PetRoomba: Interacting with household pets via SCI

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ABSTRACT
In this paper we wish to explore the ability of Shape-Changing Interfaces (SCI) to change pets' perception of autonomous household robots (AHR). More specifically we look at the effects of adding different types of shape change that resemble animal behaviour, and investigate how this affects canines. Studies have suggested that canines have issues with the entry of AHR's into the home, due to disruptions in the hierarchy. We suggest that by placing various SCI's on the robot, some basic animal behaviour can be mimicked, making it easier for the canine to place the robot within its social hierarchy, while still maintaining the core functionality of the AHR. We present the PetRoomba that draws on previous work within the Human-Robotic Interface and SCI community and try to draw this work into Animal-Computer Interaction. This early work with the PetRoomba shows a promising opportunity for further work in the ACI field.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Author Keywords
Shape-Changing Interfaces; Animal-Computer Interaction; Autonomous Household Robots

INTRODUCTION
In the recent years autonomous robot vacuum cleaners like the Roomba[4] have become more common in households. By adding an autonomous entity to the home, household pets, and especially dogs, are getting confused about the hierarchy of the entities in the home[6]. As dogs need a sense of the hierarchy in the household[12], different attempts have been made to adjust the hierarchy, after the entry of an autonomous robot vacuum in the household[6]. Additionally, as it can be seen in the video[1] related to this paper, some dogs are scared of the Roomba, when it roams autonomously around the house. This tension in the hierarchi tends to create a clash between the natural and robotic companions in the household. In this paper we suggest a new approach to resolving these issues, by adding zoomorphic features to the robotic vacuum cleaner using SCI. In Figure 1 the final prototype can be seen. By adding these zoomorphic features via shape changes, we try to establish a clearer hierarchy between the dog and robot, and thereby potentially releasing the tension between the natural and the robotic inhabitants in the household. In the following sections we will go through some of the related work in the field, our general research focus and how we have conducted our design process, working iteratively using feedback from empirical evaluations. Additionally we are going to reflect on our prototype and discuss how our work positions itself in the field. Finally we present some possible future work and conclude on our findings.

Figure 1. Then final prototype. a) Inner workings, b) Closed prototype and c) Protruded ears and tail.

RELATED WORK
With more autonomous household robots entering homes it is natural that researchers are starting to focus on the impact of these in the home setting. In the following we present the current state of the art related to household robots, specifically focusing on the Roomba from iRobot. Since it is a relatively new field, it has been difficult to find ACI work in this specific area, which lead us to look into the ACI manifesto[7] and what HCI work could be used as potential inspiration.

Clara Mancini has through her work shown interest in expanding the boundaries of interaction design to not only include HCI, but also ACI. In 2011 she wrote a manifesto on ACI[7] where she suggests that ACI can be used to increase the life expectancy and quality of both wild and domestic animals. Additionally she writes that a possible way of entering the world of ACI is to look at human-centered design protocols and that ACI has strong ties to HCI[7][8].

Sung et. al[15] has presented research that shows that owners of Roombas have intimate feelings towards the autonomous household robots. With the majority of their research subjects describing the Roomba more as a companion with lifelike qualities than a robot. The majority of users also named their Roombas, as this seemed natural, with some research subjects even giving them names that seemed to fit the robot's "personality". This idea of the Roomba having a "personality" was further enhanced by some participants not wanting to return

[1]https://vimeo.com/153741726

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the machines under warranty out of fear of not getting that exact machine with a specific "personality" back.

Jones et. al.[5] have also done research with autonomous household robots. In their experiments they modify the Roomba to have different canine and zoomorphic traits. The main focus of their work is an investigation into the relationship between the robot and its owners, trying to explore whether these added interaction and appearance traits could influence satisfaction and the willingness to ignore mistakes that the robot makes. They found that different users have different preferences, and that users became increasingly polarized when faced with a zoomorphic Roomba.

This and other research has prompted researchers to investigate how to use Roombas for different modes of communication. Singh & Young[14] argue that it is increasingly important to work on effective interfaces between autonomous household robots, since they are becoming an increasing presence in our homes. They suggest using a tail, since the dog is one of the most well known animals in the western world, making a dog's communication easy to decode. They found that a tail interface was accepted by their test subjects and that they were able to communicate different states. Their study found that a static tail had less of an influence than a moving tail, and that different speeds influenced their test subjects perceptions. Based on this work they list a number of design guidelines that correlate to different attributes and descriptive keywords, and that can be utilized by other researchers and designers. As future work Singh & Young point out that a dog uses more than just the tail to communicate, and that this should be explored as well.

Earlier work from Singh & Young[13] into the field of using a tail for communicating different states of the Roomba also cites that one could use the tail vocabulary seen in tailed animals such as dogs or cats, not limiting it to only a dog, and trying to understand which can be leveraged in HRI. In this early research they also point out that the tail only forms one part of the overall animal expression.

