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# Interaction with a Zoomorphic Robot that Exhibits Canid Mechanisms of Behaviour

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**Despite parallels between the cooperative use of domestic dogs in human society today, the predicted similar deployment of robots in the future, and the plethora of superficially dog-like robotic entertainment devices, very little effort has been directed at exploiting any understanding of social cognition between dogs and humans when designing interactive robotic systems. This paper describes an experiment in which we gave interactive robots zoomorphic appearances and dog-like behavioural properties. We analysed human reactions to robots exhibiting differing levels of zoomorphism and dog-like behaviour during an interaction task; we were particularly interested to determine whether behaviour and/or appearance that mimicked that of dogs facilitated increased satisfaction in robot performance and a willingness to persevere with a robot that made mistakes. Our findings show that neither the appearance or behaviour of a robot had an impact on the participants' rating of robot performance whilst there was also no significant difference in the self-reported categories of frustration, excitement and desire to persist with an interaction. However, our findings suggest that differences in individual preferences are revealed when people are asked to interact with robots that exhibit dog-like behaviours and other zoomorphic characteristics and that further research is required in order to better understand these differences.**

## I. INTRODUCTION

THERE is a great deal of current research centred upon the creation of artificial systems which might be considered, by humans, to be social entities, agents or actors [1][2][3]. In particular, the development of social robots [4] is a highly active field which is being driven by the widespread belief that we will, within a matter of a few years, be expected to engage in social interactions with embodied robotic systems in everyday environments [5]. However, to-date, examples of robots (other than toys) are exceptions in human society rather than the norm. In order for them to be accepted in human society, robots must have the capability to interact with people, do collaborative tasks, navigate through crowds, explain their actions and avoid conflict. At present robots still generate, at best, suspicion or, at worst, fear in the general public. The austerity and complexity of current interfaces and the very mechanical behaviours of robotic devices themselves do little to improve the public view of them. One of the main issues with the introduction of robots into human society therefore is how they will be perceived and received. The appearance and behaviour of future robots are likely to be quite diverse, with devices perhaps having designs that could be industrial, zoomorphic, anthropomorphic, or even having the form of everyday objects. Psychologically, this has many implications and previous research has, for instance, assessed human attitudes towards robots of differing appearance [6] and the resulting effect on communication [7], aversion towards robotic features resembling human form [8], and principles of interaction and engagement with humans [9].

If we take a well-known example from science fiction, C-3PO and R2-D2, from the film Star Wars [10], are instances of two morphologically different robots that also interact with humans in different ways. C-3PO is portrayed as an intelligent, multi-lingual, adult-sized humanoid with a static facial appearance, whilst R2-D2 is a smaller cylindrical domed-head droid which communicates using variable beeps and tones. C-3PO comes across as irritating, perhaps like a human with a character flaw; whereas R2-D2 has qualities that could be said to be cute and endearing. It has been suggested that anthropomorphic robots, such as the fictional C-3PO, that do not meet our expectations may be rejected on the basis that we find them confusing when they do not live up to the level of realism that we expect [8][11][12]. R2-D2 has vocal, as well as behavioural, traits that are more commonly found in pets such as domestic dogs (Canis familiaris) – higher ranged tones occur during attention seeking excitement and lower drawn out tones relate to more threatening or warning contexts [13]. To most humans, this form of communication appears very familiar, and there is increasing evidence which suggests that not only has the dog evolved unique cognitive abilities to accurately understand human behaviour [14] but also that humans have co-evolved to adapt accordingly [15]. For robotics, therefore, the domestic dog has great appeal as much from an aesthetic perspective as its intellectual prowess - dogs are not just pets that provide entertainment and companionship but are considered useful agents in human society - performing tasks such as: search and rescue, disability and medical assistance, security patrolling, household chores and educational assistance. It is worthy of note that the robotics research community are focussing on many of these very tasks for robots of the future. It is likely that the robots that will perform these tasks in the future won't necessarily appear dog-like in form but we have advocated in the past [16] that dogs might provide deep insights into the design of future robots and especially their behaviours when interacting with humans. In our current work we are interested in analysing the unique social relationship between humans and dogs and, through experimentation, determining how we might give robots 'dog-like', or canid, qualities that might be intuitively useful and effective when interacting with humans. This paper describes an experiment in which we gave interactive robots dog-like, or more generally, zoomorphic, appearances and dog-like behavioural properties. We analysed human reactions to robots exhibiting differing levels of zoomorphism and dog-like behaviour during an interaction task; we were particularly interested to determine whether behaviour and/or appearance that mimicked that of dogs facilitated increased satisfaction in robot performance and a willingness to persevere with a robot that made mistakes.

