Dawn of the living hairbrushes: Humans affective responses to movement in artefacts

Oliver Olsen Wolf and Geraint A. Wiggins

Abstract—We present an empirical study of human-robot interaction. The particular focus is on movement. By means of a previously developed methodology we measure how different forms of movement have an effect on participants affinity to a non-anthropomorphic robotic object. Using an everyday object of a hairbrush technologically modified to be able to crawl with two different movement patterns, the study investigates participants interpretation of the object under three conditions: Two different behavioural patterns, biological and mechanical, and thirdly the object in halt. Applying a previously developed metric of quantitative measures allows us to investigate whether participants interpretation apparent in conceptual boundaries of entities, like those between living and non-living, change when behaviour comes into play. We provide preliminary result under the three conditions showing effects of movement to increase the social attribution to an object and variances between the biological and mechanical movement.

1 Introduction

THE the concept of 'robot' is a moving target : "we constantly reinvent what we consider to be 'robot"' (Dautenhahn, 2013). In regard to this process the particular focus of this work is on the movement of technological objects. We present an empirical study examining two forms of movements and how they affect the way a robotic object's interpretation and shifts in the conceptualization as animated or inanimated.

The primary motivation for the work presented here comes from observations made during an exhibition featuring an artwork created by the first author. In the exhibition, an everyday object – a technologically modified hairbrush placed on a plinth – suddenly metamorphosed into a crawling animal-like robotic creature. Obververs' reactions to the hairbrush's movement ranged from refusing to favouring the object. Audience members reacted with cries of astonishment and comments like "creepy," "eery," "almost like an animal," or "it is trying to commit suicide?" when the brush crawled towards the edge of its plinth.

This intuitive process of categorizing and attributing characteristics as a dialog and understanding of things, as found in the concept of metaphor, is central to our method. Drawing from anthropomporphism—humans' tendency to interpret non-human entities' behaviour with human characteristics—we have developed a methodology to study the effect of movement on humans affinity to living and non-living agents (Wolf and Wiggins, 2017). The method was validated in an online study, showing differences in participants interpretation of various entities induced by movement, e.g. the shift of a human exhibiting mechanical breakdancing movements, towards interpretations corresponding to machines. Correspondingly to the previous work, informed by the observations and consequential quantitative method and validation in an online study, the aim of this study is twofold: First, validating the previously established methodology in a complex environment akin to the situation at the gallery featuring a physical object. Second, studying differences between two movement patterns apparent in variations of their interpretation.

By transgressing the familiar knowledge of an everyday object – through expectation violation – the intend of this study is first, to measure and show a person's affiliation toward an unknown agent or stimulus: that is, when and how social attributes, intentions or motives are assigned to a non-living agent (anthropomorphism). And second, display the characteristics evoked by two different movement patterns apparent in participants interpretation: one reassembles a continuous minimum-jerk pattern representative for biological movement and one a discreet bang-bang pattern modelling mechanical movement.

We expect our findings will help designers and engineers of animate objects, computational artefacts and behavioural artworks to evaluate their work using a relational approach to examine shifts in observers interpretation. Hence, we consider our design and relational approach measuring people's affinity to different movements of a non-anthropomorphic object as a contribution specifically to the field of behavioural artworks and human-robot interaction in general.

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2 Related Work

2.1 Moving Objects

Bartneck et al. (2009) assesses the effect of robots appearance and behaviour to how people perceive intelligence and animacy in robots. To find this out they use a variation of the Turing Triage Test (Sparrow, 2004). Instead of forcing people to choose between the life of a human and the life of a robot they use participants hesitation to turn off the robot as a measurement. One of the conclusion they provide from their results is that for the perception of a robots animacy the behavior is more important than its embodiment. Hence physical design should focus on appropriate rich facial expressions and gentle, smooth animations.