RESEARCH FOCUS

As mentioned in the introduction, the aim of this project is to conduct research on how SCI can potentially help fit an autonomous robotic vacuum cleaner into the household hierarchy. This in turn should help the household dog to place itself in said hierarchy. Rasmussen et al.[11] describes an SCI framework with different types of shape change. With these different types of shape changes in mind, we laid out a set of design criteria, to ensure a varied set of experiments for us to conduct. Rasmussen et al. describes 8 different types of shape change, and we decided that by using these as a framework, we wanted an output from the shape changes that was digital, an output that was analog, and finally an output that had to be an aesthetic interaction. Even though Rasmussen's 8 types of shape change are meant for use in HCI, we draw inspiration from Mancini's work [7][8], and use this framework as a starting point for bridging SCI with ACI. In short, this means that our research focus consists of using the different types of shape changes to create a series of SCI's for the purpose of fitting the autonomous robot in the household hierarchy. This focus was the starting point for the design process, which will be described in the following section.

DESIGN PROCESS

The first step in the design process was to investigate what work had already been done in the field. As the related work section shows, the research had mainly been done in regards to how the autonomous robotic vacuum cleaner would interact with humans, from a Human-Computer Interaction (HCI) and HRI perspective. We outlined in the introduction that humans are not the only ones influenced by the introduction of autonomous household robots. This motivated our research to go in an Animal-Computer Interaction (ACI) direction, while attempting to integrate the related work, since ACI has strong ties to both HCI and HRI[8][9]. For inspiration we used concepts from the related work and we then started brainstorming and sketching the most promising ideas. Of the sketched ideas, the most prominent ones revolved around body language, as this is one of the main ways for dogs to communicate[16]. Because of this, we chose to proceed by building a prototype, consisting of a shield resembling the shape of a typical robot vacuum, like the Roomba. This iteration of the prototype is a lower fidelity version of the one described later. The way this prototype shape-changed, and interacted with dogs, was to protrude two ears from the base Roomba-like shape. According to Rasmussen et al.[11] , this type of shape change could be argued to be a combination of transformation of form and orientation, as the ears protrude from the basic Roomba-like shape, then changes direction when protruded, and finally retracts the ears back into the basic shape. In regards to our design criteria, this prototype covers the digital and analog modes of interaction, since the ears basically had two possible usages. The first would be to just flip them up or down, which makes it digital. The second would be to place the ears in different positions, with different speeds for the up and down movements thus making it analog. To evaluate this first iteration of the prototype, we tested it with a dog in it's home. We remotely controlled the prototype, and tried the different modes of the ears, to see how the interaction with the dog would work. During the evaluation we added a phone to the inside of the prototype, that played a sound of a vacuum cleaner. It turned out that the dog did not care about the prototype at all, and just went completely unfazed about with it's everyday life.

The next step was then to build a higher fidelity prototype, and evaluate that, to see if it had any effect on dogs. In the second iteration we added a wagging tail in addition to the ears, to see if that would have a bigger effect on the body language and communication with the dogs. Additionally the tail, in cooperation with the ears, covers our third design criteria about the aesthetic interaction. Singh and Young[14] presents a vocabulary revolving around how the movement of a dogs tail can mean different states of mind. The tail we added can move in different patterns to express these states. The final movement functions of our prototype, for both ears and tail, can be seen in Figure 2. For the second iteration of the prototype, we made a new shield, which was entirely coated in a fur-like blanket, to give the prototype a more animal-like look and feel. Both ears and tail could be hidden

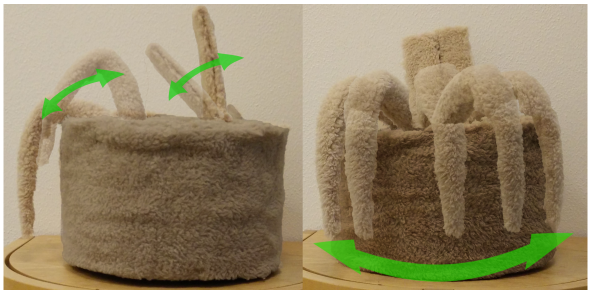

Figure 2. Prototype Function Diagram

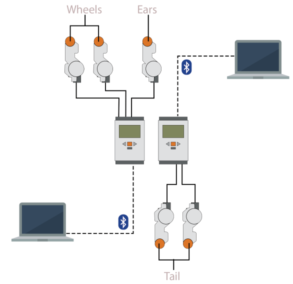

Figure 3. A technical schematic of the second iteration

in the basic Roomba-like shape, which now had to be taller and more cylindrical to hide all the inner workings. These inner workings will be described in the end of this section, with related schematics. The design of the second iteration can be seen in Figure 1b and c, and in the related video [2]. This second iteration of the prototype was then evaluated with three dogs, described by their owner as having significantly different personalities, and especially one dog would usually be scared of vacuum cleaners. At first one dog was introduced to the PetRoomba at a time, to see how they would react individually. Afterwards all three dogs were let into the room with the PetRoomba together. The evaluations showed that one of the dogs was a little more anxious about the PetRoomba than the others were individually, but this anxiety seemed to disappear when the three dogs were let in together. While the dogs did pay more attention to the second iteration of the prototype, they still seemed to be unfazed by the different modes of interaction. This prototype was tested both with and without a phone playing the vacuum sound, and neither had any major effect on the dogs.

