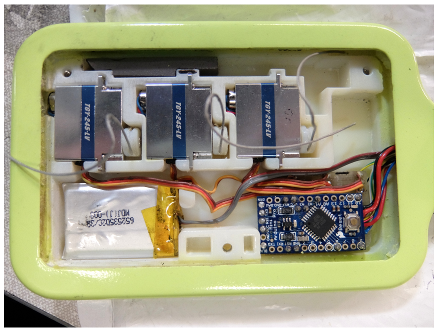
In terms of the morphology, the goal for the second version was to hide all the indications for the brush's morphological capabilities so it looked like a ready-made hairbrush. To achieve this another brush with a bigger cavity was used to integrate all the electronic parts. Following a longer investigation into the morphology of hairbrushes, a so-called paddle brush, found at *Pak's*, a speciality shop for hair and cosmetics located on Kingsland Road in London, seemed to be a candidate for the targeted improvements. The hollow handle and the large cavity underneath the rubber provided enough space to place the components inside. Unfortunately, running tests with this brush revealed signs of fatigue due to the softness of the casing's plastic, resulting in the motors loosening or even ripping out. This significantly reduced locomotion.



(a) Screenshot of the 3D model with the three servo motors with pulleys and strings attached to the rubber employed to generate the locomotion.



(b) 3D printed parts, varnished and ready to assemble.



(c) Assembled casing with the servo motors, battery and microcontroller.

Figure 5.8: Development of the 3D model for the second prototype of the hairbrush at various stages. Image 5.8a by Patrick Stieger, published with his permission. Images 5.8b and 5.8c by the author.

To achieve a more sustainable solution a 3D-model was designed and manufactured. A 3D-model of the brush was created, as shown in Figure 5.8a, with slots for all the parts as well as the pulley system for bending the rubber. The final 3D-model was printed, painted with filler, sanded and finally coloured with varnish resulting in the individual parts shown in Figure 5.8b. The assembled casing, with the battery, micro-controller and the three servo motors with the pulleys and the strings to be attached to the rubber, is shown in Figure 5.8c. The same hardware was used in the first prototype (see Figure 5.5). However, this time the light sensor to measure the 'dawn of the day' and the compass module to determine the orientation were inserted in the brush's handle. The parts mounted in the designated spots as shown in Figure 5.8 provided stability and a rigid structure. The final version shown in Figure 5.9 looked identical to the purchased paddle brush and showed no sign of its morpho-functionality.

Figure 5.9: The subject of the empirical study: the second prototype of the technologically modified hairbrush with inconspicuous morpho-functionality. Image by Bruce Horak, published with his permission.

Conclusion for the Prototypes

In conclusion the process of building two working prototypes and applying principles of bio-inspired robotics guided the construction of a novel type of robot with a non-anthropomorphic/zoomorphic/mechanoid morphology. The particular morphology of this everyday object is considered as an ideal candidate for the subsequent study for two reasons. First, it allows to study differences in people's interpretation of an everyday object that lacks any human, animal or machine-like appearance and as such provides a particular focus for the effect of movement alone. Second, applying continuous or discrete movement patterns, the former modelling biological and the latter mechanical movement, provides the basis for the subsequent study assessing differences in people's interpretation evoked by different forms of movement.

5.2 EMPIRICAL STUDY

This section presents an empirical study examining two forms of movement applied to an artefact, a ready-made robotic object described in the Section 5.1, and how its movement affects people's interpretation of it. To study this the methodology outlined in Chapter 4 is employed.

The subject of the study is an everyday object of a hairbrush that is technologically modified to move in two different ways, either with a continuous biological or a discrete mechanical movement, as described in the previous Section 5.1.3. The study is using the feature-space set-out in Section 4.2 and informed by *Study A*, and in congruence to *Study B* carried out in Section 4.3 examines the effect of movement. However, in contrast to *Study B* the objective here is twofold. The first is to investigate possible shifts in participants' affiliation to an entity in response to different forms of movement. The second goal is to validate the methodology in a real-world scenario which provides, in contrast to screen-based approaches, further ecological validity. In addition, the inferential methods described in Section A.2 are deployed to provide a statistical estimate of the results.

5.2.1 *Aim of the Study*

Following from Heider and Simmel's (1944) seminal work showing that movement of non-anthropomorphic objects like triangles and dots are predominantly interpreted in social terminology as actions of animate beings, the focus of the present work is differences in the interpretation of a non-anthropomorphic/zoomorphic/mechanoid object elicited by movement. In contrast to their work, and subsequent screen-based work with animated objects, as surveyed in the related work Section 3.2 , this study comprises a real-world scenario resembling a human-robot interaction with a ready-made object that moves autonomously. The present work explores how movement, in particular different types of organic and mechanical movement patterns, applied to a non-humanoid robot, here a technologically modified hairbrush, affects participants' interpretative relationship to the object.

Humans' intuitive process of categorising and attributing characteristics as a dialogue and understanding of things, as found in the concept of metaphor described in Section 2.2.1, is central to the method. Drawing from the linguistic concept of animacy described in Section 2.2.3, which expresses how sentient or alive an entity is interpreted as being, the study investigates whether conceptual boundaries of entities, like those between human and non-human, change when movement comes into play. Differences in the degree to which features are attributed is considered to provide indications of divergence in the way participants interpret the hairbrush's behaviour.

5.2.2 *Design of the Study*

To explore differences in subjects' interpretations using the methodology described in Chapter 4, a between-subject study based on one variable with three conditions was developed. The study was set up as a 'design study' asking participants to participate in design research involving assigning packaging labels to five different hairbrushes placed on a table, as shown in Figure 5.10. The three experimental conditions are determined by applying either of the two movement patterns, biological or mechanical, or no movement pattern, to one of the hairbrushes. The three conditions where equally distributed over the participants. The study's procedure is described below.

Procedure

Participants were asked to take part in a design research study which comprises attributing labels to objects. The participants were presented with a table on which five different types of packaging labels, a cardboard box covering five different hairbrushes and five areas marked with a grey circle, designated for the label assignment task, were placed. The set-up, with the cardboard box removed, is shown in Figure 5.10. After an introduction and signing the informed consent form, participants were invited to engage in a design study consisting of two parts.

Figure 5.10: Study set-up inviting participants to assign labels to the brushes. Image by the author.

THE FIRST PART comprised the label assignment task. As soon as the instructor left the room they were asked to remove the cardboard box and spend about two minutes assigning the packaging labels intuitively to the brushes they thought corresponded best. This step was less to have participants find the right label for the brushes but rather to have participants examine, touch and to establish an initial relationship with the objects (Sung et al., 2007). In the case of the two movement groups, the brush was programmed to start moving after about 15 seconds in either of the three conditions and kept on doing so until the end of the study. After about two minutes the instructor returned with the request to move on to the second part of the study.

THE SECOND PART participants were invited to attribute a set of 23 features, the feature-space developed in Section 4.2, on a Likert scale in response to the question "To what extent is each of the attributes below applicable to the green hairbrush?" The scale ranged from 0-6 with three anchor points: 0 for "Not at all", 3 for "Undecided" and 6 for "Very Much". After rating the features, participants were invited to "Describe the experience of the green brush in a couple of sentences", and finally, to fill in demographic data featuring age, occupation and gender.

This study design was approved by Queen Mary University of London's ethics committee. The participants provided their informed consent before participating in the study and were briefed that they could withdraw at any stage of the study. After completion of the study, participants were debriefed and thanked.

5.2.3 *Evaluation*

Participants' interpretation of the hairbrush was evaluated in two steps. First, in line with Section 4.3, participants feature attributions were projected into the feature-space developed in the methodology Section 4.2. Using this metric, results were obtained graphically as well as numerically. The results represent differences in the interpretations resulting from the three movement conditions of the hairbrush in relation to the previously determined regions representative of humans, animals and machines. The use of statistics in this part is interpretative and not inferential. A second step provides further validation of the results using inferential statistics. This is approached by first determining significant features from the feature-set following the process described in Section A.2.1, and second, using factor analysis as described in Section A.2.2. An exploratory use of factor analysis i) provides an interpretation of the results that is more parsimonious, facilitating easier interpretation, and ii) allows for statistical inference of the findings.

The Participants

There were 65 participants out of which the answers of $k = 59$ could be used. Two participants had to leave during the study and a further four were removed because they acknowledged during or after the study that they were primed by a third source. The study procedure took approximately 10 minutes per participant and was run in two locations in London, UK, the Victoria & Albert Museum and the Computer Science building of Queen Mary University. 64% of the 59 participants identified themselves as male and 36% as female, with an age range of 47% between 26-34, 29% between 18-25, 22% between 35-54 years, and 2% between 55-64 years of age.

Applying the Methodology

To compare the attribution of features to different movement conditions of the hairbrush, the feature-space developed in the methodology Section 4.2 was used. The feature-space was obtained from people's ratings of features in respect to depictions of either humans, animals or machines (*Study A* with $k = 93$ described in Section 4.2). It consists of designated regions of features representative for the categories of humans, animals and machines as shown in Figure 4.2. Because the same set of features were used, participants' interpretation of the hairbrush under the three movement conditions could be projected into the feature-space. The methodology for computing the subjective responses uses the findings from *Study A*, the reduced and calibrated feature-space, to compare participants' responses to the hairbrush under the different conditions.

THE THREE STEP PROCEDURE from the methodology Section 4.3 is applied and carried out as follows.
Step 1, collecting the data: individuals' interpretation of the hairbrush using the feature-set in respect to the three movement conditions — none, biological and mechanical movement — were gathered.
Step 2, processing the data: participants' ratings of the hairbrush under the different movement conditions were projected into the feature-space. Using Equation 4.2 clusters of individual interpretations and their mean-interpretations (centroids) were allocated in relation to the

regions for the given categories (humans, animals and machines). In addition, Equation 4.3 was applied to calculate the displacement of typicality for each movement condition in respect to humans, animals and machines.

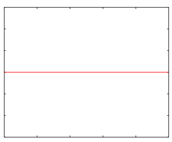
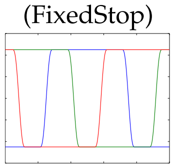
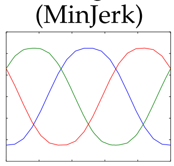
Step 3, measuring the effect of movement: the difference between the interpretations of the static, mechanical and biological movement were calculated. Equation 4.4 was employed to calculate the divergence in distance resulting from subtracting the typicality of the static ($\hat{F}_{none}$) from the two dynamic ($\hat{F}_{mechanical}$, $\hat{F}_{biological}$).

Following these three steps, the differences in participants' interpretation of the hairbrush as an effect of the three conditions were calculated and the following results obtained.

Results in the Feature-space

Based on the procedure using the measurement tool, the feature-space, results were obtained showing differences between the three movement conditions on two levels. On the one hand visually, as shown in Figure 5.11, by projecting the results into the feature-space and applying principal component analysis. On the other hand numerically, listed in Table 5.1 using geometrical computation of the mean interpretations for each condition and contrasting them.

Table 5.1: Study results showing the distances between the mean interpretation of the three movement conditions in relation to humans, animals and machines.

Movement	None	Mechanical (FixedStop)	Biological (MinJerk)
			
k =	20	20	19
Distance	$\hat{F}_{none}$	$\hat{F}_{mechanical}$	$\hat{F}_{biological}$
to human	3.06	2.48	2.28
to animal	2.73	2.38	2.16
to machine	1.51	2.28	2.26
Distance between		$d(\hat{F}_{none}, \hat{F}_{mechanical})$	$d(\hat{F}_{none}, \hat{F}_{biological})$
to human		-0.58	-0.78
to animal		-0.36	-0.57
to machine		0.77	0.75

The results indicate a shift in interpretations from the non-moving to the two moving conditions closer to humans and animals and further away from machines. In addition they reveal a minor difference between the two moving conditions. The interpretations of the biological movement in comparison to the mechanical movement are slightly closer to humans and animals. The typicality of the biologically moving is interpreted with a shift towards humans (−0.78) and animals (−0.57) in respect to the non-moving, while the distance to machines (0.75) increases. The same is applicable to the interpretation of the mechanical movement. Here, slightly less than in the biological condition, the distance to humans (−0.58) as well as animals (−0.36) decreases in respect to the non-moving, while the distance to machines increases (0.77) slightly in contrast to the biological condition.

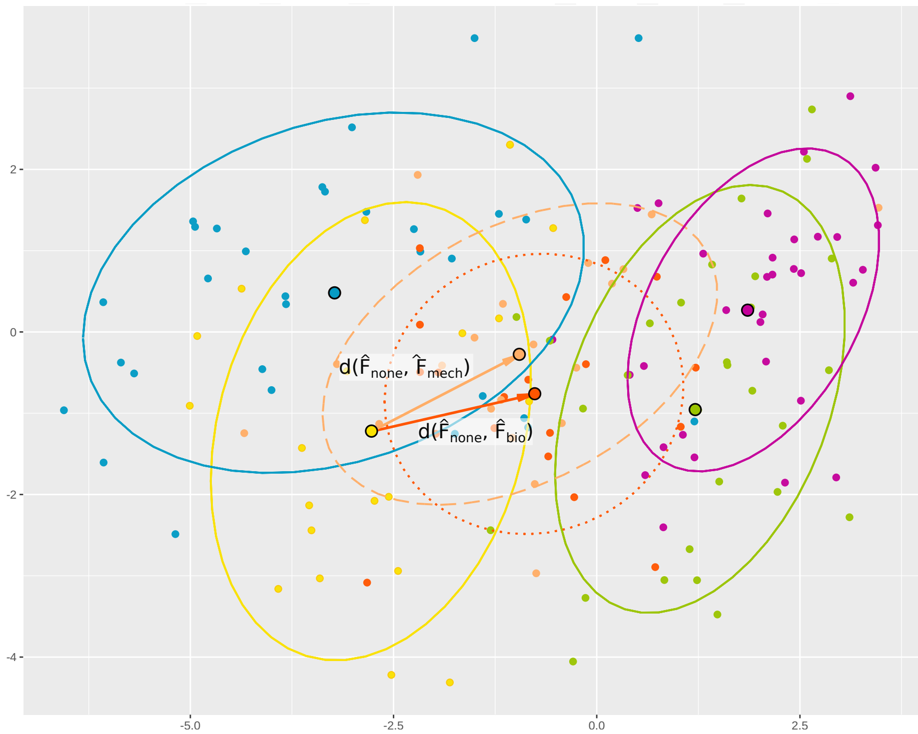


Figure 5.11: Study result based on the first two principal components, showing the displacement of the two movement patterns — biological (orange-dotted) and mechanical (pale-streaky) — in relation to the non-moving (yellow-continuous) within the designated regions attributed to humans (magenta), animals (green) and machines (blue). With the individual normal probability ellipsoids and centroids (circled in black) representing mean-interpretations.

IN CONCLUSION, results obtained from applying the procedure deployed in the methodology Chapter 4 illustrate differences in participants' interpretative relationship to an object as affected by movement. Principal Component Analysis (PCA) is used to understand the geometrical space in terms of individual dimensions and to visualise specific 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 to 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.

In this process the use of statistics is interpretative and not inferential. To provide further validity to the result an initial analysis was employed.

Further Validation Using Inferential Statistics

This section employs the methods described in Section A.2.1. The purpose is to add further validity to the results from the feature-space by using inferential statistics to assess how the three movement conditions affected participants' interpretations.

Participants' responses were given on a Likert (ordinal) scale and preliminary exploratory analysis indicated non-normality of the data. Due to these two factors, and following Bryman and Cramer (2002) and Field et al. (2012) the two non-parametric methods described in Section A.2.1 were selected for the analysis. This comprises, first, the Kruskal-Wallis test outlined in Section A.2.1.1 to indicate significance for the individual feature, and second, the post-hoc analysis described in Section A.2.1.2, to find significant differences between the movement conditions on that individual feature.

During the Kruskal-Wallis analysis, a test on each of the 23 features identified 15 significant features: 10 features with a significant difference of $p < .01$ and another five with $p < .05$. These are features with significant differences between the three movement conditions. The second, post-hoc analysis, determines the significance of individual features within the movement condition. The significance in respect of each individual movement condition culminated to 25 significantly contrasting features within the movement conditions and an additional 6 showing a trend with $p < .10$ (see appendix Table A.4 for the results for all 23 feature ratings).

FINALLY, applying both steps indicated the significance of individual features. However, these tests not only lead to an overwhelming amount of significant features but also fail to provide any inferential information about the overall shifts between the static and dynamic conditions across all features of the feature-space. To examine the feature-set in its entirety an exploratory use of factor analysis was employed.

Factor Analysis

The subsequent factor analysis follows the procedure laid out in Section A.2.2. This comprises five steps.
Step I, carry out a preliminary analysis to assess the suitability of the data for factor analysis.
Step II, specify the type of analysis and method of extraction.
Step III, determine the number of factors to retain from the data.
Step IV, extract and validate the factors.
Step V, rotate the factors to facilitate the subsequent interpretation.

The objective of the factor analysis carried out below is to provide parsimony and subsequent statistical validity of the result. The objective is to first reduce the feature set down to a smaller number of factors by clustering features of similar dimensions into factors, and second to create composite scores for these factors to be used in the subsequent statistical analysis.

STEP I: PRELIMINARY ANALYSIS OF THE DATA. To find out if the data is suitable for factor analysis, the *factorability* of the 23 features was examined. Ensuing from the procedure delineated in Section A.2.2.1 the following well-recognised criteria for the factorability were used.

- Firstly, it was observed from the correlation matrix that 18 of the 23 items correlated at least 0.3 with at least one other item suggesting a reasonable factorability (The output of the full correlation matrix is found in appendix Table A.5). Regarding the sample size, a total of $k = 59$ participants is at the bottom of the scale provided on page 162. However, having about 20 participants per variable is above the 10-15 rule of thumb and other elements, like the amount of factors grouped together (four or more loadings) and their communalities (greater than 0.6), are considered after factorising the matrix.

- Secondly, the *Kaiser-Meyer-Olkin measure of sampling adequacy* (MSA) for the data was 0.66 with all 23 features. According to the practice of removing items that are considerably below the suggested 0.5 margin, described on page 155, the features "Caring" and "Synthetic", showing individual KMO values of 0.39 and 0.31 respectively, were removed. This resulted in a MSA of 0.74 for the remaining 21 features and following the index on page 155 considered to be 'good'.

- Thirdly, *Bartlett's test of sphericity* returns a significant result, $\chi^2(253) = 633.77, p < .001$ indicating that correlations between the items are high enough. The determinants with $1.4e-05$ above the $1.0e-05$ threshold indicate that the correlations are not too high either.

Given these overall indicators, factor analysis was deemed to be suitable with 21 of 23 features.

STEP II: TYPE OF FACTOR ANALYSIS AND METHOD OF EXTRACTION. Section A.2.2.2 lists various types of factor analysis and methods for extraction.

- The factor analysis carried out here is exploratory in nature. In contrast to confirmatory factor analysis, the aim is not hypothesis testing and validating whether the data fits a model, but rather to explore and develop a parsimonious (simple) analysis and interpretation of the data.

- The principal component method was selected to extract the factors. This is due to the objective to first reduce the feature set down to a smaller number of factors, and second to create composite scores for these factors for use in subsequent statistical analysis. The assumption that the differences in the extraction method techniques are negligible, as reviewed in Section A.2.2.2, are proved by the results of different extraction methods. The application of both extraction methods, principal component analysis (PCA) and principal axis factoring (PAF) show identical outcomes in terms of variable clustering (see appendix Table A.8).

An explanatory factor analysis based on the principal component method is carried out. The next step is to look at how much factors to retain.

STEP III: HOW MANY FACTORS TO BE RETAINED. Section A.2.2.3 lists two common methods to resolve the amount of factors to be preserved. Both the *Kaiser's criterion* and the *Scree-test* provide criteria for how many factors to keep. Both are based on the eigenvalues from the previously computed *correlation matrix* (see in appendix Table A.5). A scree-plot of the eigenvalues shown in Figure 5.12 illustrates the relative importance of each factor within the data.

- Based on the *Kaiser's criterion* the first 6 components (or factors) have eigenvalues with a magnitude > 1.0, suggesting to extract 6 components based on Kaiser's criterion.
- Applying the *scree-test*, the shape of the curve suggests a point of inflexion between the third and forth factor and another between the sixth and the seventh.