## II. Related Work

Some examples of, mainly entertainment based, technological artefacts which purport to be based on studies of dog-human interaction have appeared in recent times. A number of researchers are developing entertainment-oriented software systems [16], [17] or embodied robots [4] which allow for social interactions between humans and simulated dogs. Very little of this work has been based on genuine ethological studies (exceptions include work at the Synthetic Creatures Group at MIT [17], [18], and [19]). Additionally, to-date, applications which feature dog-like agents have, for the most part, been either very restricted in scope, such as the MS Office dog Rocky, and the cartoon-dog in the ALIVE project [20], or ability – such as Sony's AIBO. However, sustained consumer interest in AIBO (and its copycats such as i-Cybie and WowWee's RoboPet) and the commercial success of computer-games such Dogz, Dogs Life, and, in particular, Nintendogs, are convincing examples of the widespread appeal of interacting with artificial, albeit rather basic, representations of dogs. The designers of such toys and applications are no doubt aware of the quantifiable positive effects of the human-animal relationship and the ease and comfort with which people, including children and older people, can interact with doglike devices. However, we are not aware of any work that has developed dog-like robots for anything other than entertainment purposes. Bartneck et al, [21] studied human attitudes to zoomorphic and anthropomorphic robots, computers, and people by asking people to offer praise and punishment towards team 'members' following a competitive task. The study showed that people were more forgiving of robot errors than those of humans or computers - yet participants were unaware that they had treated partners unequally. Of the two humanistic robots, the one with the most anthropomorphic qualities was praised more and punished less than the other. However, the zoomorphic robot, AIBO, was praised more and punished less than all of the partners (human, computer and anthropomorphic robots). Our familiarity with sounds and the association with their source lead us to appreciate organised structural contexts in which we discern our environment. Just as Mori's uncanny valley shows that visual realism is tantamount to believability and acceptability [8], so is our acceptance of sound within a given context. For instance we expect cats to meow and dogs to bark. Komatsu & Yamada [6] show how people relate more to a computer beeping than an AIBO emitting the same sound for expressing positive and negative states. Even when accompanied by AIBO's in-built motions for expression, the beeps were not interpreted any better. Komatsu & Yamada's conclusions suggest that AIBO's behaviour was not efficient in informing participants of its primitive attitudes, positive or negative. Bartlett et al, [22] have also shown, through studies with robots and children, that AIBO is deemed to be a dog and not a robot unless it betrays its canine identity such as by talking with a human voice or singing. In previous but, as yet, unpublished research, we performed a study with an AIBO, a Philips iCat, a Lego NXT robot, and an iRobot Roomba which were given dog-like, or canid, mechanisms of interaction. The robots' task was to interrupt the participant to gain their attention by using barking, nudging or whimpering, and also through beeping or via an artificial synthetic voice. Our findings were that when participants heard AIBO and iCat talking with a human voice they thought it was quite disturbing - and more so when the iCat barked or whined like a dog. In another unpublished study [23] barking and whimpering mechanisms of interaction were ranked in a canid as highly annoying behaviours. However, within different contexts, and across individuals, many respondents also ranked these same mechanisms as endearing.

## III. Methodology

### A. Experiment Overview

The aim of the reported experiment was to study human perseverance and attitude in a simulated training exercise with a robot whose performance was predetermined and controlled via Wizard of Oz (WoZ) [24] experimentation (Fig. 1). Participants were deceived into believing that they were participating in a voice recognition experiment with a robot to distinguish between the letters P and B; the stated reasoning being that "the letters P and B are similar in sound and difficult for artificial systems to distinguish". This deception was necessary to protect the primary focus of the research – their interaction with the system. There were three conditions to the experiment and three participant groups - for which one set of participants was exposed to only one condition. Each condition featured the same robot in one of the three guises described below:

- Condition 1: The robot (an iRobot Roomba as shown in Fig. 2) was modified to exhibit similar mechanisms of interaction to that used by a dog. It was given a tail that could be raised, lowered and wagged; eyes that move; and ears that covered wireless speakers used to emit barking and whining sounds. The robot was covered in synthetic spotty fur to create a zoomorphic appearance.