The above mentioned findings will be discussed further in the next two sections. In the following the mechanics of the second iteration prototype is described.

As mentioned, we chose to operate our prototype remotely. We used Lego Mindstorms NXT 2.0, in order to move the prototype and actuate both the tail and the ears. As seen in the following schematic (Figure 3), we utilized two NXT 2.0 bricks, in order to control the amount of actuators we needed for the prototype, since a single NXT 2.0 brick only has three ports for actuators, and we used five. The chosen actuators are the simple NXT motors. The actuators labeled "Wheels" on Figure 3, are motors used to rotate the wheels, making it able to drive and turn. The ears are actuated by using a vertical motor, labelled "Ears" on Figure 3. This motor enables the ears to be protruded from the original Roomba-like shape, and also allows us to remotely lower or raise the ears either manually or in three predefined transitions; slow, medium and fast. This allows us to present the ears as both a digital and an analog output. The tail is actuated by using one vertical motor, and one horizontal motor both labelled "Tail" on Figure 3. The vertical tail-motor functions like the vertical motor used for the ears. It allows us to protrude the tail from the original Roomba-shape, and to control where the tail should be positioned. The horizontal motor is used in order to make the tail wag. The assembled inner workings of the prototype can be seen in Figure 1a.

REFLECTION ON PROTOTYPE & DISCUSSION

As Gaver[2] writes, *we may build on one another's results, but we can also usefully subvert them, suggest alternatives, or establish entirely new constructions, and this applies equally to our concepts, methods, processes, artefacts and approaches to evaluations.* Considering this our project and prototype is placed somewhere in the middle of building upon other's results and taking a new approach to the concept of adding zoomorphic features to a robotic vacuum cleaner. Even though our prototype has not yet shown the desired results, it could be used as a stepping stone for a next iteration to do research through design, either by ourselves or by others.

We saw no impact in using different transitions or using the analog or digital output as mentioned in the previous section. Current work within the SCI-community highlight that it is hard to communicate how a transition actually occurs[11]. It would be interesting to do further work on how to tailor specific transitions for animals, perhaps even making it possible for the Roomba to respond in a variety of ways dependent on the "input" from a dog, e.g. making itself smaller, signalling that it is submissive if the dog becomes aggressive, and then thoroughly documenting these transitions. This relates to the work presented by Singh & Young[14], where the Roomba showed servility to the human users. Although we have tried to implement some of their design suggestions, we have not had much success in communicating state to our test dogs. This suggests that further work is needed, perhaps both in the documentation of different transitions and of the specific tailoring of these transitions if they should be applicable to canines and potentially other pet companions.

A dog owner also suggested to us that we could use smell as a way to communicate with dogs, and we agree that this is definitely a possible solution. Work done by Horowitz[3] also supports this theory, by noting that smell is so important to dogs, that some species have developed bigger ears to increase air circulation around their noses to smell more of the environment, and that dogs often utilize the sense of smell even when exhaling. It could become problematic if the Roomba started to smell so intensely that its human owners were bothered by the smell, but dogs have a sense of smell roughly 40 times bet-

[2]https://vimeo.com/153741726

ter than the human nose. Potential future work could combine smells with a shape-changing interface.

Lastly we discussed using sound in our prototype to further enhance the communication with the dogs. But ultimately we decided not to do this, since it would go against the work presented by Jones et. al.[5] which, as mentioned in the related work section, states that users are more comfortable with a hybrid Roomba. We also drew on work done by Japan's National Institute of Advanced Industrial Science and Technology, which have shown through work on their advanced medical robot Paro[10], that it can be problematic to attempt to model animals that are well known to users. These models either have a hard time being convincing enough, thus seeming mechanical, or they find out at a later point that the "animals" are actually robots - disappointing them even more.

FUTURE WORK

As mentioned, a dog owner from the second evaluation suggested that we tried adding some new scents to the prototype, e.g. by placing the prototype in a dog bed for a while. The owner also suggested that we could investigate how different sounds, other than the sound of a vacuum cleaner, could influence how the dogs would react to the prototype. Additionally Furukawa et al.[1] has conducted research on how to make fur bristle by adding vibration motors to opossum fur. By adding this to our prototype, it would be possible to use another trait of the dog's body language, namely bristling fur on the back. This could be interesting to investigate in a next iteration of the prototype, since it would both add an animal scent, but also the texture type of SCI which could be argued to add another digital and aesthetic layer to the prototype.We previously discussed how our project potentially could be used as a stepping stone to conduct further research on using SCI as a way of adding zoomorphic features to a robotic vacuum cleaner. Including the above future work, this could be explored further.

CONCLUSION

In this paper we have presented our shape-changing prototype, the PetRoomba, that attempts to bridge the gap between HRI and SCI bringing them into the area of ACI. While the results of this early work is not thorough enough to make any conclusions, we feel that the related work, and the initial results show a promising new field. We call for fellow researchers to help explore how autonomous household robots influence not only our daily lives, but also the lives of our pet companions.

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