Complementary Darling et al. (2015) report a study exploring people's relation to little robotic objects based on movement and empathy. The authors evaluate the effect of empathy to the robots, here insect-like robots of hexapods, evoked by three different levels of personified stories provided before the study, furthermore the effect of no and lifelike movement. As a main measure or dependent variable serves the time participants hesitate to strike the robot with a hammer. Additionally they look into the subjects' trait empathy measured by the results of an 'Interpersonal Reactivity Index' filed by the participants after the study. As a result their first hypothesis that lifelike movement is considered to have an influence on human perception of robot animacy is not confirmed but their results show that participants with high trait empathy (empathic concerns) as well a personified stories extent the hestiation-time significantly.

2.2 Differentiating Movement

Differences in the perception of *biological* and *non-biological motion* is investigated by Cook et al. (2009). Natural motion is exemplified by a minimum-jerk movement, featuring a characteristic velocity profile minimizing jerkiness over a movement trajectory, while gravitational movement with a constant velocity (CV) is taken as a representation of *non-biological movement*. In their 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 are shown a series of visual stimuli of a falling tennis-ball and a moving arm, either composed by different proportions of *biological motion* (minimum-jerk) and *non-biological* (gravitational) motion. The participant's task was to pick the less natural. 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* couldn't be found.

A perspective from product design is provided by Weerdesteijn et al. (2005). The aim of their design research is to investigate the possibilities of using expressive movement for creating products with predefined expressive qualities.This is carried out by a case study designed to explore the possibility of using expressive movement as the main design feature. They developed objects that exemplified the dynamic expression of six emotions: sadness, anger, fear, joy, pleasant surprisei, and attraction. As part of their results they report that kids where able to imitate and translate theses expressive emotions in their own dynamic body language.

Hoffman and Ju (2014) offering design strategies with the aim to facilitate the feasibility of real-world human-robot interaction by prioritizing the communicative aspect of movement. In four case studies their iterative design approach presented focuses on the expressiveness of robots, their appearance and movement being part throughout the whole design process. They contrast their "visual approach" with a "pragmatic design approach" The latter predominantly aiming towards achieving a physical goal and mechanical optimization while the later is taking the communicative power of movement into consideration. One of the ideas is that movement-centric robot design may open the door to more simple non-anthropomorphic robots that engage with humans primarily through their movement, such as abstract volume robots or robotic furniture.

This is explored for example in studies using a Wizard of Oz technique animating doors (Ju and Takayama, 2009). The paper examines different gestural motions, "door gestures" resulting from the alleged automatic movement of a physical door. The aim of the authors is to examine participants interaction with the different behaviours of the door while walking towards it. In particular how different physical gestures resulting from altering speed and trajectory create different levels of approachability to participants. People's experiences and how their responses change to different "door gestures" are measured using Likert-scale and open-ended questions. The outcome suggests that even in non-anthropomorphic objects, like the door, gestural motions can convey a sense of approachability.

2.3 Interpretation of Movement

Interpreting movement, e.g., peoples description of simple shapes moving around, gives evidence of our innate tendency to perceive meaningful structures as social interaction and establish a social narrative (Heider and Simmel, 1944; Simion et al., 2013). The causal and social structure of the world is recovered by inferring properties such as causality and animacy (Scholl and Tremoulet, 2000). This involves the interpretation of an entity as as characters with emotions, motivations, and purpose as found in the concept of anthropomorphism, understood as a special form of metaphor rather than an explanation of a system's behaviour (Duffy, 2003). Hence describing an entities behaviour e.g., as helping, hindering, chasing, fleeing, cannot be reduced to a spatio-temporal vocabulary (Carey, 2009, 12). In this sense peoples description of behaviour ranges from social or *reason explanation* (Malle, 1999), apparent in intentional and psychological vocabulary and building a social narrative (Heider and Simmel, 1944; Kiesler et al., 2006), to *causal explanation*, descriptions referring mainly to the domain of physics, involving a factual description and usage of spatio-temporal wording (Blythe et al., 1999; Michotte, 1963).

Similar to the movement of a puppet, belonging to multiple ontological categories (object/live) (Seibt, 2015), playing with ontological uncertainty animating objects can be considered as an enactment of animate vs. inanimate contradiction (Ghedini and Bergamasco, 2010). Stimulus belonging simultaneously to multiple ontological categories, elicit a state of discomfort because of their ambiguity, thus considered to afford people to categorize and participate in making meaning (Burleigh et al., 2013; Gaver et al., 2003).