- Condition 2: The robot had the same appearance as in Condition 1 but used beep sounds for vocalisations. Unlike in Condition 1, it could not animate its modifications e.g. it could not move its eyes and tail,
- Condition 3: The robot was stripped of its zoomorphic appearance (and hence was essentially an unmodified Roomba) but retained the wireless speakers for emitting a beep sound.

For all three conditions the robot had basic mobility: travelling forwards, backwards, and rotating clockwise or anti-clockwise to effect direction changes. Additionally, in all three conditions the sound was transmitted through the wireless speakers at the same frequency.

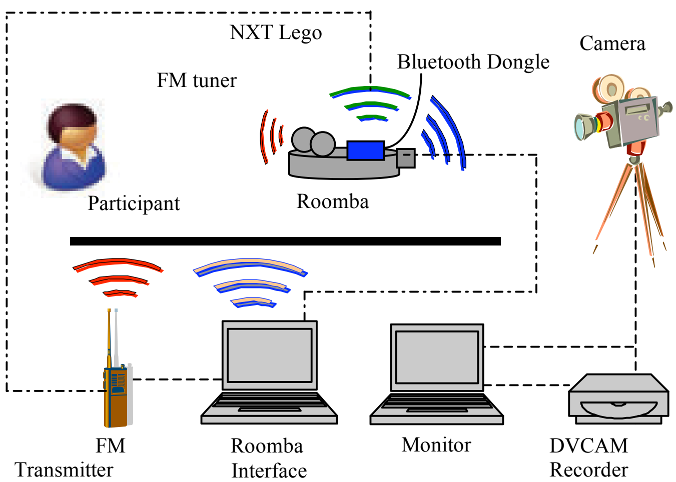


Fig. 1. System diagram for Wizard of Oz experiment.

## IV. Experimental Setup

We took the commercially available iRobot Roomba robotic vacuum cleaner (Fig. 2) and removed its rear dirt collection unit and brushes. This area served to hold a Lego NXT brick and two motors controlling the tail section (up, down and wagging). A third motor was seated atop the Roomba with two painted polystyrene balls attached to give the appearance of eyes (see Fig. 3). Two wireless speakers were also situated on top and give the appearance of ears when fur was attached (see Fig. 4). The robots' mobility and behaviour control interface were programmed using Microsoft Robotic Studio.

Fig. 2. iRobot's Roomba vacuum hoover.

Fig. 3. Roomba with Lego NXT modification – rear hoover section removed and NXT brick in situ with three motors: tail mechanism and vertical eye movement.

Fig. 4. Roomba-Lego NXT hybrid with spotty fur.

## V. Experimental Procedure

A total of thirty participants took part in the experiment – ten for each of the three experimental conditions. The procedure, and especially its inherent deception of participants, was approved by a local ethics committee. To record the interaction we used an observation lounge comprising two rooms divided by a one-way mirror. The experiment room was set up with a place for the participant to stand, a robot constructed to represent one of the three conditions described above, an interaction zone (for the participant to instruct the robot), and two A4 sized letters (P and B) standing upright some distance away on the floor. In the observation room there was a mounted camera directed toward the interaction zone of the adjoining experiment room to record the interaction between the participant and the robot. The room also contained a laptop from which the human Wizard controlled the robot unbeknown to the participant. The robot was piloted, using a GUI, according to a set pattern for all participants: starting position - facing the participant and aligned within the interaction zone, rotated 180º and then moved towards, and in-between, the letters P & B. Upon arrival at the neutral zone between P & B the robot was rotated 90º and piloted toward the predetermined letter and brought to rest. The robot was then rotated 180º and returned via the same path, and halted at the interaction zone to face the participant once more. The robot's movement could not be precise for each run, nor could the timing of the robot's canid behaviour operations activated in response to the participant. This is an artefact of the system which invariably alters the conditions for each participant. However, these differences are negligible since the participant was exposed repeatedly to these small variances and was mainly focused on the robot executing instruction, awaiting the outcome, and delivering a praising or a berating response. There was no variance for the canid behaviour operations once they had been initialised; this process was automated.