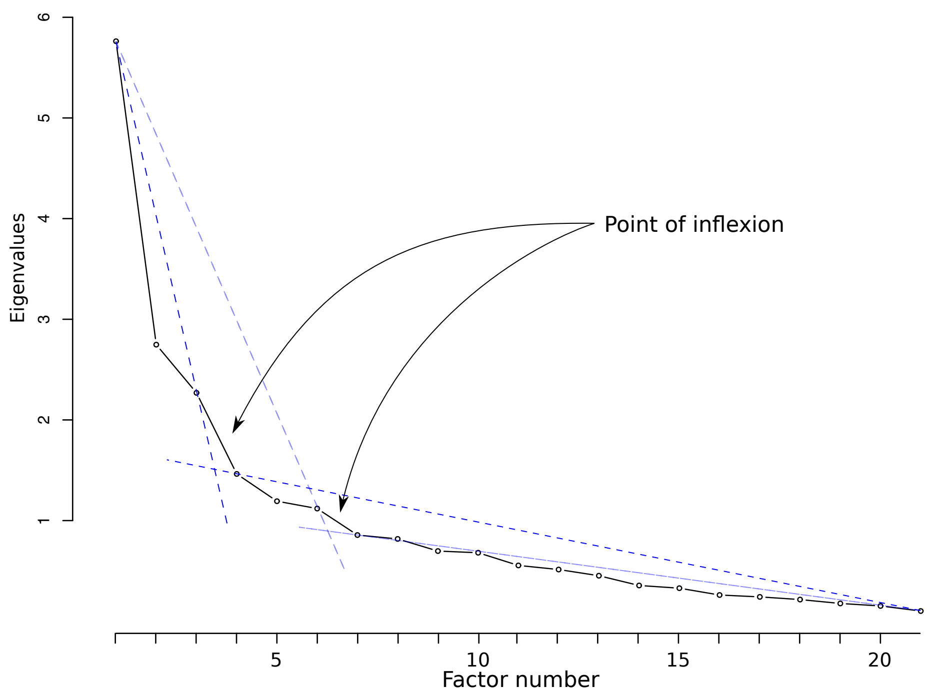


Figure 5.12: Scree-plot of the eigenvalues with the point of inflexion indicating the amount of factors to be retained.

Consequently the number of factors to be retained is considered to be either 3 or 6. It is common to find more than one solution, which makes it difficult to determine how many factors fit the data best. Field et al. (2012), following Zwick and Velicer (1986), point out that there is no objective definition of the cut-off point between the important and trivial factors. As indicated by Yong and Pearce (2013), "[o]ne usually conducts the analysis on several solutions with more or fewer factors, and chooses the one that makes the best 'sense."' Following the suggestion of Field et al. (2012, p. 782), this is addressed by conducting the analysis on both number of factors and comparing the results. This is carried out in the following paragraph.

STEP IV: EXTRACTION OF FACTORS. The previous analysis returned two measurement alternatives for the numbers of factors to be retained. In this step a model for both is generated and compared to determine how many factors should be retained. Following the procedure delineated in Section A.2.2.4, this comprises specifying the cut-off point for the factor loading then comparing the criteria for validating the amount of factors to specify what the most appropriate number of factors should be.

The cut-off value for the factor loadings is determined by considering the sample size and the uniqueness of factor loadings.

- In respect to the sample size of ~60, following from the Table A.3, the suggested corresponding cut-off is 0.7. Applying this cut-off to the data isolates the remaining amount of features to be significant to four which is insufficient for subsequent analysis.
- Analysing the values in terms of their uniqueness, a cut-off value for the factor loadings of $|0.5|$ would insure that items were clearly related to the factor. This cut-off is situated between the 0.45 considered as fair and 0.55 considered as good and is commonly used in other HRI studies e. g. Carpinella et al. (2017). Requiring a loading to be 0.50 is asking that 25% of the variance on the item be shared with the factor, which is relatively stringent.

A cut-off value of $|0.5|$ for the uniqueness of the features was used. Applying this cut-off to the data using the model for extracting factors, as defined in Equation A.6, returns a model of the correlation matrix created with three factors as shown in Table 5.2 (full output of the model in the appendix section on page 170). Correspondingly the six-factor model of the correlation matrix is presented in Table 5.3 (full output of the model in the appendix section on page 171).

The two factor solutions are compared using the three criteria described in Section A.2.2.4. These are Kaiser's criteria, the residuals and cumulative proportions of variance.

For the three-factor model:

- *Kaiser's criteria* with 21 variables or features results in an average communality (h2 column) of 0.51 and none of the features have a communality above 0.7.
- In terms of the residuals resulting from the difference between the fitted and the original model, the measure of the fit of the

Table 5.2: R output for the three-factor model based upon the correlation matrix with factor loadings (0.50 cut-off) and the communalities (h2).

	PC1	PC2	PC3	h2
Creative	0.79			0.64
Spontaneous	0.78			0.68
Aware	0.76			0.63
Sentient	0.72			0.55
Sociable	0.69			0.57
Devious	0.66			0.60
Creepy	0.63			0.65
Complex	0.60			0.55
Controllable	-0.58			0.37
Spiritless	-0.49			0.44
Sympathetic				0.44
Sensitive				0.18
Goal.driven		0.63		0.58
Aggressive		0.57		0.67
Logical		0.56		0.55
Productive		0.55		0.45
Instrumental		0.52		0.49
Lonely				0.36
Clunky				0.57
Organic			0.58	0.35
Efficient				0.49

	PC1	PC2	PC3
SS loadings	5.77	2.75	2.27
Proportion Var	0.27	0.13	0.11
Cumulative Var	0.27	0.41	0.51
Proportion Explained	0.53	0.25	0.21
Cumulative Proportion	0.53	0.79	1.00

three-factor model is 0.91 and the proportion of residuals above 0.05 is 53%.

- The cumulative proportion of variance adds up to 51% for all three factors.

(See full output of the model in the appendix on page 170 for reference.)

For the six-factor model:

- In respect to the *Kaiser's criteria* the communalities (h2 column) of 12 features are above 0.7 with an average of 0.69.
- A measure of the fit of the model is 0.96 and proportion of residuals above 0.05 is 40%.
- The cumulative proportion of variance sums up to 69% for all six factors.

(See full output of the model in the appendix on page 171 for reference.)

In conclusion, for both measurement in respect to *Kaiser's criteria*, the sample size of $k = 59$ is well below the suggested 250. However, the

Table 5.3: R output for the six-factor model with a cut-off of 0.50 for the factor loadings based upon the correlation matrix and the communalities (h2).

	PC1	PC2	PC3	PC4	PC5	PC6	h2
Creative	0.79						0.79
Spontaneous	0.78						0.75
Aware	0.76						0.83
Sentient	0.72						0.67
Sociable	0.69						0.70
Devious	0.66						0.62
Creepy	0.63						0.74
Complex	0.60					0.50	0.86
Controllable	-0.58						0.70
Spiritless	-0.49						0.77
Sympathetic							0.49
Goal.driven		0.63					0.70
Aggressive		0.57					0.72
Logical		0.56					0.76
Productive		0.55					0.67
Instrumental		0.52					0.63
Lonely							0.42
Clunky							0.60
Sensitive				0.61			0.66
Organic			0.58		0.59		0.76
Efficient							0.72

	PC1	PC2	PC3	PC4	PC5	PC6
SS loadings	5.77	2.75	2.27	1.47	1.19	1.12
Proportion Var	0.27	0.13	0.11	0.07	0.06	0.05
Cumulative Var	0.27	0.41	0.51	0.58	0.64	0.69
Proportion Explained	0.40	0.19	0.16	0.10	0.08	0.08
Cumulative Proportion	0.40	0.58	0.74	0.84	0.92	1.00

six factor model returns 12 features with communalities above the suggested 0.7 and above the suggested average of 0.6. The average communality for the three-factor model at 0.51 only approximately fulfils this criterion. The fit of the three-factor solution is fairly close to the suggested 0.90 and above in the six-factor solution. Correspondingly the proportion of residuals above 0.05 is reasonably close to or lower than the recommended threshold of 50%. In terms of variance explained, the three-factor model explains 51% while the additional three factors in the six-factor model add another 18% resulting in 69%.

The evidence from the *Kaiser's criterion* suggests a six-component solution may be better, as the version with six factors reasonably fulfils the requirements for communality levels. However, as noted in Section A.2.2.3, *Kaiser's criterion* often overestimates the number of factors. The other criteria of the fit of the model and the proportion of its residuals are reasonably fulfilled by both models. The decision about numbers of factors is additionally aided by examining the results of the two models derived from the correlation matrix. In the six-factor model, four of six factors were represented by just one feature per each factor with loadings higher than 0.5. Additionally two features reveal cross-load on two factors. As indicated by referring to Tabachnick and Fidell (2007), for something to be identified as a factor it should assemble at least three features or variables.[9]

Based on these insights and the motivation to reduce the number of features to a minimum, the three-factor solution is considered appropriate. In addition, the cumulative variance of 51% for this solution is reasonably high and within the generally accepted range for studies involving humans.

As a next and final step, the matrix of the factor solution is rotated to facilitate the subsequent interpretation of the factors.

STEP V: ROTATING AND INTERPRETING THE FACTORS. In according with the fifth step, detailed in Section A.2.2.5, here the three-factor solution obtained from the previous steps is first rotated to enhance the interpretation. Its reliability is then measured and lastly the factors are interpreted and labelled.

Factor rotation is executed with a factor oblique rotation method to aid interpretation. The oblique rotation is chosen over the orthogonal due to the evidence, explained in the Section A.2.2.5, that it often produces more accurate results for research involving human behaviours. The output of the pattern matrix using oblique rotation for the three-factor model is presented in Table 5.4. A graphical representation of the factor loadings for the three-factor solution is shown in Figure 5.13.

The rotation of the factor structure revealed three factors with four to eight features loading onto each of them and four features excluded as they did not emerge as strong constructs. Subsequently reliability estimates for each factor were obtained as a measure of each factor's consistency.

Factor reliability measures were carried out following the procedure listed in Section A.2.2.5. *Cronbach's alpha*, a measure of consistency for each factor, was computed to determine the reliability of the previously acquired result from the factor rotation.

The results in Table 5.4 show that two of the features correlated negatively on the first factor. On the occasion that variables or items have a negative correlation in a factor Field et al. (2012, p. 804) advise to reverse score the item before the reliability analysis. This includes also

9 This applies to a rotated factor solution. A rotation of the six-factor solution results in two factors with two features and two factors with three features, with one of them cross-loading. See output in appendix on page 174.

Table 5.4: R output of the pattern matrix with oblique rotation for the three-factor model with a cut-off of .50 for the factor loadings.

	RC1	RC3	RC2	h2
Clunky	-0.77			0.57
Spontaneous	0.75			0.68
Aware	0.71			0.63
Sympathetic	0.69			0.44
Sociable	0.69			0.57
Sentient	0.64			0.55
Creative	0.64			0.64
Spiritless	-0.58			0.44
Sensitive				0.18
Aggressive		0.84		0.67
Creepy		0.78		0.65
Complex		0.71		0.55
Devious		0.70		0.60
Lonely				0.36
Organic				0.35
Controllable				0.37
Goal.driven			0.71	0.58
Logical			0.68	0.55
Productive			0.67	0.45
Instrumental			0.63	0.49
Efficient			0.55	0.49

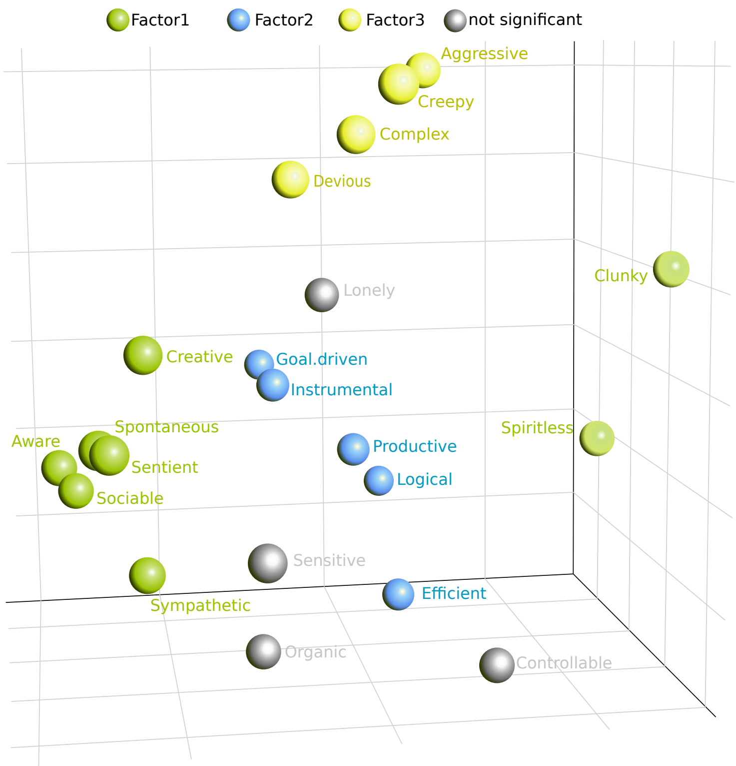


Figure 5.13: Geometrical representation of the factor loadings with a three-factor solution.

reversing the direction of the phrasing of the item or feature when interpreting the factors.

The first factor returned an α-value of 0.86 (the full output of *Cronbach's alpha* calculation for this factor consisting of eight features, with two of them reverse-scored, can be found in the appendix on page 175). For the second factor consisting of five features an α-value of 0.68 is returned (see appendix Table A.12 for full output), and for factor three with four underlying features, the reliability measure is 0.82 (see appendix Table A.13 for full output). In the final analysis, the result for the first and the third factor are above 0.8, thus certainly in the region considered as good reliability. The α-value for the second factor is lower but still, as set out in Section A.2.2.5, within the range to be expected for this kind of social science.

Nonetheless, the output of the second factors' reliability calculation was analysed based on the output shown in Table 5.5. To that effect Field et al. (2012, p. 801) propose looking at two measurements to specify particular features' contribution to the reliability of the factor and identify possible irregularities. The first is the effect of an item to the

Table 5.5: Abbreviated R output for reliability measurement based on Cronbach's alpha calculation for the second factor.

```
Reliability analysis
Call: psych::alpha(x = features.factor2[, 1:5])

  raw_alpha  std.alpha  G6(smc)  average_r  S/N   ase  mean   sd
       0.68       0.68      0.7        0.3  2.2  0.066  4.1  1.1

 lower  alpha  upper     95% confidence boundaries
  0.55   0.68   0.81

 Reliability if an item is dropped:
             raw_alpha  std.alpha  G6(smc)  average_r  S/N  alpha se
Instrumental      0.64       0.64     0.61       0.31  1.8     0.076
Efficient         0.65       0.65     0.64       0.31  1.8     0.075
Goal.driven       0.62       0.62     0.59       0.29  1.6     0.082
Logical           0.62       0.62     0.58       0.29  1.7     0.081
Productive        0.63       0.63     0.63       0.30  1.7     0.079

 Item statistics
              n  raw.r  std.r  r.cor  r.drop  mean   sd
Instrumental  59   0.64   0.65   0.54    0.41   4.3  1.6
Efficient     59   0.63   0.64   0.50    0.40   4.3  1.5
Goal.driven   59   0.71   0.68   0.59    0.47   4.3  1.8
Logical       59   0.69   0.68   0.60    0.46   3.6  1.6
Productive    59   0.65   0.67   0.54    0.44   4.0  1.5
```

α-value when that item is removed from the measurement, thus reflecting changes to the outcome without that item. This is represented in the output of values in the column labelled *raw_alpha*, listing the values of α without that item. The second measurement is the correlation of a feature or item with the total scale without that item included, indicating the item's contribution to the internal consistency. This is indicated by the values listed in the column *r.drop*. In respect to the first measurement, Table 5.5 shows that none of the features would increase the reliability if they were deleted because all values in the *raw_alpha* column are smaller than the overall reliability of 0.68. For the second measurement, all the values of *r.drop* are above the 0.3 cut-off, values below which would indicate fairly poor consistency. None of the values break ranks so cannot be identified as a potential problem and qualify for removal.

In conclusion, the factor rotation resulted in a distinct structure with three factors. Two of the factors showed a high reliability and the third had both an α-value and a consistent internal structure within the expected range for research involving humans. The next step is to look at the content of the features that load onto the same factor, interpret them and identify common themes.

Factor interpretations are carried out on the mathematical factors produced by the analysis (see Section A.2.2.5). If the factors represent real-world constructs then common themes among the items, or features that are unique to them, can help identify what the construct might be and name them appropriately. In respect to the three-factor model presented in Table 5.4 the interpretations and common themes are determined as follows:

- The first factor is characterised by the features that load highly on it. These are "Spontaneous" with the highest loading of 0.75, "Aware" with 0.71, "Sympathetic" and "Sociable" (0.69 each), and "Sentient" and "Creative" (0.64 each). Additionally the feature "Clunky" and "Spiritless" load negatively on this factor with -0.77 and -0.58 respectively. As a result of the reverse-scoring of both items carried out during the previously employed reliability test (Section 5.2.3), the two features are reverse-phrased to "Non-Clunky" and "Non-Spiritless". All these items involve active awareness, meaning-making and having motivations and seem to relate to features characterising intentional and animate beings. Therefore this factor was labelled *intentional/animate*.

- In respect to the second factor, "Goal driven" loads highest with 0.71, followed by "Logical" (0.68), "Productive" (0.67), "Instrumental" (0.63) and "Efficient" (0.55). These items implicate emotionless action, automatic and robotic behaviour and seem to relate to inanimate entities e. g. tools and instruments. Therefore this factor was labelled *automatic/inanimate*.

- The third factor contains four loadings, all of which have rather high values, headed by "Aggressive" with a loading of 0.71, followed by "Creepy" (0.78), "Complex" (0.71) and "Devious" (0.7). These features seem to relate to the uncanniness of the experience denoting an encounter with an eerie entity. Therefore this factor was labelled *uncanny/eerie*.

The correlation matrix for the three factor model shown in Table 5.6 indicates that the first factor is unrelated to the second factor (-0.07), likewise the second factor to the third (-0.01). The relatively high correlation of 0.33 between the first and the third factor is conceivably attributable to both factors representing characteristics of life-like entities.

Table 5.6: Correlation matrix for the three-factor model with oblique rotation.

	RC1	RC3	RC2
RC1	1.00	0.33	-0.07
RC3	0.33	1.00	-0.01
RC2	-0.07	-0.01	1.00

Factor Analysis Summary

An exploratory factor analysis based on the principal component method for extraction was conducted on 21 features with oblique rotation.

The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis as good, with an MSA of 0.74. Two features were removed due to individual KMO values below the 0.5 limit. Bartlett's test of sphericity, $\chi^2(253) = 633.77, p < .001$, indicated the correlations between the features were sufficiently high for factor analysis. An analysis to obtain the eigenvalues returned six components with eigenvalues higher than Kaiser's criterion of 1. The scree plot was slightly ambiguous and showed points of inflexion justifying a retention of either six or three factors. With the objective to provide parsimony, and given that the six-factor solution did not have enough features per factor (four of six factors were represented by just one feature per each factor and two features cross-loading on factors), three factors were retained in the final analysis. The explained variance for the three-factor solution of 51% is reasonably high and within the generally accepted range for studies involving humans. Table 5.4 shows the factor loadings after rotation.

The features that cluster on the same factors suggest that the first factor represents an *intentional/animate* interpretation of the hairbrush, the second factor an *automatic/inanimate* and the third factor an *uncanny/eerie* interpretation.

The result obtained from the exploratory factor analysis presents a simple and parsimonious three-factor solution substantiated by several well-recognised criteria. In the following sections this outcome is analysed and validated using inferential statistics carried out by analysing how the three factors are affected by the different movement conditions.

Analyse and Validate the Results by Comparing the Movement Conditions

To analyse and validate the simplified structure produced by the previously carried out factor analysis, and finally to verify the results obtained in the first part, the feature-space analysis, the data is evaluated in terms of differences between the three movement conditions over the three factors. To compare the movement conditions in respect to the factors, two tests are executed in accordance with the methods presented in Section A.2.1. The first test, a Kruskal-Wallis or H-test provides information about the statistical significance of the differences between the three factors. This test is followed by a post-hoc analysis, a Mann-Whitney U test, which consists of pairwise comparisons of the different combinations to reveal significant differences between the conditions for each of the factors.

