Hapticat: Exploration of Affective Touch

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ABSTRACT

This paper describes the *Hapticat*, a device we developed to study affect through touch. Though intentionally not highly zoomorphic, the device borrows behaviors from pets and the rich manner in which they haptically communicate with humans. The Hapticat has four degrees of freedom to express itself: a pair of ear-like appendages, a breathing mechanism, a purring mechanism, and a warming element. Combinations of levels for these controls are used to define the five active haptic responses: *playing dead*, *asleep*, *content*, *happy*, and *upset*. In the paper we present the design considerations and implementation details of the device. We also detail a preliminary observational study where participants interacted with the Hapticat through touch. To compare the effects of haptic feedback, the device presented either active haptic renderings or none at all. Participants reported which of the five responses they believed the Hapticat rendered, as well as their degree of affect to the device. We observed that participants' expectations of the device's response to various haptic stimuli correlated with our mappings. We also observed that participants were able to reasonably recognize three of the five response renderings, while having difficulty discriminating between *happy* and *content* states. Finally, we found that participants registered a broader range of affect when active haptic renderings were applied as compared to when none were presented.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Haptic I/O, Input devices and strategies, Interaction styles*

General Terms

Human Factors, Design, Experimentation

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Figure 1: The Hapticat device

Keywords

Affective touch, haptics, affective computing, affect, emotion, socially interactive robots, robot pets

1. INTRODUCTION AND MOTIVATION

Our research interests are in examining the emotional nature of touch; the abstract, intangible qualities of touch and the variety of responses they evoke. One field that addresses the relationship between touch and emotion is that of intimate interfaces ([10] [7] [5], for example). Additionally, this type of research naturally intersects both the fields of haptics and affective computing; however, currently there is little overlap in research between the two. Much of the research in haptics fails to address emotion; rather, it falls into one of two areas: the physiological/neurological aspects of touch, or devices for rendering realistic haptic sensations [8] [18]. Conversely, though affective computing examines emotions, it rarely considers the role of touch for expressing or evoking emotions.

The premise for the approach we have taken in this paper stems from animals and the symbiotic relationship humans have with them. Darwin documents a broad spectrum of emotional expression from both humans as well as animals [4]. We have chosen to initially focus on cats, concentrating especially on their haptic means of expression.

A cat provides a variety of tactile interaction. When it sits on one's lap, one feels the cat's weight, warmth, furry exterior, vibrations from purring, and subtle movements as it adjusts positions. In addition, directly interacting with the cat (e.g., stroking or petting) causes many of these tactile features to adjust. For example, the cat may push against

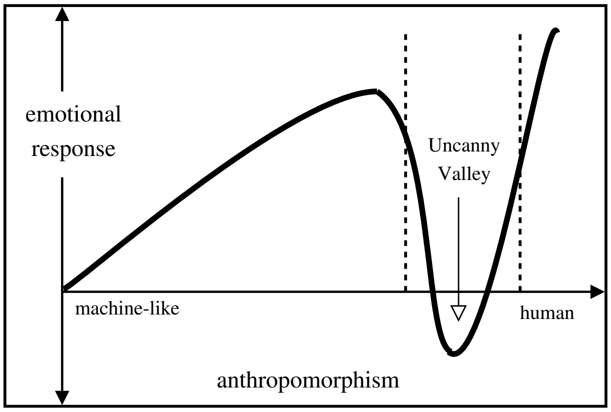

Figure 2: M. Mori's "uncanny valley" in which human emotional response dramatically dives when a robot nearly approximates human qualities.

the human's hand and its purring increases. We are careful to note, however, that we are not attempting to produce a realistic artificial cat. Rather, we are using a set of cat-like qualities as a starting point.

This approach has several advantages. Most importantly for our project, it gives us the freedom to include other tactile and affective features not inherent to a cat, as well as eliminate features as we see fit. Secondly, we obviate the pitfalls of the *uncanny valley* (Figure 2) since the device never approximates realism [13]. Finally, both complexity and cost are greatly reduced, allowing for rapid iteration of designs. To that end, we have developed the *Hapticat*, a device designed to study affect and emotion through touch (Figure 1).