2.4 Relational Approach

Our measurement tool developed in previous work and validated in an online study aims to measure differences in participants interpretation of an entities action. It comprises a relational approach on two levels: First, we establish a relationship between subjects and their interpretation of various entities using features used to describe movement and behaviour. With this indirect method, the aim is to avoid the controversial use of words in studies of having subjects choose between e.g. alive creature, non-alive object, (Gelman et al., 1995) as for the most part this terminology is not morally neutral (Coeckelbergh and Gunkel, 2014). Second, participants interpretation is not just a rating of accept the feature as true or false, simple black/white or either/or issue, rather than a matter of degree. On that account we provide a scope of attribution ranging from "not at all" to "very much." Participants interpretation of the object, differences in movement based on the attribution of the features is our primary measurement. These findings are furthermore supported by results from the second part of the survey looking at varieties in participants descriptions of their experience of the object for example ranging between *reason* or *causal explanations*.

The focus of this work is object's movement. Accordingly an everyday object of a hairbrush, is considered as predestined to set a focal point on movement. Its non-anthropomorphic appearance minimizes pre-conceptions of a robots/objects appearance and its 'natural' behaviour (Dautenhahn, 2013; Fink, 2012). Thence, applying two types of movement patterns, one comparatively to biological and the other to mechanical movement, to a non-anthropomorphic robot, here a technologically modified hairbrush able to crawl, allows us to study movement's intrinsic ability to affect peoples interpretation of an object's actions and intends.

3 STUDY

To examine this we designed a between subject study based on one variable with three conditions. The conditions are determined by applying either of the two movement patterns, organic or mechanic, or no movement pattern, to the brush.

The participants so far amounted to a total of 65 out of which the answers of $k = 57$ could be used because of priming, people acknowledged during or after the study that they knew about it. The study procedure took approximately 10min per participant and was running at two different places, the Victoria & Albert Museum and in the Computer Science building of Queen Mary University both in London, UK. 65% of the participants identifying themselves as male and 35% as female. With an age range of 46% between 26-34, 32% between 18-25, 21% between 35-54 years, and 2% between 55-64 years of age.

3.1 Procedure

As initial situation, the three conditions(no, biological and mechanical movement) are equally distributed over the participants, furthermore they are presented with a table holding ready five different types of boxing labels and next to them five different hairbrushes (as shown in Figure 1) covered by a cardboard box.

Subsequently participants are invited to engage in a design study following a two-part procedure:

The first part consists of the label assignment task. The participants are invited to take part in a design research which comprises attributing labels to objects. As soon as the instructor left the room they are asked to remove the cardboard box and spent about 2 minutes assigning the labels rather intuitively to the brushes the way they think they correspond most. The idea behind this step is less having participants finding the right label to the right brush

Fig. 1. Study set-up inviting participants to assign labels to the brushes.

rather than by examining, touching and experience them, to become familiar and having them establish an initial relationship with the objects (Sung et al., 2007). In case of the two movement groups, the brush is programmed to start moving after about 15 seconds and keeps on doing so until the end of the study. After about 2 minutes the instructor returns with the request to move on to the second part.

In the second part participants are invited to attribute a set of 23 features resulting from previous research on a Likert scale in response to the question "To what extent is each of the attributes below applicable to the green hairbrush?". Subsequently to "Describe your experience in a couple of sentences.", and finally, to fill in demographic data featuring age, occupation, gender and a self-assessment of English proficiency.

3.2 Evaluation

Corresponding to our previous work we use the *feature-space* to evaluate the participant's interpretation of the hairbrush on two levels, first looking at the attribution of the features and second, evaluating participants short description of the experience.