For the intentional/animate factor, the outcome of the first test $\chi^2(2, 59) = 23.2, p < .0001$, signals significant differences between the movement conditions. The subsequent post-hoc analysis reveals that there are highly significant differences $p < .0001$ between the non-moving and the biological-moving condition as well as between the non-moving and mechanical-moving condition.

The second factor, automatic/inanimate, resulted in $\chi^2(2, 59) = 6.2, p < .046$ for the first test, which is below .05, hence still considered significant but with a smaller effect size. The post-hoc test showed, based on a .05 level of significance, there is no significant difference between the movement conditions. But the result shows a trend between the non-moving compared to the biological-moving condition $p < .07$ and similarly $p < .074$ between the non-moving and mechanical-moving condition.

For the uncanny/eerie factor, the first test returns a significant result, $\chi^2(2, 59) = 22.7, p < .0001$. The post-hoc test specifies highly significant differences $p < .0001$ between the non-moving and the mechanical-moving conditions as well as between the none and biological-moving

Table 5.7: Study results listing participants' interpretation of the hairbrush in terms of the variations and their statistical significance between the three movement conditions in respect to the three factors originating from the feature attribution. Two tests provide inferential statistics on the results. The H-test provides levels of significance for the differences between the three factors, and the second, post-hoc test yields significance levels for the difference between the none, biological and mechanical movement conditions for each factor.

Factors	intentional/ animate	automatic/ inanimate	uncanny/ eerie
H-test			
$\chi^2(2, 59) =$	$23.2, p < .0001$	$6.2, p < .046$	$22.7, p < .0001$
Post-hoc test		p-values (fdr corrected)	
difference between			
none and biological	$.0001^{***}$	$.07^{+}$	$.001^{**}$
none and mechanical	$.0001^{***}$	$.074^{+}$	$.0001^{***}$
biological and mechanical	.978	.932	$.075^{+}$

conditions $p < .001$. Additionally a trend $p < .75$ between the biological and mechanical-movement condition is observed.

Both tests compare the three movement conditions in respect to the three factors derived from the previously carried out factor analysis. The results obtained from both tests are listed in Table 5.7 and illustrated in Figure 5.14.

Discussion of the Inferential Statistics

Looking at the interquartile ranges for the different movement conditions in respect to the three factors, Figure 5.14 shows participants' interpretations in the non-moving condition on average have a larger variance in all factors.

For the first factor, *intentional/animate*, the distribution of answers in the non-moving condition might be attributed to the appearance and design of the hairbrush. This is supported by participants' comments in the non-moving condition. One participant for instance commented on the association of the green colour of the hairbrush with something lively. Another made an association to an apple and one even identified it as "must have a good personality, it is inviting to use." For the second and third factor, the bandwidth could be attributed to the fact that

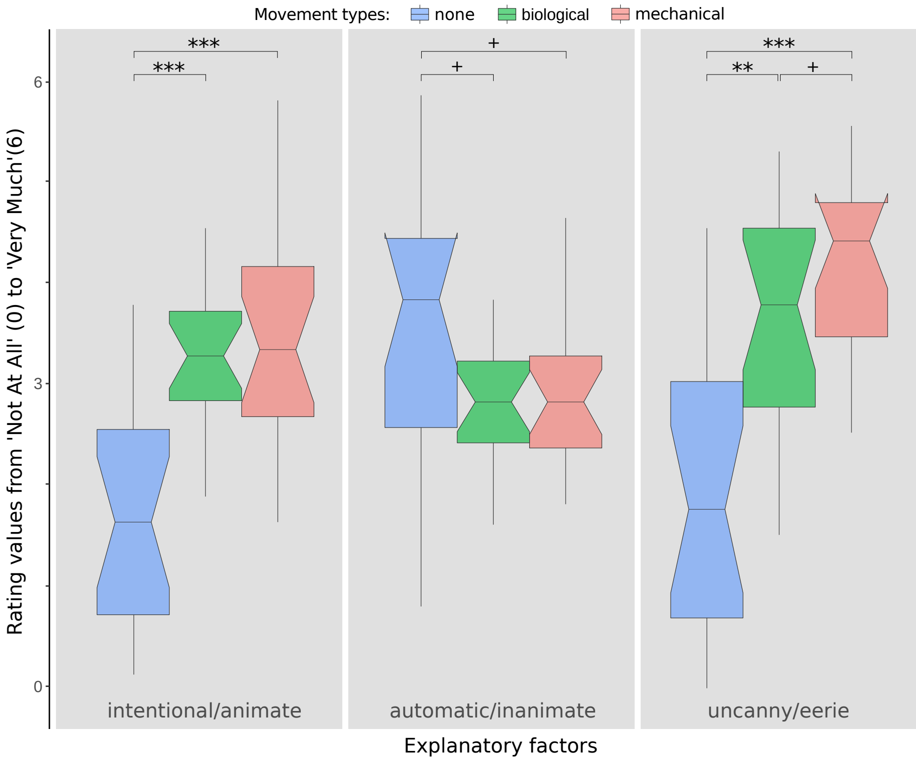


Figure 5.14: Results of the empirical study illustrating participants interpretation of the hairbrush in terms of the variations and their significance between the three movement conditions in respect to the three factors originating from the feature attribution.

asking someone to apply this range of features to, in this case, a 'plain' everyday object might be bewildering, hence causing dispersion. Similarly, within the first *intentional/animate* factor, the larger variance of the mechanical movement condition in respect to the biological movement suggests a larger spread of the interpretations as a consequence of the mechanical movement.

5.3 FINDINGS OF THE EMPIRICAL STUDY

Following the execution of the procedure laid out in Chapter 4 results showing differences in people's interpretation of the hairbrush evoked by the different movement conditions were obtained.

The results based on the feature attribution in the feature-space, listed in Table 5.1 and visually illustrated in Figure 5.11, indicate a shift in the interpretations of the hairbrush from the non-moving to the two moving conditions closer to humans and animals and further away from machines. In addition they reveal a minor difference between the two moving conditions. The interpretations of the biological movement in comparison to the mechanical movement is slightly closer to humans and animals.

These results were further validated using inferential statistics. Testing the significance of each individual feature under the specific condition lead to an overwhelming amount of results. Furthermore these significance levels don't provide any inferential information in terms of the overall shifts between the static and dynamic conditions. Therefore factor analysis was employed. An exploratory use of factor analysis i) provided an interpretation of the results that was more parsimonious, facilitating easier interpretation, and ii) allowed statistical inferences on the findings to be carried out.

The results of the factor analysis listed in Table 5.7 and illustrated in Figure 5.14 indicate differences in participants' interpretation of the hairbrush between the three movement conditions and in respect to the three factors originating from the feature attribution. The differences in the interpretations are highly significant between the non-moving and the two moving conditions for the first factor classifying intentional and animate features. This significant difference holds true for the third factor containing the features associated with the eeriness and uncanniness of the experience. Furthermore a trend in the difference of the second factor, classified by inanimate and automatic features, is indicated. The result from the first factor suggest the hairbrush's movement leads to a significantly higher interpretation as animate/intentional, thus increasing a sense of agency and animacy. The trend in the second factor, with the skewed distribution in the non-moving condition towards being interpreted as more inanimate and automatic, is likely related to the object being conceived of as a tool or instrument serving the purpose of a hairbrush. Furthermore significant differences in the third factor suggest that the movement of the objects is more disconcerting as a result of the ambiguity and concomitant ontological uncertainty provoked by the animation of an object commonly known as inanimate. In terms of variations between the two movement conditions none of the results specify statistical significance but indicate a trend with regard to differences in the interpretation of the third factor encapsulating the uncanny and eeriness features. When it comes to designing the behaviour of the hairbrush this suggest mechanical movement, compared to biological movement, evokes a minor intensification of uncanniness and eeriness of the objects' interpretation.

The outcomes of applying the factor analysis correspond to the result obtained from the allocation of the interpretations in the feature-space. The interpretations shift closer to humans and animals in the movement conditions, indicating an increase in their interpretations in terms of their agency and animacy, while the mechanical movement was perceived as slightly closer to machines. Both analysis methods validate the idea that movement increases perceptions of agency and animacy, contrasting the interpretation of a static everyday object with its autonomously acting counterpart.

5.3.1 *Limitations of the Study*

Neither the cultural background nor the effect of participants' loneliness were measured. Carey (2009, p.33), citing Quine (1969, 1977, 2013), 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 and Peng (1994). Similarly Gelman et al. (1995) show that same motion is interpreted differently depending on the context provided. Additionally loneliness has an effect on anthropomorphism as shown by Epley et al. (2008a).

Participants interpretation of the hairbrush were put in relation to static representations of the human, animal and machine categories. Collecting ratings of dynamic representation of the categories and put them in relation would illustrate differences in respect to dynamic interpretations of the categories. However, obtaining ratings of dynamic representation was not possible within the scope of this work.

5.4 SUMMARY AND CONCLUSION

This chapter reported the application of the methodology based on the feature-space from Chapter 4 in an empirical study measuring the relation between human observers and a non-humanoid robot. The subject of the study was an everyday object, a ready-made hairbrush technologically modified to make it move autonomously in a either biological or mechanical way. Participants' relationship to the object was assessed by having them attribute traits or features to the object under either a biological, mechanical or a no-movement condition. Based on the sociolinguistic device of the metaphor as an indicator for differences in the way an entity is perceived, the particular focus of this study was to show that people's interpretative relationship to the robot significantly changes when movement comes into play.

To measure differences in participants' interpretation in respect to the movement conditions, the subjective responses were allocated and compared in a feature-space. This geometrical space was previously established and used in studies as part of the methodology. The feature-space consists of a geometrical representation of feature attributions with designated regions representing humans, animals and machines. The geometrical allocation of participants' responses in this space indicated divergences in respect to these regions and revealed differences in participants' interpretation based on movement.

The results obtained by applying this methodology indicate differences in participants' relationship to an everyday object as a function of its movement. In particular biological and mechanical movement lead to the object being interpreted as closer to humans and animals, as shown by a significant increase of the attribution of animate features as compared to the non-moving hairbrush. The non-moving object is interpreted as more inanimate and closer to machines, in line with the hairbrush being perceived as a device and tool fulfilling a function. Furthermore both types of movement are associated significantly more with features representative of uncanny and eeriness, with a slight increase for the mechanical movement compared to biological movement.

Ultimately, the results emanating from the application of the methodology provide two key contributions to this thesis. The first is the result, which indicates shifts in the interpretation of an object with non-anthropomorphic/zoomorphic/mechanoid morphology as more intentional and animate based on movement alone. These results extend a well-documented phenomena (surveyed in the related work Chapter 3). They correspond to findings of screen-based work on animated abstract shapes and real world Wizard of Oz scenarios, where objects' behaviours are remotely controlled by a human. These works show that the movement of abstract shapes or non-anthropomorphic objects are interpreted as animate, more in social terminology and less in factual and impersonal language. However as the empirical work brings together people and an autonomously acting robotic object in a real world scenario, it transfers these findings from cognitive psychology and computer graphic animation to the field of human-robot interaction. The second is the application of the methodology developed in Chapter 4 in a human-robot interaction-like scenario demonstrates its use and validity in a setting with a higher ecological validity than screen-based evaluation techniques (e. g. the online study in Section 4.3 or work reviewed in the related work Section 3.2). Therefore, the methodology provides a measurement tool using a feature-space to evaluate differences in subjective interpretations based on the attribution of different degrees of features to entities.

6

EVALUATION

This selection of participants' comments and responses to the hairbrush were collected during the empirical study. It represents a selection by the author for general interest and to demonstrate the diversity of the responses considered in this chapter.

> "like something that has just come to life and still need to adjust..."
>
> "Simple, typical brush. However, It was the hardest one to assign [the label] since it didn't really match with any of the labels."
>
> "Quite a strange product, I do not understand why a hairbrush needs to be driven by a motor."
>
> "The green brush may not know he is different, by the same reason he is a unique of his kind."
>
> "She's the rebel of the group."
>
> "The fact that it is motorised does not seem to contribute much to its functionality."
>
> "It has no regard for its environment / surroundings, it will continuously make the same relentless movement regardless. Seems overly-manufactured. Overkill for the application of brushing hair."
>
> "Standard ladies green brush. Long hair horsey type of person who works in finance but love animals."
>
> "overly complex, mildly disturbing, and environmentally unfriendly"
>
> "The brush seemed possessed when I first lifted the box. The sudden movement made it seem "frightened" and like it was trying to get away from me. It's movement is mechanical, and rhythmic."
>
> "It was surprising me and was a bit robotic and sterile."
>
> "A hairbrush whose base has movement that move the bristles."
>
> "Interesting creature. It surprised me initially seems like a cool pet I can afford to adopt!"
>
> "noisy and unsociable for use in bedrooms"

In this chapter, the results from the empirical study presented in Chapter 5 are validated. This is carried out by evaluating differences in participants' short descriptions of the hairbrush given at the end of the empirical study. The rationale behind this section is to substantiate the findings of the quantitative methods through a content analysis of the qualitative data resulting from the short descriptions.

In line with the methodology from Chapter 4, which provided a method to examine movement as a determinant of variances in the interpretation of an entity (here, a hairbrush), the intention here is to consider differences in the short descriptions provided by the participants. Related to Malle's (1999) coding scheme which differentiates *cause* and *reason explanation* in the psychological explanation of behaviour, here the objective is to look at how participants described and assigned different social, conceptual, and linguistic features to the hairbrush under the different conditions. The analysis of these differences is carried out on the one to five sentence descriptions of the participants' experiences of the hairbrush that were provided by the participants as part of the study.

The purpose of analysing the content of the descriptions was to find similarities and dissimilarities, and to assess their differences across the movement conditions. This is methodologically grounded in Verbal Data Analysis, which provides a method for exploring and describing streams of language (Geisler, 2004).

This method presents a systematic way to evaluate written data and comprises two steps which are described and carried out in the subsequent section. Accordingly, the first step is to condense the data into smaller analysable units through the creation of categories and concepts derived from the data. The second step involves converting the data into categories of numerical variables for computational analysis.

6.1 Verbal Data Analysis

This section describes how verbal data analysis is conducted to examine the use of language in verbal or written articulations. The section reports its application to participants' responses, the written descriptions of their experience of the hairbrush given in at the end of the second part of the empirical study described in Section 5.2.2.

Verbal data analysis provides a framework to systematically approach verbal or written language. It is an exploratory method for identifying, analysing, and reporting patterns across a data set. It provides a systematic way to analyse the use of words, with a focus on building a descriptive analysis that can be articulated, makes sense, and is reliable in determining differences in modes of expression (Geisler, 2004, p. xiii). Conceptually, Geisler grounds verbal data analysis in protocol analysis (Geisler, 2004, p. xviii). Furthermore, it is related to data coding (e. g. Lockyer, 2004) and is often used synonymously with content analysis (e. g. Holsti, 1969). However, as Geisler points out, the latter does not make provisions for determining the reliability of the analysis. Another approach to analyse verbal data is conversation analysis (e. g. Garfinkel, 1964), where the focus is more on oral interaction, speakers' allocation, and other rules of engagement.

Verbal data analysis comprises two steps to systematically code text and verbal data.The first step constructs a descriptive framework which is then utilised in the second step to analyse the data. Consequently, participants' descriptions of the hairbrush are analysed in the following two sections. In the first section, the descriptions are screened to indicate degrees of uniformity in the answers and build a descriptive framework. In the second, this framework is used to examine patterns of distribution and highlight possible variations, originating from the different movement conditions.

Step I: Constructing a Descriptive Framework

This step involves first preparing the data for analysis; second, coding the data to reveal phenomena of interest; and finally, isolating the dimensions of analysis in a codebook. Ultimately, this step produces a codebook to be used as a descriptive framework to repeat and validate the coding by a second coder.

THE DATA is prepared by fitting the descriptions given by the participants in an Excel table. Therein the data is divided into units of analysis, here *t-units* as the smallest group of words that can make a move in language (Geisler, 2004, p. 31). For the $k = 59$ participants' descriptions this resulted in 185 units for analysis.

THE CODEBOOK is determined by the content of the units to which codices are ascribed. An inspection of the units leads to a set of 12 recurrent codices or variables. These 12 categorical variables in turn are consolidated in three concepts as follows:

- The first concept consolidates *inanimate descriptions of the object*. Here the object is depicted as a device and tool fulfilling a function and serving a purpose. These descriptions portray the object as unintentional, automatic, causal or programmed, and impersonal, factual, instrumental and mechanical language is used.

- The second unifies *animate descriptions of the object*. Therein the object is described similarly to a sentient entity and active agent with life-like features. The object is portrayed as intentional, being autonomous or having reasons, and social language describing living beings, animals or humans is used and could include gender attribution.

- The third reassembles *affective descriptions of the object*. These are characterised by the emotional experience of the object. This includes positive emotions like attraction, interest, pleasure or sympathy, negative emotions like expressing discomfort, uncanniness or eeriness, as well as affective remarks in respect to the surprise effect or violation of expectancy. This description uses personal and psychological language.

The full codebook with the 12 categorical variables distributed over the three concepts is shown in Table 6.1.

THE VALIDATION of the codebook was carried out by measuring the reliability in respect to a second coder. The second coder was given the codebook, with the indications for the different codes, and the descriptions divided into units. They were then asked to follow the instructions, applying the code that seemed most appropriate to each unit by marking it with a 1, leaving the other codes for that unit blank.

Subsequently, upon completion of the coding of the descriptions, the reliability of the code annotations was quantified by calculating the simple and corrected agreement (Geisler, 2004, p. 79). The simple agreement is calculated by dividing the number of agreements by the total number of decisions given, thus providing an indication of the percentage of decisions that are agreements in respect to the second coder. The corrected agreement involves calculating Cohen's Kappa (κ) as a method to correct for any agreements made by chance.

From the 185 items analysed, 10 produced disagreement. These were, for instance, units such as "Innovative piece of design" which was identified by one coder as a 'positive emotion' thus an affective description, while the other understood this as a remark on the 'appearance and design' of the object and therefore assigned it to inanimate descriptions. Similarly, "unsociable for use in bedrooms" was coded by one as an 'instrumental description' while the other assigned it to 'negative emotions'; or "Interesting creature" with the discord being whether 'crea-

Table 6.1: Empirical study — codebook developed for the verbal data analysis.

Concepts	**Inanimate description**			**Animate description**				**Affective description**			**Other**	
Specification	Describes the object as a device and tool fulfilling a function and serving a purpose. Portrays the object as unintentional, automatic, causal or programmed. The description is using impersonal, factual, instrumental and mechanical language.			Describes the object as a sentient entity and active agent with life-like features. Portrays the object as intentional, being autonomous or having reasons. The description is using language describing living beings, animals or humans and could include gender attribution.				Describes the emotional experience of the object. This includes positive emotions like attraction, interest, pleasure or sympathy, negative emotions like expressing discomfort, uncanniness or eeriness, as well as affective remarks in respect to the surprise effect or violating expectancy. The description is using personal and psychological language.			items that could not be included in any of the others	
Codes	**Appearance Design** Color, Size, Shape, Feel	**Instrumental Description** Functional, Purposeful, Usable	**Causal Movement** Unintentional, mechanical, programmed	**Lifelike Description** Using metaphors describing the brush as a sentient entity	**Zoomorphic Description** Using animal metaphors to describe the brush	**Anthropomorphic Description** Using human traits and metaphors to describe the brush	**Gender Attribution**	**Negative Emotions** discomfort, uncanniness, repulsion	**Positive Emotions** affection, approval, pleasure	**Expectation** novelty, surprise	**Misc**	**Sound Noise**
Examples	*“A plastic hairbrush with cheap coloring”* *“It's quite fat in both the handle and the paddle.”*	*“useful”* *“massage one’s head”* *“will do its job”*	*“A hairbrush that moves”* *“mechanical movement”* *“driven by a motor”*	*“Sentient and goal directed creature”*	*“Seems like a cool pet”*	*“It seems like the rebel of the group.”*	*“She’s a rebel”* *“He is ...”*	*“The colours clash weirdly.”* *“It just feels a bit cold,”* *“I dislike”*	*“It is really interesting when it is moving.”* *“I like”* *“cute”*	*“Surprising object”* *“very unexpected”* *“Absurd, weird”*	*“It was the hardest one to assign.”*	*“Noisy”* *“Very mechanical sounding”*

ture' refers to an animal, thus a 'zoomorphic' description, or a 'lifelike' entity.