Fig. 5. A participant interacting with a robot during the experiment.

The participant was requested to speak aloud the letters P or B to the robot according to a predefined sequence. The robot then moved, apparently under the instruction of the participant but really under the control of the Wizard, towards one of the two letters, whereupon it entered the chosen letter zone and returned to the participant. The robot appeared to be artificially intelligent, apparently responding to vocal commands and selecting letters. However, the robot appeared to respond erroneously to the participants as a consequence of its voice recognition ability. Unbeknown to the participants, the robots' success was predetermined for each letter with a success rate set to 80% for letter P and 50% for letter B. Upon returning the participant was required to acknowledge the robot's performance by praising it for a correct letter or speaking to it accordingly for an incorrect letter. The participants were not instructed further on how to talk to the robot or what sort of language to use. An example video-grab of a participant interacting with a robot is shown in Fig. 5. Afterwards, the participant was required to answer a short questionnaire which asked the participant to score, on a Likert scale, the following: a) the robot's performance at fetching the letters P and B. b) their own level of frustration when the robot performed poorly, c) their level of excitement when the robot performed well, d) their willingness to continue testing with the robot. The questionnaire also asked if the participant was, or ever had been, a pet-owner.

In addition to the questionnaire data, the audio stream of the video footage of the experiment was analysed by two independent judges. The visual stream was removed in order to blind the judges to the experimental condition they were assessing. For each participant, the judges assessed praise and berate interactions from a two minute stream at the beginning of the experiment, and praise and berate interactions from a similar time frame at the end of the experiment. The judges were required to determine: a) whether a participant's interaction was personal or impersonal, e.g. did the participant engage with the robot as they would with a person or a device, b) whether the participant attributed gender, e.g. using language such as "here boy/girl", c) the level of vocal enthusiasm used during interactions and the level to which a participant either praised or berated the robot.

## VI. Results

A Kruskal Wallis ANOVA was used to analyse the effect of type of robot on the ratings by participants for the robot's performance at fetching the letters P and B, and their self-reported frustration, excitement and desire to persist with training. We found no significant difference in any factor. A Mann-Whitney U-test or 2-Sample t-test was used (depending on the distribution of the data) to determine whether there was an effect of the participant factors gender and pet ownership on any of the outcome variables. Again, no significant differences were identified. However, some differences in the pattern (as opposed to central tendency) of response were worthy of note. Fig. 6 shows the distribution of participant rating scores for performance in each task (fetching the letters P and B) and suggests that, when the robot appears zoomorphic and has dog-like behaviour, there is greater variability in participants' opinion of the robot when its performance was reasonably good (task P). However, this was not apparent in the dataset relating to the task with a lower level of performance (retrieval of B), suggesting that participants' rating may be dependent upon an interaction between the form of the robot and its performance. In Conditions 2 and 3, the results are more consistent with the expectation that rating should correlate with actual performance, with the response in Condition 3 (non-zoomorphic robot) appearing most consistent.

Inter-judge rating of vocal enthusiasm and level of each type of interaction (praise and berating) was generally consistent and the resulting data was therefore deemed suitable for parametric analysis, which allowed the effects of test group, gender and pet ownership status to be investigated. It was found that there was no effect of experimental Condition (1 to 3), gender of participant or pet ownership status on the level of vocal enthusiasm. Effects of praise were also not significant; however one effect on the amount of berating was found: there was less berating in the latter phase of the task during Condition 2, P = 0.033).


Fig. 6. Distribution of participants' ranks for robot fetching the letters P and B define conditions 1, 2, and 3.