3.2.1 *Feature Attribution*

In our previous work we developed a measurement tool resulting from $k = 93$ ratings of features in respect to pictures of either humans, animals or machines. As a result we obtained a *feature-space* consisting of designated regions of features representative for the categories of humans, animals and machines. Using the same set of features we where able to project participants interpretation of the hairbrush under the three conditions with a total of $k = 57$ into the *feature-space*. As a consequence of this first part of the study we can illustrate difference in the way participants relate to the brush mediated by movement. These differences in the interpretation can be shown graphically and numerically. The former using principal component analysis and the latter as a result of the mean interpretation, which is computed for each condition by averaging over its features, as in Equation 1.

$$\hat{F} = \frac{1}{n} \sum_{i=1}^{n} f_i \tag{1}$$

where f_i represents each of the features and $n = 23$.

3.2.2 Causal and Reason Explanation of Action

Additionally we amend our results by evaluating participants description in the second part considering differences in the explanation. Related to Malle's coding scheme differentiating *cause* and *reason explanation* in the psychological explanation of behaviour (Malle, 1999), here the aim is to look at how participants describe and assign different social, conceptual, and linguistic features to the object. Answers could range from *causal explanation* e.g. 'the brush moved into a direction'; *intentional* e.g. 'the moved away from others'; to *mentalistic* e.g. 'the brush was afraid of others'.

3.3 Results

With our approach, depicting different regions representative for different interpretations and concomitant mean-interpretations, shifts in participants' interpretation can be measured and visualised, by displaying them using principal component analysis (Figure 2) and as the geometrical distance of their centroids or mean-interpretations (Table 1).

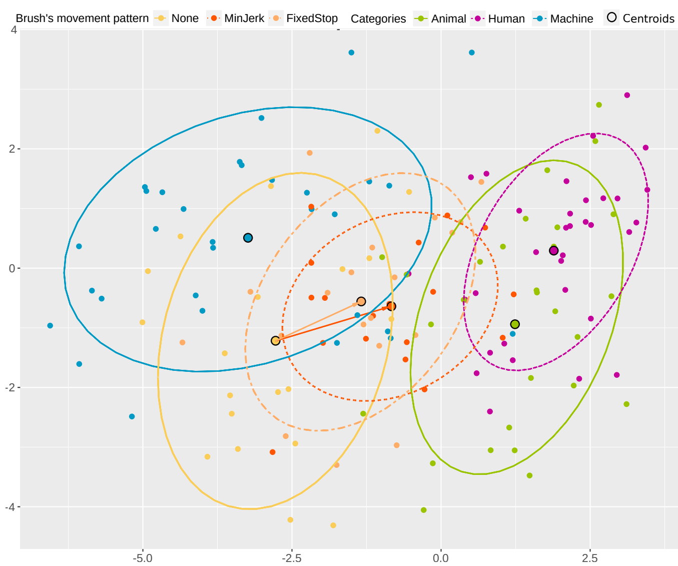
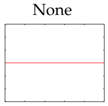
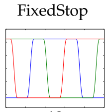
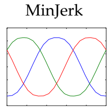


Fig. 2. Study result showing the displacement of the two movement patterns in relation to the non-moving object and the regions attributed to human, animals and machines.

TABLE 1
Study results – distance between the mean interpretation of the three movement conditions in relation to humans, animals and machines

	None	FixedStop	MinJerk
Movement			
$k =$	20	18	19
Distance (euclidean)	$\hat{F}_{none}$	$\hat{F}_{FixedStop}$	$\hat{F}_{MinJerk}$
to human	3.06	2.66	2.33
to animal	2.73	2.46	2.21
to machine	1.51	2.23	2.26

The results indicate a shift of participants' interpretation of the two moving conditions in comparison to the static, away from the centroid of the machine region, towards the centroids of the human and animal regions. As the graphic in Figure 2 and the values in Table 1 indicate. The **biological** and **mechanical movement** in comparison to the **static** is interpreted closer to humans and animals. This supports our predictions and shows the capabilities of our methodology. However, the significance of the difference between the two movement conditions remains to be tested.