Coding the descriptions in accordance to the codebook resulted in an inter-annotator agreement of 0.945, or 0.931 corrected when using κ. Both results are considered to be 'very good' in terms of strength of the agreement. The extant discrepancies where resolved by a third coder's response on the controversial units to obtain agreement on all items. As a result of this step, a framework was obtained to be used in subsequent analysis investigating variations in the descriptions as an effect of movement.

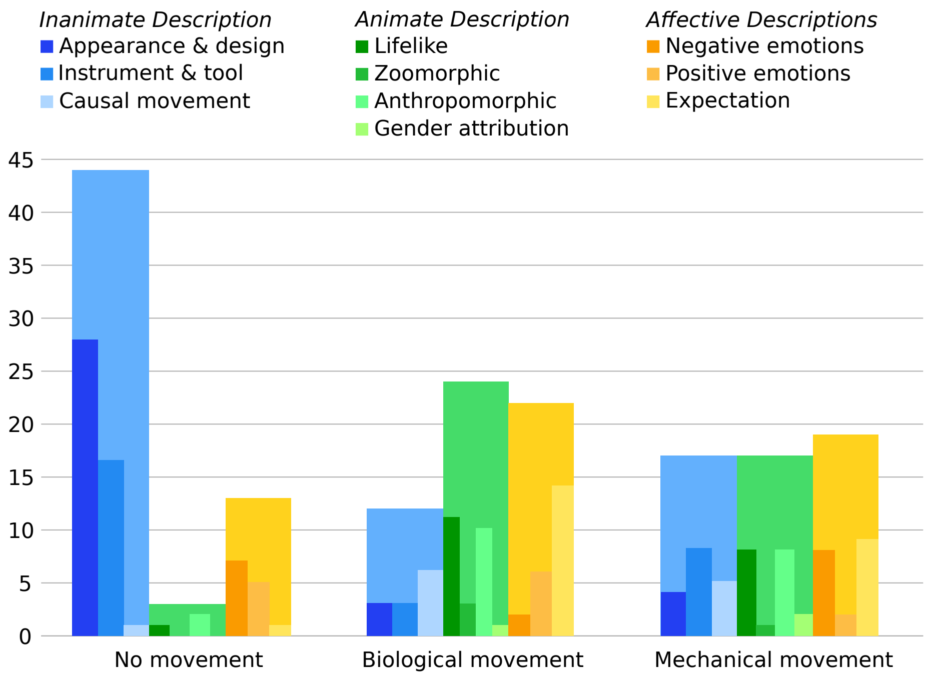
Step II: Using the Descriptive Framework to Determine Differences

In this step the descriptive framework with the classified descriptions resulting from the previous coding is used to identify differences as a result of the movement conditions.

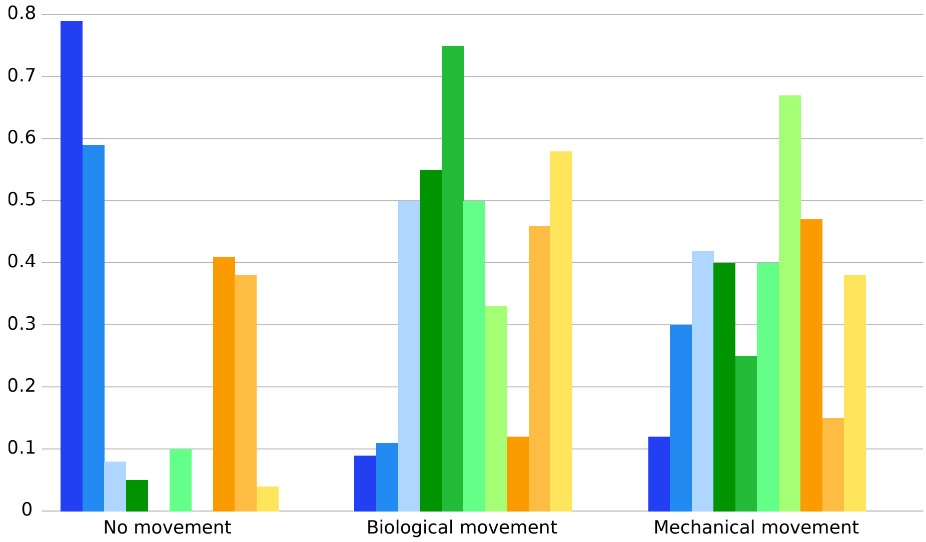
To delineate the effect of movement as a determinant of variances in the descriptions, the patterns of distribution are compared in terms of their frequencies. The frequency scores are represented in (a) and (b) in Figure 6.1. Both illustrate the differences between the movement conditions for each of the codes and concepts determined in the codebook. The concepts are specified by inanimate, animate, and affective descriptions derived from 10 of 12 recurrent variables (the 2 variables for miscellaneous units are removed from the plot). Figure 6.1a represents the codes and their scores in terms of frequencies. Figure 6.1b shows them in terms of their relative frequencies.

THE STATISTICAL SIGNIFICANCE of the differences between the descriptions where analysed using a χ^2 (Chi-square) test. To conduct a χ^2 test, two assumptions have to be fulfilled. The first requires that each observation is independent of all the others (e.g. one observation per subject). The second requires that no more than 20% of the expected counts are less than 5 and all individual expected counts are 1 or greater (Moore et al., 2014, p. 965).

Geisler (2004, pp. 189–190) remarks that verbal data analysis meets the first assumption. The codebook was developed on the basis that each *t-unit* can only fit into one of the description categories which makes the categories independent of each other. The coding of each *t-unit* is done independently, without considering that the coding of other *t-unit's* influence on this one. Therefore the dataset and coding meets the assumption of χ^2.



(a) Frequency counts



(b) Relative Frequencies

Figure 6.1: Study results from the verbal data analysis, illustrating participant interpretation of the hairbrush in terms of the frequency variations of descriptions between the three movement conditions and the three concepts originating from the 10 recurrent variables.

As shown by Figure 6.1a, the detailed categories do not have enough counts to meet the second assumption (expected counts less than 5). The three dimensions with the inanimate, animate, and affective descriptions are therefore taken into account. Accordingly, a 3x3 χ^2 analysis is carried out. The calculations are shown in Table 6.2. The chi square statistic resulting from the calculations is $\chi^2(4, 171) = 40.5, p =$

Table 6.2: Chi-square test for the association between the movement conditions and the three dimensions coming out of the descriptions. The numbers highlighted in red (greater than ±1.96 SD) indicate the dimensions that contributed the most to the significance.

Movement		Descriptions			
		inanimate	animate	affective	total
biological	N	12	24	22	58
	%	20.7	41.4	37.9	100
	residuals	-2.6	2.3	.9	
mechanical	N	7	17	19	53
	%	2.1	32.1	35.8	100
	residuals	1.2	.9	.6	
none	N	4	3	13	60
	%	3.3	5.0	21.7	100
	residuals	3.6	-3.2	-1.4	
Total	N	73	44	54	171
	%	42.7	25.7	31.6	100

.00001. Thus, there is a significant relationship between movement type and description type; in other words, the type of movement contributes to the type of description it incurs.

6.2 RESULTS

The results of the verbal data analysis, comprising the two steps carried out above, indicate that movement type influences description type. A χ^2 test showed a significant relationship between the movement type and the descriptions.

The numbers in results Table 6.2 highlighted in red (greater than ±1.96 SD) indicate the dimensions that contributed the most to the significance. Therefore, biological movement contributed the most to animate descriptions and lack of inanimate descriptions. No movement contributed the most to the inanimate descriptions and lack of animate description.

The following conclusion can be drawn interpreting Figure 6.1 showing the relationship of the responses and the stimulus-configurations set by the three movement conditions:

- In the no movement condition, participants use inanimate descriptions the most. More specifically, people most frequently reported on the appearance and gave instrumental description.
- In the biological movement condition, participants reported animate description the most. More specifically, expectation, lifelike description, and anthropomorphic description are the most frequent.
- In the mechanical movement condition, participants reported equally frequent instrumental description, lifelike description, anthropomorphic description, negative emotions, and expectation.
- Regarding negative emotions, the biological condition had the lowest frequency.
- Movements seem to be positively correlated with animate descriptions.
- In the biological condition, people use more animate descriptions and affective descriptions than other groups.

6.2.1 *Interpretation of the Results*

The results revealing the variations in the distribution of the descriptions are instructive to the findings using the feature-space in the empirical study, reported in Section 5.2.3, on two levels.

First, in correspondence to the findings employing the feature-space, the result from the verbal data analysis provides indications that movement has an effect on the interpretation of an object. This is apparent in the predominantly animate interpretation of the hairbrush in both movement conditions, in contrast to the no movement condition. The latter is primarily indicated by descriptions of the object as a device or tool fulfilling a function using factual and impersonal terminology, while the former mostly reassembles descriptions of an animated being employing lifelike, zoomorphic, or anthropomorphic metaphors and using social and personal language.

Secondly, in terms of the differences between the two movement conditions, the responses resulting from the affective description emphasise the findings from the feature-space. Evidence suggests that mechanical movement leads to an increase of negative emotions while biological movement is positively correlated with positive emotions. This corresponds to the slightly more uncanny and eerie reading of the mechanical moving hairbrush pointed out by the results of the feature attribution using the feature-space as reported in Section 5.3. However, contrarily to that outcome, here the biological movement shows an increase in the descriptions that address the expectancy or surprise and in general a slight increase of affective descriptions in contrast to the mechanical movement.

Moreover, the verbal data Analysis draws attention to differences between the movement conditions that are not reflected in the feature attribution. While the biological movement is interpreted to a greater extent using lifelike, zoomorphic, and anthropomorphic terminology – reassembling animated descriptions – the mechanical movement is described using more inanimate phrasing, in particular increasingly in terms of describing the object as an instrument and tool.

6.2.2 *Discussion of the Results*

The conclusions from both research instruments – the quantitative method employing the feature-space and the qualitative verbal data analysis – provide an instance of multi-strategy research. The rationale behind the integration of both was to employ the findings from the latter to validate the first. In that respect, combining the research instruments, Bryman (2006) highlights that the collection of qualitative data in the course of employing a research instrument that has been devised in terms of survey principles can have an effect on participants responses.

To mitigate effects of the survey instrument on participants' responses, a strategy facilitating the collection of open responses, such as those gathered during the initial exhibition of the hairbrush at the gallery described in Section 1.2, could provide corrective action. Equally, audio recordings of the loose conversation following the study might also facilitate the reduction of interferences between the survey instrument and participants' responses. Simultaneously, the 'slot' given during the survey to provide the descriptions of the hairbrush was apprehended by all participants, which isn't guaranteed within a more open setting where people can just walk away.

The study was designed to collect data for both types of analysis sequentially, as described in Section 5.2.2. A simultaneous collection of data for both would have been preferred to mitigate the effects described here, but this was difficult to implement in the study design. However, participants from all movement conditions had previously completed the feature attribution in the feature-space, using the same set of features, thus all are 'primed' in the same way. Additionally, the part evaluated here using verbal data analysis is subsequent thus excludes similar retroactive effects to the primary analysis based on the feature attribution in the feature-space carried out in Chapter 5.

7 CONCLUSION AND FURTHER WORK

7.1 SYNOPSIS OF THE WORK

In this thesis the relationship between people and technological objects was explored. The particular focus was on people's perception of movement and how it affects their relationship to various entities. This includes biological entities as well as technology simulating life-like qualities e. g. technological objects and animated artefacts – be it a tinky-winky Lucky cat or a Roomba robots' cleaning boogie. The general aim was to provide a better understanding of how movement affects humans' perception of these technological objects.

The motivation for the work presented here comes from my artistic practice employing machines and technology in a creative context by mechanising and animating artefacts . The introduction in Chapter 1 listed works emanating from this practice alongside observations made during a public exhibition of one of the works: a technologically modified hairbrush that moves autonomously. The creation of the robotic hairbrush and observations made while it was exhibited gave rise to the objective for this research: How does movement affect peoples' perception of technological objects? Furthermore, the creation of this work provide the practical basis, and the observations form the theoretical interest for the work presented in the follow up chapters.

The background in Chapter 2 provided an approach to movement and the perception of movement from the perspective of the arts. I presented a personal approach listing related inspirational works from an artistic context together with concepts referring to influential literature. The aim was to learn more about the role of movement for human perception. I presented different perspectives on the overarching research question on how movement changes the perception of artefacts. Firstly, I presented movement as one of the primary factors that provokes affection and forms the basis for our relationship to things. Secondly, the objective was to show with examples how language can reveal differences in the way we communicate that relationship, ranging from animate to inanimate descriptions apparent as degrees of animacy and agency. Thirdly, I illustrated that movement can be used as a stylistic device to evoke differences in the affective relationship to things ranging from repulsion to attraction. Correspondingly to the previous chapter, the related work Chapter 3 provided a survey of works predominantly using language to assess differences in peoples' relation to human and non-human entities presented on screens, as well as, in laboratory or real-world scenarios. These works stemming from cognitive psychology, computer graphic animation and human-robot interaction present key empirical works on the topic. The reviewed body of work on the one hand provide evidence of how human characteristics are assigned to non-human entities (anthropomorphism) or vice versa through dehumanising humans, as well as showing how different forms of movement affect peoples' interpretation of an entity as animate or inanimate.

The key concepts and findings from both chapters are transferred into an agency-framework to highlight observed movements, structures and kinematics as potentially being interpreted as animate or inanimate. In conclusion, the methodology Chapter 4 reassembles findings from both chapters and presents a relational approach to measure differences in the way an entity is perceived. The evaluation method first establishes ontological categories for humans, animals and machines, and second, used the categories to assess changes in the interpretation as displacements in ontological commitments evoked by movement. Additionally, the method permits a measurement deploying a relationship rather than just attributing properties on a simple black/white or either/or ratio.

The methodology developed is a quantitative method that uses language as an instrument to evaluate the way an entity's movement characteristic affect the way thoughts and actions are directed to them. Drawing on the linguistic concepts of animacy and agency that indicate how sentient or alive an entity is perceived to be, the method uses a set of features that are characteristic of human and non-human behaviour. Inviting participants to attribute degrees of these features to entities and representing these subjective responses in a geometrical feature-space allows the individual attributions to different entities under different conditions to be compared and contrasted. The resulting metric provides a measurement tool that allows to measure and describe effects and changes in peoples' interpretations, which can be examined through shifts in the metric's feature-space.

The methodology was established and informed by two studies. The first, *Study A* ($k = 93$), provided the procedure to obtain a feature-space as a measurement tool: based on individual interpretations captured by the rating of traits, specific regions for three ontological categories (humans, animals and machines) were determined and allocated in a geometrical structure. For the second study, *Study B* ($k = 72$), the dimensionality of the feature-space was reduced and the influence of movement on this classification was analysed. By having people interpret entities, displayed either as static or dynamic, and rate them along the same set of features, the results could be projected into the previously obtained feature-space. The results show how movement affects people's interpretation of an entity. For example, a human represented using mechanical movement, by virtue of break-dancing moves, shifts interpretations towards the region designated to machines: less intentional and more mechanical.

In Chapter 5 the outlined methodology is applied in an empirical study presenting a HRI-like scenario. For this study an enhanced version of the hairbrush, whose iterative development was described at the beginning of the chapter, was used. This version's morphology was improved by hiding all the electronics inside, removing marks of its morpho-functionality and making it appear like an everyday object. The transformative capacity of this non-anthropomorphic object, lacking resemblances to e. g. faces or body structure similar to animals and humans, was used to study how movement affects its interpretation. Additional improvements were made in the locomotion mechanism so it could move with two different patterns (biological, mechanical) as well as remaining static, providing three different conditions for the study.

Applying the methodology in an empirical study ($k = 59$), in which subjects had to interpret the hairbrush under the different movement conditions, led to results indicating differences in the feature attribution as an effect of movement. In particular, the study showed that the applied biological and mechanical movement resulted in an interpretation closer to humans and animals, most clearly seen in a significant increase of the attribution of animate features in contrast to the non-moving hairbrush. The non-moving object is interpreted as more inanimate and closer to machines as a hairbrush that is perceived as a tool that fulfills a function. Furthermore, the application of factor analysis revealed that both movements are associated significantly more with features representing the uncanny and eeriness of the experience, with a slight increase for the mechanical movement condition compared to biological.

In the evaluation, Chapter 6, the results of the empirical study were verified by a second research instrument. This was carried out by conducting a verbal data analysis on short descriptions given by the participants as part of the study. The results obtained here also show that movement has an effect on the way an object is described. They align with the findings in the feature-space, apparent in the predominantly social description of the object in the movement conditions in contrast to the no-movement condition. Furthermore, differences between the two movement conditions suggest that mechanical movement leads to an increase of negative emotions while biological movement is positively correlated with positive emotions. Moreover, this analysis drew attention to differences between the movement conditions that are not reflected in the feature attribution. While the biological movement is interpreted to a greater extent using lifelike, zoomorphic and anthropomorphic terminology, resembling animate descriptions, the mechanical movement is described using more inanimate phrasing, in particular through an increase in terms that describe the object as an instrument and tool.

7.2 RESULTS

Differences in the interpretative relationship as an effect of movement were shown and measured in a real-world scenario, an empirical study having people interpret a ready-made object, a hairbrush technologically modified to switch between the state of a regular hairbrush and a autonomous creature moving either biologically or mechanically. The results, obtained from the empirical work, employ the methodology set up in Chapter 4. The methodology uses a feature-space to allocate and compare peoples' interpretations, the attribution of features to the hairbrush, under different conditions in a geometrical space. The results indicate differences in participants' perception of an everyday object as an effect of its movement. In particular, it showed that the applied biological and mechanical movement led to a shift being interpreted closer to humans and animals, condensing in a significant increase of the attribution of features representative for animate creatures. In addition both movement conditions elicited an interpretation with significantly more features representative for the uncanniness and eeriness of the experience, with a slight increase for the mechanical movement.

The results relate to findings from previous works on two levels. On the one hand the methodology of using traits to assess people's interpretation connects to related work on anthropomorphism in Section 3.1. On the other hand, the results indicate ontological shifts in people's interpretation elicited by movement, as in the agency investigations discussed in Section 3.2. However, the methodology combines insights from the two and therefore differs. Because the words can potentially influence and prime people and are controversial in the process of building the measurement tool (the feature-space), an indirect method was used: displaying images e. g., of animals instead of using the word animal, as discussed in Section 3.1.3. Furthermore, features e. g. verbs and adjectives are used instead of nouns to reflect the way people interact, experience and relate to entities. Participants' interpretations in response to the entities were examined on a range (Likert scale) rather than a go/no-go, black/white or either/or level, to facilitate a relational approach of understanding 'others' as explained in Section 2.2.2.

7.3 CONCLUSION OF THE WORK

The aim of this thesis was to learn more about the role of movement for human perception. In particular how movement motivates changes in peoples' relationship towards things. In that respect, the following contributions to knowledge are provided by the work and research outlined in this thesis:

FIRST, it provides an understanding of humans' affinity to the movement of technological objects by bringing together work from various contexts. The work presented here assembles artistic, design-based and scientific approaches to the topic together with concepts from philosophy, literature and film studies; and empirical work from cognitive psychology, computer graphic animation and human-robot interaction.

The background Chapter 2 provided an approach to movement and the perception of movement from the perspective of the arts. Different perspectives on the overarching research question on how movement changes the perception of artefacts was presented in three parts. In the first I provided artistic examples to illustrate that movement not only forms the base for the living but also the basis for our relationship to artefacts and things in general. I discussed differences in how we experience and perceive movement ranging from involuntary movement associated with non-living objects to intentional action of living creatures. The focus of the second part was on the language we use to communicate our relationship to artefacts emphasising metaphors and how they reflect humans' intuitive process of categorising and attributing characteristics as a dialog and understanding of things. The particular focus was on differences apparent in the use of language ranging from animate to inanimate descriptions of things. I reasoned for a relational approach, focusing on verbs and adjectives instead of excluding nouns, to give way to an interpretative relationship that pays attention to the way people interact, experience and relate to entities. The focus of the third and last part was on movement as a stylistic device used in the arts to design an affective relationship. Therein I argued that ambiguity, as a principle of poetry, is affective through its play with familiar relationships, for instance the technological animation of artefacts making the inorganic feel live. This was supported by examples using movement as a stylistic device to design an affective relationship which can range from repulsion to attraction.

The related work Chapter 3 provided key empirical works with a focus on language and movement. These were empirical works predominantly using language to assess differences in peoples' perception of human and non-human entities presented on screens, as well as, in laboratory or real-world scenarios. In respect to the research question the insights from both chapters gave rise to the relational approach elaborated in the methodology.