The remaining sections of this paper cover the following topics: an overview of related work, the implementation of our device, the details of an observational study we conducted, a presentation and discussion of the results of this study, and finally, thoughts on future directions.

2. RELATED WORK

In this section we discuss the research areas with which the Hapticat intersects, specifically affective computing and socially interactive robots.

2.1 Affective Computing

Picard defines *affective computing* as "computing which relates to, arises from, or deliberately influences emotion." [12] Within the context of affective computing, we define *affective touch* to be those interfaces that display or evoke emotions by haptic means. There is a wide variety of research within the area of affective computing; however, two papers have direct relevance to our device.

McGee and Harup created PillO'Mate [9], a "contact cushion" outfitted similar in spirit to the Hapticat, to explore methods of touch interaction and relaxation.

Paiva et al. [11] created SenToy, a system that allows users to influence the emotional state of characters in a video game by means of a tangible interface. Users manipulate a physical doll into various positions that represent different emotional states that, in turn, map to the virtual character in a video game. Users were successful in utilizing SenToy for expressing emotion; however, the communication channel is input-only. The Hapticat, on the other hand, is intended to both receive information from the user as well as physically respond back.

2.2 Socially Interactive Robots

Fong et al. defines *socially interactive robots* as "robots for which social interaction plays a key role." [6] The field of socially interactive robots is becoming increasingly more important as robots are placed in environments to interact with humans. In recent years there has been a great deal of work towards making robots that can perceive as well as show emotions.

Cañamero and Fredslund built Feelix [3], a humanoid robot from LEGO® blocks, to study if humans could recognize its emotional state. Its states were rendered by means of facial expressions and sound. Breazeal's Kismet [1] also renders its emotional state by way of facial expressions. Additionally, it is capable of recognizing the emotional state of humans. While Kismet is only a head, Leonardo [2], its successor, has been developed with more complex mechanisms as well as adding limbs and skin. Scheff's Sparky robot [14] is a mobile robot using gesture and sound to convey emotion. Sparky's mechanism and gestures are much less complex than Breazeal's robots. The Hapticat, however, differentiates itself in the following ways: it is non-humanoid, it has low level of realism, and it conveys emotion mainly through touch.

2.2.1 Robot Pets

A sub-genre of socially interactive robots deals with zoomorphic creatures. Fong et al. [6] postulate that zoomorphic robots may suffer less from the "uncanny valley" (Figure 2) because relationships between humans and animals are less complicated. Examples of robot pets are Sony's Aibo and Tiger Electronic's Furby. The former represents a dog with extremely robotic features, while the latter represents an imaginary creature with very organic features.

Directly related to the Hapticat is the work done by Shibata et al. [17] that resulted in a highly realistic cat robot manufactured by Omron. However, they found that some individuals had severe reactions to the device because of expectations from real cats. In an attempt to lessen this transference by the human, they later developed a seal pup robot to study the effects of interacting with a creature to which people have no previous exposure [16]. Similarly, Hapticat also attempts to avoid human expectations by being less zoomorphic.

3. DESIGN AND IMPLEMENTATION

Two overall considerations guided our decisions for the design of the Hapticat. First, we carefully considered which distinct actuations to implement. As mentioned in Section 1, cats provide a variety of tactile interaction. In addition, we are not limited simply to cat-like qualities, so our initial set of choices is rather large. Following from this initial consideration, our second consideration was to avoid the device being perceived simply as a "bag of tricks;" a random and unrelated set of actuations. Rather, we wanted to provide a holistic, integrated experience. As a result, we finally limited the actuation to a small set we felt would work well in concert with one another. Our goal is that, as in a cat, several of these actuations together at varied settings will provide an expressive means to display emotional state.