3.3.1 Driving features

To supplement our findings we look at the results in a different way by picking five driving features considered to be most relevant for the topic of the current paper. Driving features are features that contrast substantially in the mean ratings between the static and the two movement conditions as found in Table 2 (see Appendix). Indicating that the **biological movement** is considered less *creepy* (0.41) than the **mechanical** (0.72) in contrast to the **static** (-0.45). Furthermore the **biological** is interpreted less *logical* (-0.46) and more *sentient* (0.17) than in the **mechanical** condition (-0.14 & 0.09) contrasting with the **static** (0.23 & -0.37). There's also a compelling difference in the attribution of *complexity* and *loneliness*. While for the latter the **static** (-0.2) approximates the **biological** (-0.17), the **mechanical** was interpreted as more *lonely* (0.16). Similarly for the former, the **mechanical** (0.51) contrasts highly with the **static** (-0.4) while *complex* for the **biological** is close to undecided (0.07).

3.3.2 Description of the experience

Here we look at the use of language in the description ranging from causal and rather analytical to reason explanations and conceivably anthropomorphism. At this stage of writing the analysis is still in progress therefore we just extract the following examples from the data:

Causal explanations: Examples containing factual, instrumental and analytical descriptions are: "A hairbrush whose base has movement that move the bristles.", "noisy and unsociable for use in bedrooms", "overly complex, mildly disturbing, and environmentally unfriendly."

Reason explanations: Examples using social language, describing intentional action and social interaction are: "Creepingly trying to escape from the row of the other brushes and from the table.", "A bit scary. Not sure if it was just a Green Brush or something else below it. I was expecting some kind of shock when trying to rescue it.", "An attention seeking, needy brush. Stands out from the crowd."

4 Discussion

Our methodology reassembles findings from previous research along the lines that we represent a metric using an indirect method by not providing predefined assumptions e.g. by asking participants straight about whether something is alive or not. Moreover, our method permits a measurement deploying a relationship rather than just attributing properties on a simple black/white or either/or ratio.

For the second part of our evaluation so far we just highlighted driving features. Subsequently to our analysis we expect to extract emerging features from the aggregation of the 23 features given. Additionally results for the second part looking at variances in participants descriptions as causal and reason explanations. Both outcomes to support our findings from the feature interpretations.

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TABLE 2
Normalized mean ratings of the feature set in respect to the three movement conditions and the categories from previous work. The five features considered most relevant for the topic of the current paper are marked bold.

	Categories (*Previous Study*)			Hairbrush movement patterns		
	Animal	Human	Machine	FixedStop	MinJerk	None
Goal.driven	0.05	0.01	0.54	0.02	0.13	0.13
Instrumental	-0.26	-0.03	0.49	0.05	0.15	0.12
Clunky	-0.31	-0.47	0.08	0.18	0.06	0.43
Devious	-0.4	-0.6	-0.24	0.3	0.2	-0.48
Efficient	0.13	-0.16	0.39	-0.05	-0.07	0.45
Spiritless	-0.61	-0.73	-0.17	-0.33	-0.3	0.08
Sociable	0.14	0.59	-0.38	-0.02	-0.09	-0.38
Productive	-0.08	0.13	0.56	-0.09	0	0.13
Organic	0.59	0.26	-0.46	-0.53	-0.11	-0.37
Aware	0.33	0.25	-0.33	0.09	0.07	-0.38
Creepy	-0.48	-0.75	-0.26	**0.72**	**0.41**	**-0.45**
Aggressive	-0.2	-0.57	-0.1	0.26	0.04	-0.3
Synthetic	-0.62	-0.56	0.46	0.26	0.44	0.53
Logical	-0.24	-0.28	0.52	**-0.14**	**-0.46**	**0.23**
Sensitive	0.32	0.23	-0.32	-0.05	-0.2	-0.48
Spontaneous	0.16	0.41	-0.41	0.35	0.52	-0.58
Lonely	-0.37	-0.41	0.02	**0.16**	**-0.1**	**-0.2**
Creative	-0.13	0.41	0.02	0.46	0.61	-0.4
Sentient	-0.02	0.33	-0.35	**0.09**	**0.17**	**-0.3**
Complex	0.16	0.22	0.55	**0.51**	**0.07**	**-0.4**
Controllable	-0.38	-0.25	0.34	-0.35	-0.28	0.42
Sympathetic	0.23	0.26	-0.4	-0.3	-0.19	-0.42
Caring	0.21	0.3	-0.54	-0.14	-0.26	-0.12