SECOND, the methodology's application in an human-robot interaction-like scenario demonstrated its use and validity. It provides a measurement tool using a feature-space to evaluate and compare differences in subjective interpretations based on the attribution of different degrees of features to entities. As such it presents a quantitative method that provides a relational approach on two levels. First, it permits a measurement deploying a relationship rather than just attributing properties on a simple black/white or either/or ratio. Second, it uses adjectives and verbs instead of excluding nouns, which places focus on the appearance and perception of the robot, the emotions and feelings towards the entity-in-relation.

The metric established in the methodology and informed by the studies could also be used as a quantitative method for analysing differences in subjective experiences of art installations, performances, or sculptural artworks, as well as in human-robot interaction. As such it provides a tool allowing to express subjectivity in the data and facilitating the illustration and assessment of differences between peoples' perception of entities. This is measured as distances between the interpretations of entities, and through shifts in similarity and dissimilarity between judgements on how movement affects the perception are made. The methodology presented places focus on a relational approach with the objective to overcome problems revealed when using language for evaluation. As discussed in the limitations, methods like triad task potentially allow to go without language and in this way can overcome using language as a measurement in general. The evaluation of the results (Chapter 6) obtained from the methodology show its validity, however, the use of statistics here is interpretative. To be used with confidence by others a higher sample rate would be desirable, which wasn't in the scope of this work but would facilitate using inferential statistics without the need to cluster correlating features to factors.

THIRD, the results from the application of the methodology show movement as a determinant of variances in interpretation. The findings reveal that the movement of an everyday object motivates an interpretation closer to humans and animals, apparent in increased attribution of animate and intentional features. Furthermore, evidence suggests that mechanical movement leads to an increase of uncanniness and eeriness while biological movement correlates with positive emotions.

These results extend a well-documented phenomena. They correspond to findings of screen-based work on animated abstract shapes or Wizard of Oz scenarios, where objects' behaviours are remote-controlled by a human. These works show that the movement of abstract shapes or non-anthropomorphic objects are interpreted more in social terminology and as animate, and less in factual and impersonal language (surveyed in the related work Section 3.1). However, the empirical study conducted presents people with an autonomously acting robotic object, which lacks anthropomorphic/zoomorphic or mechanoid morphology, in a real world scenario, transferring these findings from social psychology and computer graphic animation to the field of human-robot interaction.

7.4 FUTURE WORK

Further work could encompass the research framework, the methodology established and presented here, as well as the study design.

IN RESPECT TO THE METHODOLOGY and its application, two aspects are considered to be of interest for further work. On the one hand, using the methodology in another context e.g. to analyse differences in subjective experiences of art installations, performances, or sculptural artworks, as well as in other human-robot interaction scenarios. On the other hand, acquiring a higher sample rate to obtain normal distributed data. Subject to the condition that the time-slot is presumably less limited than the one available for this PhD. This could facilitate using methods for inferential statistics based on normal multivariate distributed data as for instance outlined in Goodpaster and Kennedy (2011). These methods combined with a higher sample rate could provide an inferential validation of the methodology without the need to cluster correlating features to factors.

In regard to the study design, two points are of particular interest for further work. This comprises the exploration of people's engagement with artefacts in different environments as well as their effect over time.

As Bardzell and Bardzell (2013) remark, dropping artefacts into everyday life as opposed to placing art on a plinth makes them appealing as a medium for critical research. To go about this, strategies similar to the Barbie Liberation Organisation's shoplifting procedure could be carried out (RTMark, 1989). Like their modified Barbie and G.I. Jones puppets, modified hairbrushes could be placed back in shop shelves to examine buyers' behaviour and to study recipients' reactions to the objects. However following up with a multitude of people during and after their shopping brings along logistical as well as ethical problems.

Another approach could be to use the hairbrush as a 'domestic probe' given to various peoples and households and followed by ethnographic research. This resembles cultural probe studies as laid out and performed for instance in Gaver et al. (1999) and Gaver (2007), the threshold devices presented in Gaver et al. (2008) focusing on different experiences of prototypes and objects or the research presented in Forlizzi and DiSalvo (2006) and Sung et al. (2007) exploring people's intimate relationships to the household product of a Roomba robot. These studies take the effect over time into account: as people become familiar with things, it influences their relationship with them. Fong et al. (2003) for instance emphasise that judgments about robots are shaped by humans experience over time.

Finally, in contrast to the methodology presented, these approaches pay different attentions to the individual's experience and the specificity of the situation. They can provide assessments in ecologically different environments. E. g. similar to the gallery situation described in the outset Section 1.2 they allow interactions in a less formal and situated environment and more naturalistic than a controlled study setup (Dautenhahn, 2007, p. 686). These studies pay respect to the fact that every individual creates their own experience of the object and provide a way to articulate the many facets of people's experience, extrapolate narratives and dramatise the relationships established with everyday objects (Gaver, 2007).

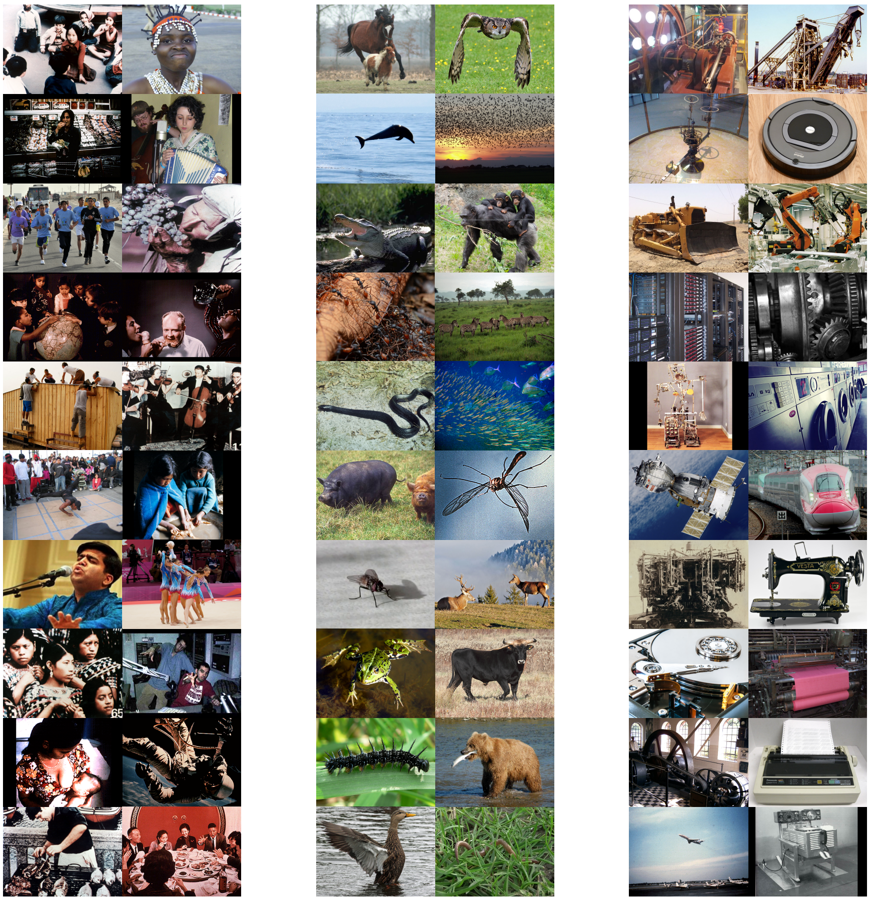
Hence, these approaches could potentially elicit multiple personal stories about people's relationship to technological objects in general. The hairbrush, due to it's non-utilitarian function, works as an interface to talk about people's social relations and perception of robots and objects in general. The ambiguity in the design of the hairbrush is an excellent hub to talk about personal stories, indicated by the individual stories brought up by visitors described in Section 1.2. However, a range of different interpretations that reflect individual experiences are presented for instance in the comments and responses given by the participants quoted on page 124.

APPENDIX

A.1 ADDITIONAL INFORMATION FOR CHAPTER 4

Section 4.2: Construction and Calibration of the Feature-space

Figure A.1 shows the picture sets used in the study informing the first part of the methodology. Table A.1 presents the full feature set, their individual applicability and selection for the reduced feature set. Figure A.2 represents the variances over the 23 principal components calculated from the 23 feature of the reduced feature set.



(a) Humans (b) Animals (c) Machines

Figure A.1: Picture sets representative for the categories of humans, animals and machines employed in the study informing the first part of the methodology. Courtesy of the United Nations Photo Library,[1] published with their permission.

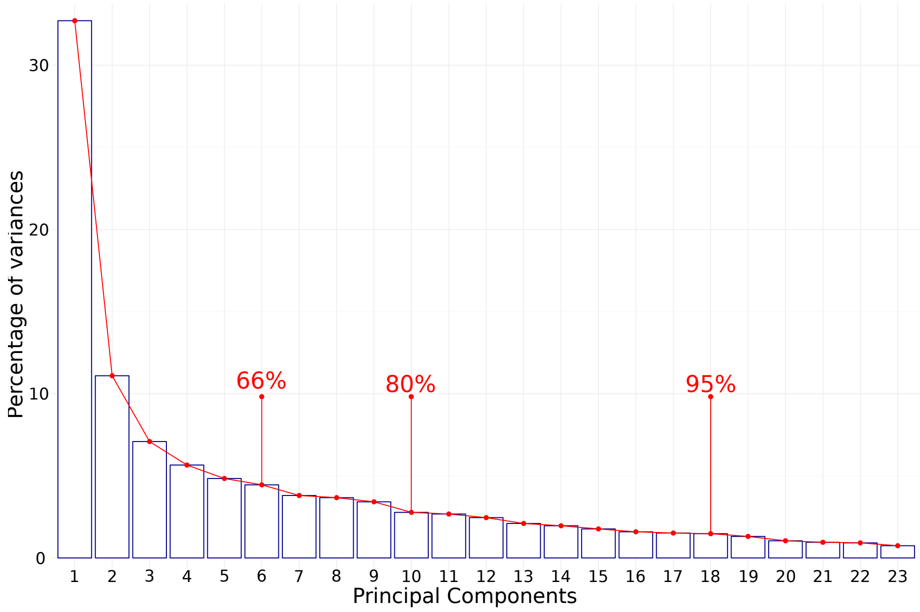


Figure A.2: Explained variances for each principal component resulting from the 23 features of the reduced feature set with percentiles of total explanation.

Table A.1: Study A – Full feature-set with individual applicability to human (H), animal (A) and machine (M) categories based on mean ratings as either applicable (✓), undecided (–) or inapplicable (x), and their selection for the reduced feature set (✓).

	Type			
Feature	**H**	**A**	**M**	*selected*
Goal.driven	–	–	✓	✓
Instrumental	–	–	✓	✓
Nervous	x	x	–	
Clunky	x	–	–	✓
Devious	x	x	–	✓
Efficient	–	–	✓	✓
Fearful	x	–	–	
Inanimate	x	x	–	
Considerate	–	–	–	
Predictable	x	–	–	
Expressive	✓	–	–	
Ceramic	x	x	x	
Spiritless	x	x	-	✓
Shy	x	x	x	
Sociable	✓	–	x	✓
Productive	–	–	✓	✓
Graceful	–	✓	–	
Organic	–	✓	x	✓
Agile	–	✓	–	
Determinative	–	–	✓	
Attractive	–	✓	–	
Purposeful	–	–	✓	
Structured	–	–	✓	
Inquisitive	–	–	–	
Aware	–	✓	x	✓
Perfect	–	–	–	
Effortless	–	–	–	
Energetic	–	✓	✓	
Autonomous	–	–	–	
Wooden	x	x	x	
Alien	x	x	-	
Empathic	–	–	x	
Exploratory	✓	–	–	
Creepy	x	x	–	✓
Sturdy	–	–	–	
Aggressive	x	–	–	✓
Weak	x	x	x	
Fast	–	–	–	
Synthetic	x	x	✓	✓
Logical	–	–	✓	✓
Sensitive	–	–	–	✓
Distractible	–	x	–	
Reactive	–	–	–	
Spontaneous	✓	–	x	✓
Lonely	x	x	–	✓
Creative	✓	–	–	✓
Precise	–	–	✓	
Disorganized	–	x	x	
Sentient	✓	–	x	✓
Breakable	–	–	–	
Slow	–	–	–	
Deliberate	–	–	–	
Complex	–	–	✓	✓
Jealous	x	x	x	
Active	✓	✓	✓	
Lost	–	x	x	
Accurate	–	–	✓	
Self-conscious	–	–	x	
Prancing	x	–	–	
Interactive	–	–	–	
Controllable	–	x	✓	✓
Sympathetic	–	–	x	✓
Responsive	–	–	–	
Decisive	–	–	–	
Lethargic	x	x	x	
Captivating	✓	–	–	
Thoughtful	✓	–	–	
Vital	–	✓	–	
Repetitive	–	–	✓	
Caring	–	–	x	✓

Section 4.3: Using the Feature-space to Show the Effects of Movement

Table A.2 presents the mean ratings for each feature in relation to the categories of human, animal and machines and the static and dynamic entities.

Table A.2: Normalized mean ratings of the reduced feature set in respect to categories and entities. The five features with the highest contrast between static and dynamic are marked bold.

	Categories (**Study A**)			Entities (**Study B**)															
	Humans	Animals	Machine	Breakdancer		Dancer		Worm		Fly		Washing machine		Roomba robot		Clouds		Leaves	
Features				static	dynamic	static	dynamic	static	dynamic	static	dynamic	static	dynamic	static	dynamic	static	dynamic	static	dynamic
Aggressive	-0.57	-0.20	-0.10	**-0.02**	**-0.64**	-0.52	-0.29	-0.79	-0.43	-0.14	-0.42	-0.27	-0.04	-0.65	-0.63	-0.59	-0.40	-0.88	-0.95
Aware	0.25	0.33	-0.33	0.45	0.15	0.56	0.44	-0.03	0.06	**-0.02**	**0.38**	-0.31	-0.44	**-0.33**	**0.17**	**-0.24**	**-0.5**	-0.08	-0.14
Caring	0.30	0.21	-0.54	-0.04	-0.33	0.02	-0.20	**-0.15**	**-0.59**	-0.52	-0.60	-0.54	-0.76	-0.48	-0.46	-0.26	-0.38	-0.10	0.14
Clunky	-0.47	-0.31	0.08	-0.37	-0.31	-0.43	-0.42	-0.31	-0.18	-0.4	-0.47	**0.08**	**0.47**	-0.10	-0.09	-0.63	-0.64	-0.65	-0.38
Complex	0.22	0.16	0.55	0.18	0.28	0.13	0.00	0.13	0.27	**-0.07**	**0.29**	-0.25	-0.22	-0.06	0.06	0.57	0.55	**0.39**	**0.10**
Controllable	-0.25	-0.38	0.34	**-0.35**	**0.41**	-0.19	0.00	-0.21	-0.22	-0.50	-0.22	0.10	0.11	0.38	0.37	-0.54	-0.43	-0.27	-0.50
Creative	0.41	-0.13	0.02	0.39	0.59	0.74	0.67	-0.23	-0.43	-0.38	-0.42	-0.08	-0.11	-0.31	-0.37	0.15	-0.07	**0.25**	**-0.24**
Creepy	-0.75	-0.48	-0.26	-0.47	-0.54	-0.33	-0.16	-0.26	-0.14	0.00	-0.22	-0.23	-0.02	**-0.65**	**-0.33**	-0.69	-0.69	-0.67	-0.81
Devious	-0.60	-0.40	-0.24	**-0.08**	**-0.64**	-0.11	-0.36	-0.46	-0.12	-0.12	-0.36	-0.35	-0.31	-0.60	-0.33	-0.63	-0.52	-0.55	-0.48
Efficient	-0.16	0.13	0.39	-0.16	0.00	-0.06	-0.29	**0.36**	**-0.31**	0.07	0.02	-0.08	0.00	0.15	0.20	0.11	-0.02	0.14	0.02
Goal.driven	0.01	0.05	0.54	**0.16**	**-0.23**	**0.15**	**-0.20**	0.38	0.00	**-0.19**	**0.11**	**-0.12**	**0.22**	**0.25**	**0.63**	-0.46	-0.62	-0.27	-0.43
Instrumental	-0.03	-0.26	0.49	-0.20	-0.28	**0.13**	**-0.18**	**-0.10**	**-0.57**	-0.57	-0.60	**-0.10**	**0.16**	0.17	0.31	**-0.31**	**-0.57**	-0.37	-0.29
Logical	-0.28	-0.24	0.52	-0.08	-0.26	-0.30	-0.42	0.05	-0.08	-0.17	-0.09	-0.27	-0.11	**0.06**	**0.43**	-0.11	0.02	-0.18	0.00
Lonely	-0.41	-0.37	0.02	-0.75	-0.59	0.11	-0.11	0.21	0.00	**0.19**	**-0.13**	**0.54**	**0.11**	0.02	-0.20	**-0.09**	**-0.57**	**-0.63**	**-0.33**
Organic	0.26	0.59	-0.46	0.33	0.15	0.26	0.27	0.79	0.59	0.45	0.56	-0.77	-0.51	-0.67	-0.87	**0.37**	**0.60**	0.84	0.95
Productive	0.13	-0.08	0.56	0.27	0.08	**0.04**	**-0.40**	**0.31**	**-0.25**	-0.14	-0.16	0.06	0.18	0.10	0.28	-0.06	0.14	0.16	-0.07
Sensitive	0.23	0.32	-0.32	0.18	0.00	0.50	0.24	0.46	0.39	**-0.24**	**0.18**	-0.52	-0.49	-0.50	-0.24	0.02	-0.05	0.35	0.38
Sentient	0.33	-0.02	-0.35	0.25	0.13	0.31	0.33	0.15	0.10	0.12	0.22	-0.31	-0.40	-0.42	-0.44	**-0.20**	**-0.43**	0.16	0.07
Sociable	0.59	0.14	-0.38	0.57	0.46	0.06	-0.04	-0.26	-0.35	-0.38	-0.47	-0.48	-0.60	-0.60	-0.78	-0.54	-0.36	-0.24	-0.21
Spiritless	-0.73	-0.61	-0.17	-0.69	-0.33	-0.72	-0.69	-0.23	-0.45	-0.33	-0.20	0.06	0.11	0.33	0.07	-0.30	-0.29	**-0.61**	**-0.33**
Spontaneous	0.41	0.16	-0.41	0.45	0.10	0.35	0.13	0.21	0.16	-0.07	0.20	**-0.38**	**-0.09**	**-0.21**	**-0.54**	0.39	0.26	-0.06	0.10
Sympathetic	0.26	0.23	-0.40	0.25	-0.03	**0.30**	**-0.11**	-0.03	0.04	-0.50	-0.36	-0.19	-0.40	-0.38	-0.39	**-0.13**	**0.17**	0.22	0.17
Synthetic	-0.56	-0.62	0.46	**-0.51**	**-0.08**	**-0.06**	**-0.49**	**-0.92**	**-0.51**	-0.57	-0.62	0.33	0.33	0.48	0.70	-0.61	-0.45	-0.78	-0.64

A.2 ANALYSIS METHODS

The aim of this section is to provide a systematic way to carry out inferential statistic analysis on the feature attributions in the feature-space resulting from the methodology described in Chapter 4. This comprises two steps. First, an initial analysis to provide statistical evidence that there is corresponding variation in the data. Second, as a result of potential difficulties interpreting the results of the principal analysis an exploratory use of factor analysis. This i) provides an interpretation of the results that is more parsimonious, facilitating easier interpretation, and ii) allows for statistical inference of the findings discussed in Chapter 5.

A.2.1 *Initial Analysis*

In the previous parts the effect of movement was measured comparing the mean-interpretations of participants' responses. This results in a general measurement to be used to compare differences in the conditions e.g. between moving an non-moving. To analyse each of the features contribution to these results an asymptotic Kruskal-Wallis test provides a method. The Kruskal-Wallis test is a non-parametric test to determine whether more than two independent groups differ (Kruskal and Wallis, 1952). It is a non-parametric equivalent of one-way ANOVA and works on the principle of ranking (Field et al., 2012, p.654).

Applying the Kruskal-Wallis test to the dataset resulting from the feature attribution to various entities or conditions determine whether the rating of each feature is significantly different between the conditions for instance whether a feature like "clunky" is rated significantly different between the moving and non-moving condition.