When trying to assess the qualitatively defined aspects of interaction (personal/impersonal), the degree of reliability between the two judges fell below 90% in all cases. Therefore, the data were examined individually for each judge and with both pooled, and cross tabulated in order to examine the relation between type of robot and form of interaction. In all cases the results were not significant, although the power and reliability of the test in this circumstance may be questioned. Numerically, Condition 1 appeared to be the least personal - ranked by judges as 40% at the beginning of the experiment and 45% at the end of the experiment. Condition 2 appeared to be the most personal at 75% and 60% respectively, and Condition 3, 65% and 50%. 20% of participants who took part in Condition 1 and 30% of participants from Condition 2 attributed gender to the robot, and used (only) the gender specific term "boy". Participants in Condition 3 did not attribute gender.

## VII. Discussion

We found that the appearance of the robot over the three conditions had no significant effect on the participants' rating of the robot's performance but that there were interesting distributions in the questionnaire data according to features and behaviour. Notably, in Condition 1 the distribution is very widespread and suggests that people either very-much liked or disliked the interaction with the dog-like robot used in this Condition. Hence a 'cute' zoomorphic appearance coupled with dog-like behaviours appeared to polarise opinion in participants: some people seemed to exhibit an anthropomorphic sympathy or empathy towards the robot; whilst in others the robot appeared to have induced a dislike for the interaction. From this we conclude that the dog-like robot in Condition 1 was more likely to produce affective or cognitive biases during interactions. There were, however, no significant differences in the self-reported categories of frustration, excitement and desire to persist with the experiment. In a related experiment reported by Bartneck [21], participants took part in a cooperative task with a robot in which they benefited according to 'team' performance; it is possible that had there been some form of personal gain within our task, our participants self-reporting would have been stronger.

The results from the independently judged audio stream revealed no effect of experiment condition, gender of participant, or pet ownership status on the level of vocal enthusiasm. There were no significant differences as to the effects of praise although it was noted that less berating was used by participants when interacting with the robot towards the end of interactions during Condition 2. The latter result may be an anomaly or it may suggest that the robot in this Condition was perceived as being less responsive to admonishment because of its ambiguous identity. Somewhat surprisingly, according to the judges, the participants in Condition 1 appeared to engage with the robot in a way that was deemed the least personal. However there were also some participants who appeared very animated during interactions with the robot in the same Condition. Conversely, there were of course participants who also responded impersonally, showing very little enthusiasm but perhaps mild amusement. These observations again support the suggestion that the combination of features used in Condition 1 may have created a greater polarisation of views amongst participants.

Participants in general commented that the robots used were intriguingly novel but they would prefer a robot to look device-like (not zoomorphic) and emit beeping sounds or even use speech. In fact, interactions with the somewhat ambiguous robot experienced by participants in Condition 2 were deemed, overall, the most personal by the judges. The appearance of such a robot may have held a certain appeal whilst it also maintained a level of auditory familiarity, i.e. it was a robot – therefore it was right that it should emit computerised sounds. Hence this finding tends to support those of other researchers [6]. As no gender was attributed to the non-zoomorphic robot by the participants taking part in Condition 3, the evidence is strongly in favour of the zoomorphic appearance causing participants to use this kind of language.

## VIII. Conclusions

We found that giving interactive robots a zoomorphic appearance and dog-like behaviours had no significant effect on the way people perceived the human-robot interaction experience. Essentially, our experiment showed that opinions of robots that were given dog-like behaviours and appearances were very polarised – some participants in our experiments very much warmed to the modification of the robot whilst others did not. Additionally, we found that people appeared most comfortable when interacting with a 'hybrid' robot that had dog-like appearance but emitted computerised vocalisations (beeps), and that this was consistent with other research (e.g. [6]). Our findings certainly suggest that there are large differences in individual preferences exhibited by humans when interacting with robots – however in our study reported here we were unable to determine the causes of such differences despite investigating participant gender and pet ownership history, for instance.

We believe that for robot systems to make further progress towards becoming pervasive in our society they will have to co-exist and interact with, and take everyday commands from humans. It is the role of the human-robot interaction community to develop interface paradigms which will enable users to spontaneously interact with the pervasive robots of the future. The work described here highlights how attempts to make robotic systems more naturally intuitive can elicit bias in peoples' opinion and also that further research is required in order to better understand the reasons behind such individual differences.

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