A.2.1.1 *Kruskal-Wallis Test*

The Kruskal-Wallis or H-test involves the ranking of the data. This is done by ordering the scores from lowest to highest, ignoring the group or condition to which the score belongs, and then assigning the lowest score a rank of 1, the next highest a rank of 2 etc. Subsequently the ranked data is put back into their associated condition and the ranks for each group are added up. The sum of ranks for each condition is denoted by R_i (where i is used to denote the condition). Once the sum of ranks is determined for each condition the test statistic H is computed as in Equation A.1 (Field et al., 2012, p.676).

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1)$$

where

$$\begin{aligned} k &= \text{the number of conditions,} \\ n_i &= \text{the number of observations for each condition,} \\ N &= \sum n_i, \text{is the total sample size,} \\ R_i &= \text{the sum of the ranks for each condition.} \end{aligned} \tag{A.1}$$

Large values of H or p-values below significance lead to the rejection of the null hypothesis (Kruskal and Wallis, 1952). Thus the feature rating for the different conditions can be considered significantly different from chance (with a probability of false rejection of 1/20) providing evidence that the feature's ratings can be attributed to different 'sources' or conditions. In other words, it indicates there is a significant difference in the distribution of a feature's rating values between conditions. However if there are more than two conditions, for example a feature rating in respect to three conditions: "no movement", "biological movement" or "mechanical movement", the Kruskal-Wallis test only indicates whether there are significant differences between all three conditions. To analyse the distribution between the individual pairs of conditions in more detail a post-hoc test needs to be considered to provide more information.

A.2.1.2 *Post-hoc Analysis*

Post-hoc tests are designed to compare the different combinations of treatment groups or conditions. They consist of a pairwise comparisons of all possible combinations and an adjustment of the level of significance for multiple comparisons (Field et al., 2012, p.447). Due to the fact that dependent variables are analysed on an ordinal scale (Likert) taken from independent groups a Mann-Whitney U pairwise comparison test is appropriate. This test is also called Wilcoxon rank-sum test (Wilcoxon, 1945) and is very similar to the Kruskal-Wallis test, above. It is a non-parametric tests based on ranked data to test the independence of two samples. It has the advantage of being used for small samples of subjects and is appropriate for groups with unequal numbers of observations (Nachar, 2008). The analysis is carried out on the ranks rather than the raw data and the null hypothesis is that the observations the samples are drawn from originate from the same group or same location (Mann and Whitney, 1947). The Mann-Whitney U test initially implies the calculation of a U statistic for each group as defined in Equation A.2 (Nachar, 2008). Consequently the null hypothesis H_0 and the alternative hypothesis H_1 is rejected if U_x or U_y is smaller than the p-threshold. In mathematical terms, reject H_0 if the p-value of $min(U_x, U_y) <$ p-threshold.

$$
\begin{aligned}
H_0 &= p(x_i > y_i) = 1/2 \\
H_1 &= p(x_i > y_i) \neq 1/2 \\
U_x &= n_x n_y + ((n_x(n_x+1))/2) - R_x \\
U_y &= n_x n_y + ((n_y(n_y+1))/2) - R_y \\
&\text{where} \\
x_i &= \text{is an observation of the first condition,} \\
y_i &= \text{is an observation of the second condition,} \\
n_x &= \text{is the number of participants in the first con,} \\
n_y &= \text{is the number of participants in the second condition,} \\
R_x &= \text{is the sum of the ranks assigned to the first condition,} \\
R_y &= \text{is the sum of the ranks assigned to the second cond.}
\end{aligned}
\tag{A.2}
$$

In other words and using the terminology of conditions and feature ratings, there is a significant difference between the conditions if the null hypothesis can be rejected as a result of the U-test, indicating that the ratings (samples) of a feature (observation) can be drawn from different movement conditions (group).

Subsequently to the pairwise comparison of each condition the false discovery rate (FDR) adjustment of the p-values is assigned. In contrast to Bonferroni-based methods designed to give strong control to the family-wise error rates, FDR is concerned with taking the proportion of falsely rejected null hypotheses under control as shown in Equation A.3 (Field et al., 2012, p.428). Thus it is reported as more powerful and less strict than Bonferroni-based methods (Benjamini and Hochberg, 1995).

$$
\text{FDR} = \frac{\text{number of falsely rejected null hypotheses}}{\text{total number of rejected null hypotheses}} \tag{A.3}
$$

The Mann-Whitney U pairwise comparison is a post-hoc test consisting of pairwise comparisons to compare all different combinations of treatment groups or conditions. It can be employed to test the significance of the differences between for instance the following three conditions: “no movement”, “biological movement” or “mechanical movement” in respect to feature ratings.

Conclusively responses are given on a Likert (ordinal) scale, thus exploring the data using the Kruskal-Wallis H-test and the U-test for post-hoc analysis, provide non-parametric methods for statistical evaluation. Both provide an analysis of the data for any between-condition difference. The first test informs whether there’s a significant difference between the conditions and in case there’s more than two conditions the posteriori analysis indicates the individual differences between conditions.

Along these lines the analysis provides an understanding of a dataset based on two tests. The first presents a method to highlight driving features or items by acquiring items that are statistically significant in respect to the whole feature-space. The second, post-hoc test reveals significant differences between treatment or conditions for each item or feature. Altogether, the number of results culminating from both tests might lead to an overwhelming number of results. It is possible that the number of result make it difficult to draw conclusions and report the measurements. Nevertheless the initial analysis expounded here provides enough statistical evidence that there is variations in the data to carry out a subsequent factor analysis with the goal of reducing the dataset to a more manageable size while retaining most of the information.

A.2.2 *Factor Analysis*

In respect to the previous analysis, the purpose of employing factor analysis as a tool to study subjects’ interpretation of entities in the feature-space here is twofold. First, to discover simple patterns or characteristics in the pattern of relationships among the feature attributions/variables. That means which of them are related an which of them are not indicated by their correlation. Characteristics that correlate, go together and constitute a factor. And second develop a parsimonious (simple) analysis and interpretation of the data to facilitate reporting of the result and to provide evidence for variations in the metaphorical interpretations through inferential statistics.

Accordingly this section describes a set of five steps to be considered in order carry out a factor analysis to a dataset resulting from feature attributions. It primarily follow the processes described in Bryman and Cramer (2002) and Field et al. (2012) consolidated into the following five steps:

> First, starting with a preliminary analysis of the data to provide assumptions to be fulfilled in order to carry out a factor analysis.
>
> Second, determine the method of extraction to resolve how the factors will be extracted.
>
> Third, delineate the criteria that specify the amount of factors to be retained.
>
> Fourth, extract the factors by a previously determined cut-off.
>
> Fifth, select a rotation method and interpret and label the factors in respect to the identified relationships amongst the items.

A.2.2.1 *Preliminary Analysis of a Dataset*

The aim of the preliminary analysis is to find out if a given dataset is suitable for factor analysis. This comprises a survey of the sample size as well as analysing the data for its factorability and criteria for removing unusable variables. Both are outlined below unifying the procedures described in Field et al. (2012) and Williams et al. (2010).

Sample Size

The adequate sample size for a factor analysis is a controversial matter and there are varying opinions. Field et al. (2012, p. 769) names a rule of thumb of 10-15 participants per variable, though stating in the same sentence that the empirical basis for that rule is unclear. On the lower end Kass and Tinsley (1979) are cited recommending having between 5 and 10 participants per variable up to a total of 300. While Tabachnick and Fidell (2007) are cited as recommending that "it is comforting to have at least 300 cases for factor analysis". While Comrey et al. (1992) consider 100 as poor, 200 as fair, 300 as good, 500 as very good, and 1000 or more as excellent.

Considering the lack of unity Williams et al. (2010) make the point that such rules of thumb can be misleading. Referring to MacCallum et al. (1999) they point out that these are just based on the sample size and not taking into account other dynamics in a factor analysis. To that effect MacCallum et al. (1999) and Guadagnoli and Velicer (1988) are cited by Field et al. (2012) to argue that despite a small sample size a factor solution can be reliable when each factor is defined several times (four or more loadings) and their loadings are high (greater than .6).

Criteria to Determine the Factorability of the Data

The factorability of the data can be determined by examining the covariance or the correlation matrix. As Williams et al. (2010) with reference to Henson and Roberts (2006) point out, the correlation matrix is most popular among investigators. To perform a factor analysis some relationships between the variables is needed. The correlation matrix provides an overview about the relationship and characteristics of the data. The factorability of these relationships are validated using Bartlett's (1951) test of sphericity to examine the fundamental variance of the data, and the *Kaiser-Meyer-Olkin* (KMO) measure to check the sampling adequacy of the data (Kaiser, 1970).

A CORRELATION MATRIX is a table of correlation coefficients informing about the relationship between the variables. The correlation coefficient presents a measure of the strength of relationship between two variables. It can be calculated following Equation A.4 (Field et al., 2012, p.209). Primarily, Tabachnick and Fidell (2007) cited by Field et al. (2012) recommend inspecting the *correlation matrix* for correlation coefficients above 0.30. If there's no correlation higher than 0.30, one should reconsider whether factor analysis is the appropriate statistical method to utilise.

$$\begin{aligned} r &= \frac{cov_{sx}}{s_x s_y} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{(N-1)s_x s_y} \\ cov_{sx} &= \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{N-1} \\ &\text{where} \\ cov_{sx} &= \text{is the covariance,} \\ s_x &= \text{the standard deviation from the first variable,} \\ s_y &= \text{the standard deviation from the second variable.} \end{aligned} \tag{A.4}$$

THE KAISER-MEYER-OLKIN (KMO) MEASURE represents the ratio of the squared correlation between variables to their squared partial correlation. It can be calculate on each individual variable or over all variables. The index resulting from its calculation ranges from 0 to 1. If the sum of partial correlation is large relative to the sum of correlation the value will approach 0. Thus indicating diffusion in the pattern and factor analysis is likely to be inappropriate. In turn values closer to 1 indicate relatively compact patterns of correlations and a factor analysis should yield to distinct and reliable factors (Field et al., 2012, p. 920). In reference to Kaiser (1974) a minimum of .5 for each variable is recommended. Variables with values below .5 should be considered to be excluded from the analysis. Removal of a variable affects the overall KMO statistics. Upon removing a variable the test should be run again. Following Hutcheson and Sofroniou's (1999) guidance Field et al. (2012) indicates the following Measure of Sampling Adequacy (MSA) resulting from the average of all variables and their suitability for factor analysis:

> .5 to .7 is mediocre,
> .7 to .8 is good,
> .8 to .9 is great,
> above .9 is "superb"(Field et al., 2012, p. 770).

BARTLETT'S TEST examines whether a correlation matrix is proportional to an identity matrix. As Field et al. (2012, p. 770) point out there's a problem if the correlations are to high or to low, the former indicating singularity (variables are perfectly correlated) and the latter an identity matrix (variables are totally independent). For the latter Bartlett's (1951) test of sphericity provides a measurement for the overall correlation between the variables. If the *Bartlett's test* is significant the null hypothesis can be rejected, the correlations are not to low thus the matrix is not an identity matrix. The opposite problem when variables correlate too high (multicollinearity or singularity) can be detected by looking at the determinant of the matrix. Field et al. (2012, p. 771) proposes the determinant of the matrix should be greater than 0.00001. Thus if the *Bartlett's test* is significant and the determinants of the matrix is $> 1.0e-5$ the overall correlation between the items is sufficient for factor analysis.

A.2.2.2 *Types of Factor Analysis and Methods of Extraction*

In this section the underlying nature of factor analysis and its common methods for extraction are described. First the basic approaches to set apart two types of factor extraction are differentiated. Subsequently elemental principles of factor analysis used for factor extraction are delineated to finally review the two most common methods to find and extract dimensions from a dataset: principal factor analysis (PAF) and principal components analysis (PCA) (See Williams et al., 2010, referring to Henson and Roberts, 2006; Tabachnick and Fidell, 2007 for additional methods).

Type of Factor Analysis

Bryman and Cramer (2002, p. 262) and in equal measures Field et al. (2012, p. 758) distinguish two types of factor analysis. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). The latter, CFA, is based on a priori dispositions and theories about the dataset. The investigator aims to compare the solution against prior specified structures and relationships about the variables. It is commonly employed by research interested in hypothesis testing as it presents a technique to determine to which extent a result fits or confirms a particular model. While in the former, the most commonly reported EFA, allows the researcher to explore dimensions in the data and generate a theory. In EFA the investigator has no expectations of the number or nature of the variables and the aim is to explore the relationships between them. EFA's heuristic is used to inform researchers about patterns within a data set and guide future hypotheses.

Method of Extraction

Generally, factor analysis is primarily concerned with describing the variance which is shared by the scores of people on three or more variables. This variance is referred to as *common variance* and Bryman and Cramer (2002, p. 264) distinguishes it from *unique variance* using the example variable x,y,z and the Venn diagram shown in Figure A.3.

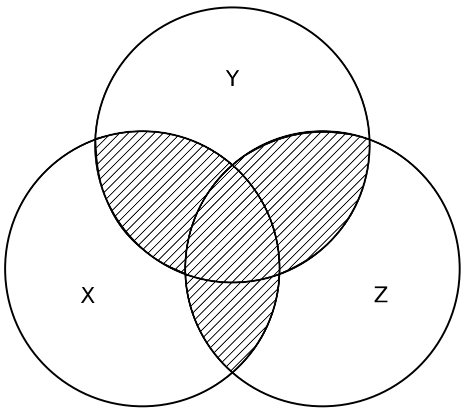


Figure A.3: Venn diagram illustrating *common variance* (shaded parts shared between two or more variables) and *unique variance* (unshaded part attributed only to one variable). Figure reproduced from Bryman and Cramer (2002, p. 264)

The shaded part shared between two or more variables represents the *common variance* while the unshaded is the *unique variance* of each variable referring to the variance that can be reliably attributed to only one measure. Additionally, there is also a variance that is specific to one measure but not reliably so, labelled as random or *error variance* (Field et al., 2012, p. 759). The total variation to assess a particular variable can be partitioned as denominated in Equation A.5 (Bryman and Cramer, 2002, p. 264).

$$\text{Total variance} = \text{Common} + \text{Unique} + \text{Error variance} \tag{A.5}$$

The proportion of *common variance* present in a variable is known as the *communality*, the proportion of variance that each item has in common with other items. As such, a variable that shares none of its variance with any other variable would have a communality of 0, while a variable without specific variance a communality of 1 (Field et al., 2012, p. 759).

THE DIFFERENCE BETWEEN THE METHODS OF EXTRACTION is essentially how they handle *unique variance* (Bryman and Cramer, 2002, p. 265). In principal axis factoring (PAF) only the *common variance*, the variance that is shared between the variables is analysed while in principal component analysis (PCA) all the variance of a variable is analysed, including its *unique variance*. In conclusion, the latter, PCA, is usually favoured as a method when the goal is data reduction. For instance when reducing a set of variables down to a smaller number of factors and to create composite scores for these factors for use in subsequent analysis. While the former, PAF, is usually preferred when the goal is theoretical explorations of the underlying factor structure.

In terms of the two methods, PCA and PAF, Field et al. (2012) indicate that the quality of both are widely discussed for example in Widaman et al. (2007) and referring to literature review from Guadagnoli and Velicer (1988) they conclude that the solutions generated from principal components analysis differ little from those derived from factor analysis techniques. Correspondingly Williams et al. (2010) acknowledge citing Guadagnoli and Velicer (1988) and Mulaik (1990), that there is almost no difference between the solution generated from both methods.

A.2.2.3 *How Many Factors to Retain*

This section explains defining criteria for deciding the number of factors to be retained in a factor analysis. Bryman and Cramer (2002) and Field et al. (2012) specify two common methods, both based on the eigenvalue as a measure to determine and reduce the number of factors to extract. One graphical known as the *Scree-test* (Cattell, 1966), and one mathematical, established as *Kaiser's eigenvalue-greater-than-one rule* (Kaiser, 1960). A detailed description of additional and more complex methods can be found in Ledesma and Valero-Mora (2007) and Zwick and Velicer (1986).

THE EIGENVALUES of factors provide an underlying measure. The basic idea for extracting factors is to retain the variables or factors with relatively large eigenvalues and reject the small ones. Thus primary to resolving the amount of factors to be preserved from a data set the eigenvalues of the *correlation matrix* are computed. The eigenvalues associated with each component or factor represent the variance explained by that particular linear component. In both of the consecutive methods the eigenvalues, as a measure of their contribution or importance to a factor, are used to determine which variables to exclude and which to retain.

Kaiser's Eigenvalue-greater-than-one Rule

Kaiser's rule is based on setting a threshold or criterion for the levels of eigenvalues. Resultant from the calculation of the eigenvalues, the criterion provides a method for selecting the amount of factors by preserving factors with eigenvalues > 1.0 (Kaiser, 1960, cited by Bryman and Cramer, 2002; Field et al., 2012). In equal measures the Jolliffe criterion retains factors with eigenvalues > .7 (Jolliffe, 1972, cited by Bryman and Cramer, 2002; Field et al., 2012). In respect of the eigenvalues' quality to specify factor reduction, Field et al. (2012) with reference to Nunnally and Bernstein (1994) points out, an eigenvalue of 1 reveals the factor explains as much variance as a variable. In this way it counteracts the intention of the analysis to reduce the original variables into more substantial underlying factors. Thus applying Kaiser's criterion often overestimates the number of factors and Jolliffe's criterion is even worse in that respect. Additionally, as with all mechanical rules, it can lead to arbitrary results when regarding a factor with eigenvalues of 1.01 as considerable and one with .99 as insignificant.

Scree-test

The scree-test is based on the analysis of the graphical representation of the eigenvalues and their corresponding factor, known as scree-plot. Field et al. (2012) with reference to Cattell (1966) specifies the amount of factors to retain by the point of inflexion in the curve of the scree-plot. The scree-plot is employed to indicate these leveling-off points. The point of inflexion is denoted by the spot where the slope of the line changes dramatically. The factors at the right are "factorial scree" – the terminology of "scree" comes from geology and is referring to the debris which collects on the lower part of a rocky slope. The factors at the left of the point of inflexion are the factors to be retained and do not include the factor at the point of inflexion itself (Field et al., 2012, p. 762).

As Williams et al. (2010) with reference to Pett et al. (2003) denote, the graphical analysis of the scree-plot over which factors should be retained is often open for debate. Depending on the shape of the graph it might be difficult to interpret unambiguously as the definition of the cut-off point between important and trivial factors is not as objective as in the mathematical solution provided by *Kaiser's rule*. Yong and Pearce (2013) indicated that an important aspect in finding a solution is the extent to which it is interpretable. Thus if both methods result in ambiguous factor solutions, the subsequent analysis is conducted on several solutions with more or fewer factors to compare the results (Field et al., 2012, p. 782).

A.2.2.4 *Extraction of Factors*

This section outlines the extraction of the previously determined amount of factors from a dataset. This comprises delineating the principle of factor loadings, consequently what threshold should be used for factor loading cut-off, followed by three criteria to be put into use for validating the amount of factors extracted.

Factor Loadings and Their Cut-off

Factor loadings represent the strength of the correlation between the variable and the factor, consequently indicate how much the variable has contributed to a factor, the higher the value, the higher the contribution. Factor loadings tell us about the relative contribution that a variable makes to a factor (Field et al., 2012, p. 755). Mathematically, a factor can be represented by a model as specified in Equation A.6 (Field et al., 2012, p. 753, and Yong and Pearce, 2013, p. 81).

$$
\begin{aligned}
&F_i = \sum_{k=1}^{n} b_k \, V_{ki} + \varepsilon_i \qquad (i = 1, 2, \ldots, p) \\
&\text{where} \\
&\quad F = \text{is the factor } i, \\
&\quad V = \text{are the variables/features}, \\
&\quad n = \text{are the number of variables}, \\
&\quad b_k = \text{are the factor loadings}, \\
&\quad \varepsilon_i = \text{is the residual of } F_i, \\
&\quad p = \text{is the number of underlying factors.}
\end{aligned}
\tag{A.6}
$$

The *factor loadings* are b_1, b_2, $\ldots$, b_n which denotes that b_1 is the *factor loading* of nth variable on the 1st factor. The factor loadings are expressed in the elements of eigenvectors. Loadings are the unstandardised eigenvectors' elements, i.e. eigenvectors endowed by corresponding component variances, or eigenvalues. The weights of each variable on the factor and their largest eigenvalues provide an indicator of their substantive importance on each factor. The relative importance b of each variables to a factor is expressed in how much they score or contribute to that factor.

THRESHOLD FOR FACTOR LOADING is generally determined by the variables/items which load most highly on it. The level of the value determining the cut-off for a loading of an item to be interpreted as part of the factor is a matter of researchers preference. Yong and Pearce (2013) citing Osborne and Costello (2009) suggest a solid factor is indicated by strongly loading items with loadings of 0.50 or better as desirable. However, as they state, there is no gold standard for the significance level of factor loadings. The cut-off value to determine which items to ignore when interpreting a factor is arguable. Bryman and Cramer (2002, p. 269) points out that the level not only depends on the sample size. Selecting the appropriate level is complicated by the fact that for a great extend the correlations have been computed on data coming from the same participants. As a solution they provide two conventions engendering a stringent set to decide which variables should be included on which factor. The first, noted as the more conventional, determines the level based on the sample size, and the second is using the correlation above which no items correlates highly with more than one factor.

The asset of the latter convention is factors are interpreted in terms of items unique to them. Thus their meaning should be less ambiguous. Occasionally, if there are gaps in the loadings across factors and the cut-off is in the gap it simplifies assigning the variables to the specific factors. In other occasions the cut-off is selected because one can interpret factors with that cut-off but not with a lower cut-off (Bryman and Cramer [2002], referring to Tabachnick and Fidell [2007, p. 654]).

In respect to the former convention, Bryman and Cramer (2002, p. 269) denote that most commonly variables with correlation below 0.30 are omitted from consideration. Accounting for less than 9% of the variance they are considered to be not important. In equal measures Yong and Pearce (2013) citing Tabachnick and Fidell (2007) indicate to be statistically meaningful, factor loadings lower than 0.32 require a sample size of at least 300. On that score suggested significances of factor loadings in respect to a range of sample sizes are listed in Table A.3.

Table A.3: Significant factor loadings in respect to sample size (Hair Jr. et al., 1995)

Factor Loading	Sample Size
0.30	350
0.35	250
0.40	200
0.45	150
0.50	120
0.55	100
0.60	85
0.65	70
0.70	60
0.75	50

Field et al. (2012) advocate the suggestion of Guadagnoli and Velicer (1988) to regard a factor as reliable if it has four or more loadings of at least 0.6 regardless of sample size. Similarly, irrespective of sample size Stevens (1996) suggests a significance level of 0.4 for the cut-off. Williams et al. (2010) referring to Tabachnick and Fidell (2007) suggest using more stringent cut-offs, in particular when the items have different frequency distributions:

0.32 (poor),
0.45 (fair),
0.63 (very good),
0.71 (excellent).

Criteria for Validating the Amount of Factors

There are three criteria for inspecting whether the correct number of factors are extracted which are subsequently explained. One attributable to *Kaiser's criterion*, another based on the *residuals* probing the fit of the model, and one resting on the *cumulative percentage of variance* explained by the amount of factors selected.

KAISER'S CRITERIA is essentially using *Kaiser's rule* stated above in Paragraph A.2.2.3 to validate the amount of factors after extraction. It suggest to drop all components with eigenvalues under 1.0 (Kaiser, 1960, cited by Field et al., 2012). This value is based on the idea that an eigenvalue of 1 represents a substantial amount of variation. Kaiser's criterion is additionally considered correct when there are fewer than 30 variables and the *communalities*, the proportion of variance that each item has in common with other items, after the extraction are greater than .7 or at sample size above 250 the average *communality* is greater than .6 (see also Stevens, 1996, cited by Bryman and Cramer, 2002, p. 267).

THE RESIDUALS provide another check for the appropriateness of the respective number of factors extracted. The residuals result from the difference between the reproduced and actual correlation matrices. The reproduced correlation matrix is the correlation matrix that result from the loadings of the reduced factors. To see how the matrices deviate, the difference between the two is computed. The guide line for suitability is fewer than 50% of the residuals should have absolute values greater than 0.05. Additionally the sum of the squared residuals divided by the sum of the squared correlations is considered as a measure of fit. Here the guide is the model fit should be greater than 0.90 (Field et al., 2012, p. 787).

CUMULATIVE PERCENTAGE OF VARIANCE is another measurement. The criterion for a threshold is an area of disagreement (Williams et al., 2010). No fixed threshold exists but certain percentages coming from different disciplines have been suggested. In natural science factors should be stopped when at least 95% of the variance is explained. In humanities, the explained variance is commonly as low as 50-60% ([Hair Jr. et al., 1995; Pett et al., 2003], cited by Williams et al. [2010]).

A.2.2.5 *Factor Rotation and Interpretation*

At the outset this section describes the process of factor rotation to improve the interpretation of the previously extracted factors. Followed by a measure to verify the rotated factors reliability. And ultimately the interpretation, involving the examination which variables are attributable to a factor, and giving that factor a name or theme.

Methods for Factor Rotation

The rotation of factors is aiming to improve interpretation. When extracting factors, the first factors typically account for a maximum amount of variance. Respectively, in an unrotated factors solution most of the variables characteristically will fall on the first factors. Thus unrotated factors can be ambiguous since subsequent factor do not correlate as highly as they might and what they represent might not be easy to interpret. In order to increase factor interpretability the variance accounted for by a factor is spread out. Through rotation the first factor no longer accounts for the maximum variance possible as the variance is distributed to other factors. The total variance accounted for stays the same. Thus to attain an optimal simple structure, rotation attempts to have each variable load on the minimum amount of factors while maximising the number of high loadings on each variable.

There are various methods for rotation. The two most commonly used are orthogonal (common technique is varimax) or oblique rotation (commonly oblimin or promax) (Bryman and Cramer, 2002, p. 268). The former produces factors that are rotate 90°to each other, assuming that the resultant factors are unrelated to each other. The latter provides solutions allowing factors to correlate as the factor axes are not forced to remain perpendicular (Field et al., 2012, p. 765).

Which method to choose depends on whether there are theoretical grounds suggesting the underlying factors are independent of each other (orthogonal to each other) or they might correlate. Bryman and Cramer (2002) point out that the advantage of an orthogonal rotation is that as a result the information the factors provide is not redundant. The scores of one factor are maximal possible unrelated to scores on other factors due to the specified 90°rotation between the axis. The detriment of this method though is that the factors may have been forced to be unrelated. This is problematic in particular in fields of social science as any factor is to some extent related to other factors. Thus forcing the factors to be orthogonal may distort the findings. Such patterns of uncorrelated axes should emerge naturally out of an oblique rotation (Bryman and Cramer, 2002). Likewise Field et al. (2012, p. 767) remark that naturalistic data, for instance data involving humans, is not very appropriate for orthogonal rotations.

Measure Reliability of Factors

In factor analysis reliability is meaningful when validating or constructing dimensions (Yong and Pearce, 2013). Reliability refers to the consistency of a measure. It is used to test whether a measure, for instance taken by a questionnaire, is consistent in terms of the dimensions that it is measuring. If a measure is reliable the result produced by a set or individual variables are consistent within the overall questionnaire (Field et al., 2012, p. 798).

Hence in respect to factor analysis reliability informs whether the variables that make up a factor are internally consistent and how reliable is each of the measured variables in respect of that factor. Bryman and Cramer (2002) and Field et al. (2012) refer to two procedures to measure reliability. The first is *split half-reliability* and the other *Cronbach's alpha*.

For the former, *split half-reliability*, a dataset is split randomly into two, followed by computing a score for each participant for each half. If the scale is reliable a person's score should be nearly the same for both halves, and across several participants the scores of both halves should correlate highly. Consequently the relationship between the two halves across the participants is expressed in a correlation coefficient, which varies between 0 and 1. Large correlations, the nearer the result is to 1, are considered as a sign of reliability. The problem with this method is the uncertainty of splitting the data. As Field et al. (2012, p. 798) points out, there are several ways to separate the data and the result could be a consequence of the way the data was split.

Employing *Cronbach's alpha*, the dilemma of separating the data affecting the result is overcome by providing a method that can be considered similar to computing the correlation coefficient for every possible ways to split the data (Field et al., 2012, p. 798). *Cronbach's alpha* essentially calculates the average of all correlation coefficients (Bryman and Cramer, 2002, p. 63). It is widely used and considered the most common measure of scale reliability. *Cronbach's Alpha* in mathematical terms, denoted as α, is delineated in Equation A.7 (Field et al., 2012, p. 798).

$$\alpha = \frac{N^2\ \overline{Cov}}{\sum s^2_{item} + \sum Cov_{item}}$$

$$\begin{aligned} &\text{where} \\ N &= \text{is number of items,} \\ \overline{Cov} &= \text{average covariance between items,} \\ s_{item} &= \text{item variances,} \\ Cov_{item} &= \text{item covariances.} \end{aligned} \tag{A.7}$$

The reliability measure α varies correspondingly to the *split half-reliability* from 0 to 1. Commonly $\alpha - values$ of 0.7 to 0.8 are referred to as being acceptable but Field et al. (2012) with reference to Cortina (1993) remark that such general guidelines should be used with caution. The size of the α value depends one the number of variables or items. As Equation A.7 indicates, the nominator for calculating the α value depends on the number of items squared. Thus large amounts of items or variables result in larger $\alpha - values$. In addition Bryman and Cramer (2002, p. 63) point out if a factor analysis confirms that a measure comprises a number of dimensions *Cronbach's alpha* will probably exhibit a low level of internal reliability. Cut-off values for the $\alpha - values$ are context dependent. The generally accepted value of 0.8 is useful for instance in cognitive tests while for ability tests 0.7 is considered more suitable and values below 0.7 can be expected when dealing with psychological constructs (Kline, 2013, cited by Field et al., 2012).

Factor Interpretation

Factor interpretation requires examining the previously acquired rotated factor solution. It involves investigating which variables are attributable to a factor, and assigning a name or label to them. It is considered a process that involves art as well as science (Tabachnick and Fidell, 2007, p. 654).

The pattern matrix resulting from a rotated factor solution with a predetermined cut-off facilitates to identify isolated items that measure similar dimensions. These dimensions are determined by subsuming variables that correlate highly with a group of other variables without correlating with variables outside that group. Thus each dimension is constituting a factor representative for the underlying variables. Generally, for something to constitute a factor it should have at least 3 variables or items (Tabachnick and Fidell, 2007, cited by Yong and Pearce, 2013). As a general guide, rotated factors that have 2 or fewer variables should be interpreted with caution. A factor with 2 variables is regarded reliable when the variables' loading is above 0.7 and fairly uncorrelated with other variables. In equal measures, a factor with fewer than three variables is considered weak and unstable (Osborne and Costello, 2009).

When a set of factor loadings corresponding to a factor has been identified the next step is to try to interpret and name them in a manner that will provide a reasonable summary of the data. There are no rules for naming factors, except applying names to the factor that fit best the underlying variables (Yong and Pearce, 2013). However, the constructs constituting a factor and their labels should reflect the theoretical and conceptual intent of the work (Williams et al., 2010).

A.2.2.6 *Factor Analysis Conclusion*

This section explained in five steps an exploratory use of factor analysis bringing together knowledge from various sources. The outlined procedure provides a method to determine the degree to which observed variables can be explained by a smaller number of variables called factors with the main objective to provide easier interpretation of results, produce a solution that is more parsimonious, and facilitate inferential statistical analysis .

However, the application of factor analysis is not without controversy or criticism. These criticism mainly apply to the heuristic nature of explanatory factor analysis (Henson and Roberts, 2006; Thompson, 2004, cited by Williams et al., 2010). The subjectiveness originating from the fact that more than one interpretation can be made of the same data factored the same way. To strengthen this deficiency it requires a series of thoughtful researcher judgements and making informed decisions. In that respect this section provides a structured and grounded procedure on two-levels. On the one hand defining the process of exploring and reducing a data set from a group of interrelated variables into a smaller set of factors in steps provides various levels to make possible subjectiveness transparent, and on the other various generally accepted criteria to validate and measure the reliability of the factors are implemented.

A.3 additional information for chapter 5

Section 5.2.3: inferential statistics

Table A.4 lists the results from the Kruskal-Wallis test and Mann Whitney U pairwise comparison. Table A.5 shows the correlation matrix of the features from the feature-set.

Section 5.2.3: Factor Analysis

unrotated factor models: the solution with three factors is shown in Table A.6 and the six factor solution in Table A.7.

rotated factor models: the rotated solution with three factors is shown in Table A.8 and the six factor solution in Table A.10.

factor reliability measures: the Cronbach's alpha calculation for the first factor is listed in Table A.11, for the second factor in Table A.12 and for the third factor in Table A.13.

Table A.4: Results from the Kruskal-Wallis test and Mann Whitney U pairwise comparison for the ratings of the features in the feature-space.

Feature	Descriptive statistics by movement type Mov Type	Mean	SD	Asymptotic Kruskal-Wallis Test	post hoc Mann-Whitney U pairwise comparison	p val (fdr corrected)
Organic	Mechanical	2.45	1.47	$\chi^2(2,57) = 4.0, p = .13$	Biol. — Mech.	0.144
	Biological	3.68	1.97		None — Mech.	0.548
	None	2.9	1.89		None — Biol.	0.303
Instrumental	Mechanical	4.2	1.06	$\chi^2(2,57) = 0.9, p = .63$	Biol. — Mech.	0.651
	Biological	4.26	1.24		None — Mech.	0.651
	None	4.35	2.23		None — Biol.	0.651
Clunky	Mechanical	4.35	1.50	$\chi^2(2,57) = 7.0, p = .03$ *	Biol. — Mech.	0.427
	Biological	4.11	1.56		None — Mech.	0.078
	None	5.3	1.59		None — Biol.	0.046 *
Efficient	Mechanical	3.95	1.32	$\chi^2(2,57) = 14.7, p = .0006$ ***	Biol. — Mech.	0.344
	Biological	3.63	1.42		None — Mech.	0.002 **
	None	5.35	1.39		None — Biol.	0.002 **
Spiritless	Mechanical	3	1.45	$\chi^2(2,57) = 8.8, p = .01$ *	Biol. — Mech.	0.909
	Biological	3.05	1.75		None — Mech.	0.023 *
	None	4.25	1.33		None — Biol.	0.023 *
Sociable	Mechanical	4.25	1.83	$\chi^2(2,57) = 5.5, p = .06$	Biol. — Mech.	0.278
	Biological	3.58	1.54		None — Mech.	0.085
	None	2.85	1.63		None — Biol.	0.22
Goal driven	Mechanical	4.05	1.61	$\chi^2(2,57) = 0.34, p = .84$	Biol. — Mech.	0.807
	Biological	4.32	1.53		None — Mech.	0.807
	None	4.4	2.14		None — Biol.	0.807
Aware	Mechanical	4.35	1.81	$\chi^2(2,57) = 10.1, p = .006$ **	Biol. — Mech.	0.931
	Biological	4.26	1.45		None — Mech.	0.012 *
	None	2.85	1.50		None — Biol.	0.012 *
Creepy	Mechanical	5.75	1.45	$\chi^2(2,57) = 30.2, p = 2.8e-07$ ***	Biol. — Mech.	0.186
	Biological	5.21	1.47		None — Mech.	0.000 ***
	None	2.65	1.42		None — Biol.	0.000 ***
Aggressive	Mechanical	4.6	1.43	$\chi^2(2,57) = 6.5, p = .040$ *	Biol. — Mech.	0.409
	Biological	3.95	1.99		None — Mech.	0.027 *
	None	3.1	2.02		None — Biol.	0.253
Synthetic	Mechanical	5.3	1.22	$\chi^2(2,57) = 3.27, p = .20$	Biol. — Mech.	0.446
	Biological	5.26	0.93		None — Mech.	0.446
	None	5.6	1.10		None — Biol.	0.224
Logical	Mechanical	3.45	1.36	$\chi^2(2,57) = 15.44, p = .0004$ ***	Biol. — Mech.	0.081
	Biological	2.74	1.10		None — Mech.	0.015 *
	None	4.7	1.72		None — Biol.	0.001 **
Sensitive	Mechanical	4.25	1.62	$\chi^2(2,57) = 9.0, p = .011$ *	Biol. — Mech.	0.132
	Biological	3.26	1.41		None — Mech.	0.012 *
	None	2.55	1.70		None — Biol.	0.153
Spontaneous	Mechanical	5.1	1.52	$\chi^2(2,57) = 30.0, p = 3.1e-07$ ***	Biol. — Mech.	0.287
	Biological	5.58	1.22		None — Mech.	0.000 ***
	None	2.25	1.52		None — Biol.	0.000 ***
Lonely	Mechanical	4.35	1.79	$\chi^2(2,57) = 3.66, p = .16$	Biol. — Mech.	0.228
	Biological	3.37	1.95		None — Mech.	0.204
	None	3.4	1.73		None — Biol.	0.966
Creative	Mechanical	5.8	1.24	$\chi^2(2,57) = 30.25, p = 2.7e-07$ ***	Biol. — Mech.	0.977
	Biological	5.74	1.37		None — Mech.	0.000 ***
	None	2.8	1.44		None — Biol.	0.000 ***
Controllable	Mechanical	3.15	1.35	$\chi^2(2,57) = 19.65, p = 5.4e-05$ ***	Biol. — Mech.	0.873
	Biological	3.11	1.66		None — Mech.	0.000 ***
	None	5.25	1.29		None — Biol.	0.000 **
Sympathetic	Mechanical	3.65	1.73	$\chi^2(2,57) = 3.53, p = .17$	Biol. — Mech.	0.977
	Biological	3.58	1.26		None — Mech.	0.185
	None	2.75	1.65		None — Biol.	0.185
Caring	Mechanical	3.9	1.02	$\chi^2(2,57) = 4.49, p = .11$	Biol. — Mech.	0.065
	Biological	3.11	1.20		None — Mech.	0.594
	None	3.65	1.76		None — Biol.	0.395
Devious	Mechanical	4.65	1.57	$\chi^2(2,57) = 15.48, p = .0004$ ***	Biol. — Mech.	1
	Biological	4.42	1.87		None — Mech.	0.001 **
	None	2.55	1.54		None — Biol.	0.003 **
Productive	Mechanical	3.7	0.98	$\chi^2(2,57) = 2.97, p = .23$	Biol. — Mech.	0.545
	Biological	3.84	1.64		None — Mech.	0.255
	None	4.4	1.70		None — Biol.	0.479
Sentient	Mechanical	4.75	1.55	$\chi^2(2,57) = 15.46, p = .0004$ ***	Biol. — Mech.	0.581
	Biological	4.53	1.31		None — Mech.	0.001 **
	None	2.9	1.55		None — Biol.	0.001 **
Complex	Mechanical	5.25	1.21	$\chi^2(2,57) = 16.53, p = .0003$ ***	Biol. — Mech.	0.084
	Biological	4.26	1.76		None — Mech.	0.000 ***
	None	2.8	1.85		None — Biol.	0.017 *

Table A.5: Empirical study: correlation matrix of the features from the feature-set

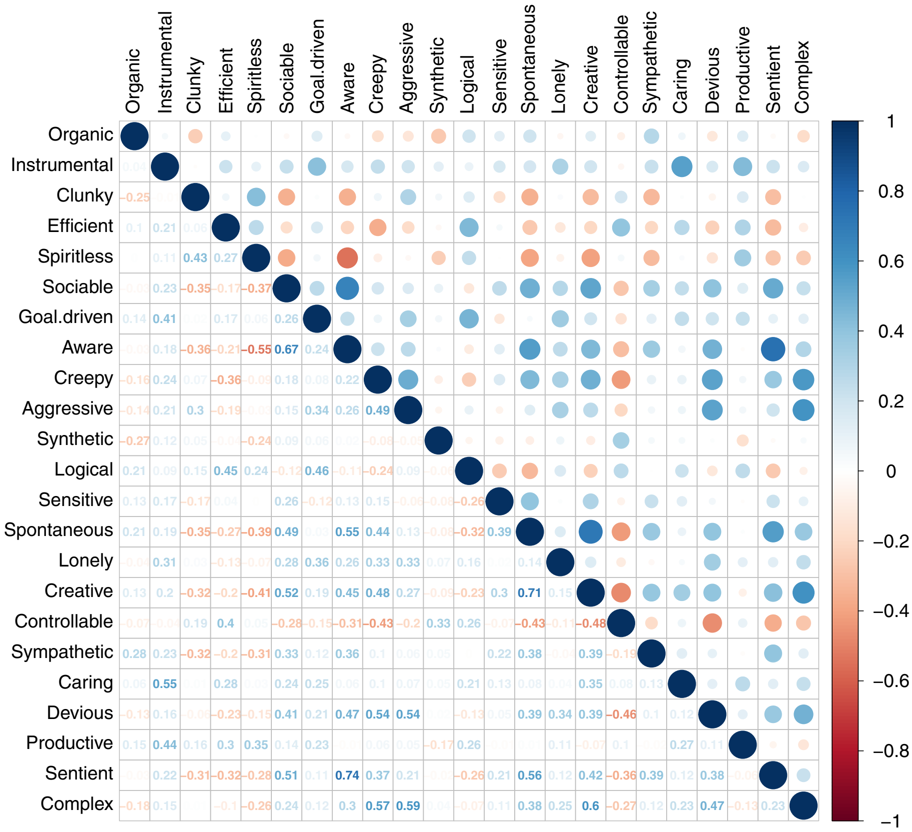


Table A.6: R output for the three-factor model based upon the correlation matrix and the communalities (h2).

```
Call: principal(r = featuresMatrix, nfactors = 3, rotate = "none")
Standardized loadings (pattern matrix) based upon correlation matrix
             item   PC1   PC2   PC3   h2   u2  com
Creative       15  0.79 -0.06  0.07 0.64 0.36  1.0
Spontaneous    13  0.78 -0.20  0.15 0.68 0.32  1.2
Aware           8  0.76 -0.06  0.21 0.63 0.37  1.2
Sentient       20  0.72 -0.14  0.10 0.55 0.45  1.1
Sociable        6  0.69  0.00  0.30 0.57 0.43  1.4
Devious        18  0.66  0.31 -0.26 0.60 0.40  1.8
Creepy          9  0.63  0.26 -0.43 0.65 0.35  2.2
Complex        21  0.60  0.25 -0.36 0.55 0.45  2.0
Controllable   16 -0.58  0.04  0.18 0.37 0.63  1.2
Spiritless      5 -0.49  0.44 -0.06 0.44 0.56  2.0
Sympathetic    17  0.47 -0.19  0.42 0.44 0.56  2.3
Sensitive      12  0.30 -0.19  0.22 0.18 0.82  2.6
Goal.driven     7  0.24  0.63  0.35 0.58 0.42  1.9
Aggressive     10  0.45  0.57 -0.39 0.67 0.33  2.7
Logical        11 -0.30  0.56  0.39 0.55 0.45  2.4
Productive     19 -0.05  0.55  0.38 0.45 0.55  1.8
Instrumental    2  0.30  0.52  0.37 0.49 0.51  2.5
Lonely         14  0.35  0.48 -0.04 0.36 0.64  1.8
Clunky          3 -0.36  0.48 -0.46 0.57 0.43  2.8
Organic         1  0.01 -0.07  0.58 0.35 0.65  1.0
Efficient       4 -0.41  0.33  0.46 0.49 0.51  2.8

                       PC1  PC2  PC3
SS loadings           5.77 2.75 2.27
Proportion Var        0.27 0.13 0.11
Cumulative Var        0.27 0.41 0.51
Proportion Explained  0.53 0.25 0.21
Cumulative Proportion 0.53 0.79 1.00

Mean item complexity =  1.9
Test of the hypothesis that 3 components are sufficient.

The root mean square of the residuals (RMSR) is  0.09

Fit based upon off diagonal values = 0.91

Residuals:
Number of absolute residuals > 0.05 =  111
Proportion of absolute residuals > 0.05 =  0.529
Fit based upon off diagonal values = 0.91
```

Table A.7: R output for the six-factor model based upon the correlation matrix and the communalities (h2).

```
Call: principal(r = featuresMatrix, nfactors = 6, rotate = "none")
Standardized loadings (pattern matrix) based upon correlation matrix
             item   PC1   PC2   PC3   PC4   PC5   PC6   h2   u2  com
Creative       15  0.79 -0.06  0.07  0.14  0.28  0.24 0.79 0.21  1.5
Spontaneous    13  0.78 -0.20  0.15  0.25  0.08  0.05 0.75 0.25  1.5
Aware           8  0.76 -0.06  0.21 -0.35 -0.29 -0.04 0.83 0.17  1.9
Sentient       20  0.72 -0.14  0.10 -0.03 -0.27 -0.21 0.67 0.33  1.6
Sociable        6  0.69  0.00  0.30 -0.15 -0.34 -0.01 0.70 0.30  2.0
Devious        18  0.66  0.31 -0.26 -0.03 -0.06 -0.14 0.62 0.38  1.9
Creepy          9  0.63  0.26 -0.43  0.30  0.09 -0.01 0.74 0.26  2.7
Complex        21  0.60  0.25 -0.36 -0.01  0.24  0.50 0.86 0.14  3.4
Controllable   16 -0.58  0.04  0.18 -0.15 -0.28  0.48 0.70 0.30  2.8
Spiritless      5 -0.49  0.44 -0.06  0.49  0.00 -0.30 0.77 0.23  3.7
Sympathetic    17  0.47 -0.19  0.42  0.00  0.24 -0.05 0.49 0.51  2.9
Goal.driven     7  0.24  0.63  0.35 -0.29  0.16 -0.12 0.70 0.30  2.7
Aggressive     10  0.45  0.57 -0.39 -0.12  0.17  0.10 0.72 0.28  3.1
Logical        11 -0.30  0.56  0.39 -0.36  0.28  0.07 0.76 0.24  3.8
Productive     19 -0.05  0.55  0.38  0.34 -0.26 -0.20 0.67 0.33  3.4
Instrumental    2  0.30  0.52  0.37  0.29 -0.24  0.06 0.63 0.37  3.7
Lonely         14  0.35  0.48 -0.04 -0.19 -0.14 -0.04 0.42 0.58  2.4
Clunky          3 -0.36  0.48 -0.46  0.15 -0.02  0.00 0.60 0.40  3.1
Sensitive      12  0.30 -0.19  0.22  0.61 -0.12  0.32 0.66 0.34  2.8
Organic         1  0.01 -0.07  0.58  0.16  0.59 -0.19 0.76 0.24  2.4
Efficient       4 -0.41  0.33  0.46  0.09 -0.06  0.47 0.72 0.28  3.9

                       PC1  PC2  PC3  PC4  PC5  PC6
SS loadings           5.77 2.75 2.27 1.47 1.19 1.12
Proportion Var        0.27 0.13 0.11 0.07 0.06 0.05
Cumulative Var        0.27 0.41 0.51 0.58 0.64 0.69
Proportion Explained  0.40 0.19 0.16 0.10 0.08 0.08
Cumulative Proportion 0.40 0.58 0.74 0.84 0.92 1.00

Mean item complexity =  2.7
Test of the hypothesis that 6 components are sufficient.

The root mean square of the residuals (RMSR) is  0.06

Fit based upon off diagonal values = 0.96

Residuals:
Number of absolute residuals > 0.05 =  84
Proportion of absolute residuals > 0.05 =  0.4
Fit based upon off diagonal values = 0.96
```

Table A.8: R output of the pattern matrix with principal component analysis (PCA) method and oblique rotation for the three-factor model with a cut-off of .50 for the factor loadings.

```
Call: principal(r = featuresMatrix, nfactors = 3, rotate = "promax")
Standardized loadings (pattern matrix) based upon correlation matrix
             item   RC1    RC3    RC2    h2    u2  com
Clunky          3  -0.77                0.57  0.43  1.6
Spontaneous    13   0.75                0.68  0.32  1.1
Aware           8   0.71                0.63  0.37  1.2
Sympathetic    17   0.69                0.44  0.56  1.2
Sociable        6   0.69                0.57  0.43  1.2
Sentient       20   0.64                0.55  0.45  1.2
Creative       15   0.64                0.64  0.36  1.5
Spiritless      5  -0.58                0.44  0.56  1.5
Sensitive      12                       0.18  0.82  1.1
Aggressive     10          0.84         0.67  0.33  1.2
Creepy          9          0.78         0.65  0.35  1.0
Complex        21          0.71         0.55  0.45  1.0
Devious        18          0.70         0.60  0.40  1.1
Lonely         14                       0.36  0.64  1.8
Organic         1                       0.35  0.65  2.8
Controllable   16                       0.37  0.63  2.2
Goal.driven     7                 0.71  0.58  0.42  1.3
Logical        11                 0.68  0.55  0.45  1.2
Productive     19                 0.67  0.45  0.55  1.0
Instrumental    2                 0.63  0.49  0.51  1.4
Efficient       4                 0.55  0.49  0.51  1.8

                       RC1   RC3   RC2
SS loadings           4.53  3.69  2.57
Proportion Var        0.22  0.18  0.12
Cumulative Var        0.22  0.39  0.51
Proportion Explained  0.42  0.34  0.24
Cumulative Proportion 0.42  0.76  1.00

With component correlations of
       RC1    RC3    RC2
RC1   1.00   0.33  -0.07
RC3   0.33   1.00  -0.01
RC2  -0.07  -0.01   1.00

Mean item complexity =  1.4
Test of the hypothesis that 3 components are sufficient.

The root mean square of the residuals (RMSR) is  0.09

Fit based upon off diagonal values = 0.91
```

Table A.9: R output of the pattern matrix with principal axis factoring (PAF) method and oblique rotation for the three-factor model.

```
Factor Analysis using method =  pa
Call: fa(r = featuresMatrix, nfactors = 3, rotate = "promax", fm = "pa")
Standardized loadings (pattern matrix) based upon correlation matrix
             item    PA1    PA3    PA2    h2    u2  com
Clunky          3  -0.72                  0.47  0.53  1.5
Spontaneous    13   0.71                0.65  0.35  1.2
Aware           8   0.68                0.60  0.40  1.2
Sociable        6   0.65                0.53  0.47  1.3
Sentient       20   0.60                0.51  0.49  1.3
Sympathetic    17   0.59                0.32  0.68  1.1
Creative       15   0.59                0.60  0.40  1.6
Spiritless      5  -0.54                0.35  0.65  1.4
Sensitive      12                       0.11  0.89  1.1
Aggressive     10          0.82         0.63  0.37  1.3
Creepy          9          0.77         0.61  0.39  1.0
Complex        21          0.67         0.48  0.52  1.0
Devious        18          0.67         0.54  0.46  1.1
Lonely         14                       0.26  0.74  1.8
Controllable   16                       0.31  0.69  2.1
Organic         1                       0.18  0.82  2.7
Goal.driven     7                 0.67  0.50  0.50  1.3
Logical        11                 0.62  0.48  0.52  1.3
Productive     19                 0.54  0.30  0.70  1.0
Instrumental    2                 0.54  0.36  0.64  1.4
Efficient       4                 0.47  0.38  0.62  2.0

                        PA1   PA3   PA2
SS loadings            3.87  3.34  1.97
Proportion Var         0.18  0.16  0.09
Cumulative Var         0.18  0.34  0.44
Proportion Explained   0.42  0.36  0.21
Cumulative Proportion  0.42  0.79  1.00

 With factor correlations of
      PA1    PA3    PA2
PA1   1.00   0.36  -0.04
PA3   0.36   1.00  -0.02
PA2  -0.04  -0.02   1.00

Mean item complexity =  1.4
Test of the hypothesis that 3 factors are sufficient.

The degrees of freedom for the null model are 210 and the objective function was
      11.19 0.4
The degrees of freedom for the model are 150 and the objective function was 4
     0.4
The root mean square of the residuals (RMSR) is  0.07
The df corrected root mean square of the residuals is 0.09 0.4
Fit based upon off diagonal values = 0.93
Measures of factor score adequacy
                                               PA1   PA3   PA2
Correlation of scores with factors            0.94  0.94  0.88
Multiple R square of scores with factors      0.89  0.88  0.77
Minimum correlation of possible factor scores  0.78  0.76  0.54
```

Table A.10: R output of the pattern matrix with oblique (promax) rotation for the six-factor model with a cut-off of .50 for the factor loadings.

```
Call: principal(r = brushMatrix, nfactors = 6, rotate = "promax")

 Warning: A Heywood case was detected.
Standardized loadings (pattern matrix) based upon correlation matrix
             item   RC1   RC3   RC2   RC4   RC5   RC6   h2   u2  com
Aware           8  1.01                                0.83 0.17 1.1
Sociable        6  0.89                                0.70 0.30 1.2
Spiritless      5 -0.76        0.62                    0.77 0.23 2.3
Sentient       20  0.72                                0.67 0.33 1.7
Clunky          3 -0.62                                0.60 0.40 2.2
Lonely         14                                      0.42 0.58 4.6
Complex        21        1.10                          0.86 0.14 1.2
Aggressive     10        0.81                          0.72 0.28 1.4
Creepy          9        0.66                          0.74 0.26 2.1
Creative       15        0.62                          0.79 0.21 2.0
Devious        18                                      0.62 0.38 3.5
Productive     19              0.89                    0.67 0.33 1.2
Instrumental    2              0.75                    0.63 0.37 1.5
Sensitive      12                   -0.78              0.66 0.34 1.7
Logical        11                    0.72              0.76 0.24 2.1
Goal.driven     7                    0.66              0.70 0.30 2.2
Spontaneous    13                                      0.75 0.25 4.2
Organic         1                          1.00        0.76 0.24 1.4
Sympathetic    17                          0.52        0.49 0.51 1.8
Efficient       4                                0.82  0.72 0.28 1.4
Controllable   16                                0.79  0.70 0.30 1.5

                       RC1  RC3  RC2  RC4  RC5  RC6
SS loadings           3.72 3.05 2.10 1.93 1.73 2.03
Proportion Var        0.18 0.15 0.10 0.09 0.08 0.10
Cumulative Var        0.18 0.32 0.42 0.51 0.60 0.69
Proportion Explained  0.26 0.21 0.14 0.13 0.12 0.14
Cumulative Proportion 0.26 0.46 0.61 0.74 0.86 1.00


            With component correlations of
       RC1   RC3   RC2   RC4   RC5   RC6
RC1   1.00  0.48  0.14 -0.27  0.43 -0.29
RC3   0.48  1.00  0.39 -0.04  0.13 -0.41
RC2   0.14  0.39  1.00  0.23  0.03 -0.14
RC4  -0.27 -0.04  0.23  1.00 -0.30  0.15
RC5   0.43  0.13  0.03 -0.30  1.00  0.12
RC6  -0.29 -0.41 -0.14  0.15  0.12  1.00

Mean item complexity =  2
Test of the hypothesis that 6 components are sufficient.

The root mean square of the residuals (RMSR) is  0.06

Fit based upon off diagonal values = 0.96
```

Table A.11: R output for reliability measurement based on Cronbach's alpha calculation for the first factor.

```
Reliability analysis
Call: psych::alpha(x = features.factor1[, 1:8])

  raw_alpha std.alpha G6(smc) average_r S/N   ase mean  sd
       0.86      0.86    0.88      0.44 6.2 0.027  3.7 1.2

 lower alpha upper     95% confidence boundaries
 0.81  0.86  0.91

 Reliability if an item is dropped:
            raw_alpha std.alpha G6(smc) average_r S/N alpha se
Clunky           0.86      0.86    0.88      0.47 6.1    0.027
Spiritless       0.85      0.85    0.86      0.45 5.8    0.028
Sociable         0.84      0.84    0.86      0.43 5.2    0.031
Aware            0.83      0.83    0.83      0.41 4.8    0.033
Spontaneous      0.84      0.83    0.85      0.42 5.0    0.033
Creative         0.84      0.84    0.85      0.43 5.3    0.031
Sympathetic      0.86      0.86    0.88      0.46 6.0    0.028
Sentient         0.84      0.84    0.85      0.43 5.3    0.031

 Item statistics
             n raw.r std.r r.cor r.drop mean  sd
Clunky      59  0.59  0.60  0.51   0.47  2.4 1.6
Spiritless  59  0.65  0.66  0.60   0.54  3.6 1.6
Sociable    59  0.75  0.75  0.71   0.65  3.6 1.7
Aware       59  0.82  0.82  0.83   0.74  3.8 1.7
Spontaneous 59  0.80  0.78  0.76   0.70  4.3 2.0
Creative    59  0.76  0.74  0.71   0.65  4.8 1.9
Sympathetic 59  0.60  0.61  0.51   0.48  3.3 1.6
Sentient    59  0.74  0.74  0.72   0.64  4.1 1.7

Non missing response frequency for each item
               0    1    2    3    4    5    6    7 miss
Clunky      0.15 0.10 0.32 0.19 0.14 0.05 0.05 0.00    0
Spiritless  0.03 0.07 0.15 0.22 0.25 0.12 0.15 0.00    0
Sociable    0.00 0.17 0.14 0.17 0.19 0.22 0.07 0.05    0
Aware       0.00 0.17 0.08 0.05 0.34 0.22 0.08 0.05    0
Spontaneous 0.00 0.17 0.08 0.07 0.10 0.27 0.15 0.15    0
Creative    0.00 0.08 0.10 0.07 0.10 0.24 0.17 0.24    0
Sympathetic 0.00 0.15 0.19 0.19 0.27 0.08 0.10 0.02    0
Sentient    0.00 0.15 0.05 0.03 0.34 0.24 0.15 0.03    0
```

Table A.12: R output for reliability measurement based on Cronbach's alpha calculation for the second factor.

```
Reliability analysis
Call: psych::alpha(x = features.factor2[, 1:5])

  raw_alpha std.alpha G6(smc) average_r S/N   ase mean  sd
       0.68      0.68     0.7       0.3 2.2 0.066  4.1 1.1

 lower alpha upper     95% confidence boundaries
  0.55  0.68  0.81

 Reliability if an item is dropped:
             raw_alpha std.alpha G6(smc) average_r S/N alpha se
Instrumental      0.64      0.64    0.61      0.31 1.8    0.076
Efficient         0.65      0.65    0.64      0.31 1.8    0.075
Goal.driven       0.62      0.62    0.59      0.29 1.6    0.082
Logical           0.62      0.62    0.58      0.29 1.7    0.081
Productive        0.63      0.63    0.63      0.30 1.7    0.079

 Item statistics
              n raw.r std.r r.cor r.drop mean  sd
Instrumental 59  0.64  0.65  0.54   0.41  4.3 1.6
Efficient    59  0.63  0.64  0.50   0.40  4.3 1.5
Goal.driven  59  0.71  0.68  0.59   0.47  4.3 1.8
Logical      59  0.69  0.68  0.60   0.46  3.6 1.6
Productive   59  0.65  0.67  0.54   0.44  4.0 1.5

Non missing response frequency for each item
                1    2    3    4    5    6    7 miss
Instrumental 0.08 0.03 0.15 0.29 0.19 0.20 0.05    0
Efficient    0.03 0.10 0.14 0.29 0.22 0.12 0.10    0
Goal.driven  0.10 0.08 0.07 0.31 0.22 0.08 0.14    0
Logical      0.10 0.17 0.17 0.27 0.19 0.03 0.07    0
Productive   0.07 0.12 0.08 0.41 0.19 0.08 0.05    0
```

Table A.13: R output for reliability measurement based on Cronbach's alpha calculation for the third factor.

```
Reliability analysis
Call: psych::alpha(x = features.factor3[, 1:4])

  raw_alpha std.alpha G6(smc) average_r S/N   ase mean  sd
       0.82      0.82    0.78      0.53 4.6 0.038  4.1 1.5

 lower alpha upper     95% confidence boundaries
  0.75  0.82   0.9

 Reliability if an item is dropped:
           raw_alpha std.alpha G6(smc) average_r S/N alpha se
Creepy          0.78      0.78    0.70      0.54 3.5    0.051
Aggressive      0.77      0.77    0.69      0.53 3.4    0.052
Devious         0.79      0.79    0.72      0.55 3.7    0.048
Complex         0.77      0.77    0.69      0.52 3.3    0.053

 Item statistics
            n raw.r std.r r.cor r.drop mean  sd
Creepy     59  0.81  0.81  0.71   0.64  4.5 2.0
Aggressive 59  0.81  0.81  0.73   0.65  3.9 1.9
Devious    59  0.79  0.79  0.68   0.62  3.9 1.9
Complex    59  0.82  0.82  0.74   0.66  4.1 1.9

Non missing response frequency for each item
              1    2    3    4    5    6    7 miss
Creepy     0.14 0.05 0.08 0.14 0.29 0.08 0.22    0
Aggressive 0.20 0.05 0.15 0.10 0.31 0.12 0.07    0
Devious    0.20 0.08 0.05 0.22 0.24 0.15 0.05    0
Complex    0.10 0.17 0.14 0.08 0.24 0.17 0.10    0
```

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