The device itself is composed of five major features: a body, two ear-like appendages, a breathing mechanism, a purring mechanism, and a warming element. The Hapticat has a total of four degrees of freedom, which are provided by the ears, the breathing mechanism, the purring mechanism, and the warming element. The device's actuation and the implementation of its major features are described in the following sections.

3.1 Prototype Actuation

The prototype at this time is controlled by "Wizard of Oz" techniques. That is, by watching the actions of the user with the device, we manually actuate the ears, breathing, and purring mechanisms to simulate a response in the Hapticat. We chose to use this approach to control the device because we wanted a fast and low cost method to evaluate our proof-of-concept before introducing sensors and computer controlled actuators.

3.2 Body

The form factor of the body is intended to be organic yet relatively non-zoomorphic. Several styles were produced, with the final body design being reminiscent of a rugby ball. The individual parts making up the body are: an outer shell, an inner filling, and a tail.

The outer shell is expected to be pleasing both visually as well as haptically. A variety of materials and colors were examined for use. The original design was to use synthetic fur, but we eventually settled upon polyester fleece for its ease of construction, comfortable feel, and lower cost. The color of the shell is solid, light brown adding to its organic appearance.

The design goal for the inner filling was to provide a balance between comfortable feel as well as proper mass for the body. The system is comprised of several small cloth bags filled with polystyrene ("bean bag") pellets that are sealed with twine. The bags are sewn in a variety of sizes to better fit the different parts within the shell. To adjust the weight and feel of the device without changing the overall size, we added uncooked rice to several of the bags.

During pilots of the device it became clear that we needed a means to conceal the hoses and cords attached to the actuators inside the body. As a result, the cords are bound together then wrapped with the same fleece material used for the outer shell, giving the impression of a non-functioning tail.

3.3 Ears

Though the main role for ears is normally hearing, in animals they also provide a means for expression. Their rigidity and orientation convey information [4]. Additionally, ears provide a physical interaction point where a human can grasp or stroke them.

Atop the body of the Hapticat are two small appendages visually resembling ears (Figure 1). Though their location is different to where one might expect ears on an animal, this position provides easy access when the Hapticat is sitting on a human's lap. Table 1 enumerates the various ranges the ears can represent.

The outer, visible portion for each ear is a skin made of a lightweight white cloth sewn into the body. The actuation mechanism is a closed-air system comprised of one balloon for each ear clamped to plastic tubing. The tubing, in turn, runs out the body via the tail to a manually controlled syringe that regulates the flow of air in the system.

Mechanism	Range
Ears	flaccid, medium, erect
Breathing	none, slow, medium, fast
Purring	none, slow, medium, fast
Warming	none, low

Table 1: Ranges for Hapticat mechanisms

3.4 Breathing Mechanism

Designed to bring a "living" quality to the Hapticat, breathing provides both visual and haptic feedback to the human. One can see as well as feel the body expand and contract with each actuation of the mechanism. Table 1 enumerates the various ranges that can be represented by the breathing mechanism.

The breathing mechanism is a closed-air system built with a latex bladder clamped to plastic tubing that exits the body through the tail. Outside the tail on the opposing end, the tubing has a coupler that attaches to a makeshift bellows used to inflate and deflate the bladder.

3.5 Purring Mechanism

Purring provides both auditory as well as haptic feedback to the human. One can hear the device purring as well as feel it when in contact with the body. Table 1 enumerates the various ranges that can be represented by the purring mechanism.

Purring is actuated by means of a small (1 watt) brushed DC motor with an offsetting weight on the shaft. It is mounted in a tight housing to protect the motor and to amplify the vibration, then enclosed in the center of the body. The motor's power lines run out the body through the tail to custom electronics that attach to a PC via the parallel port. The states are regulated by modified custom software written in C++ to drive the motor [15].

3.6 Warming Element

In an attempt to radiate warmth from the Hapticat, a heating pad is inserted between the outer shell of the body and the inner filling. An unintended positive side-effect was that the pad helped to pull the look and feel of the body together. Previously, the coarse granularity of the inner bags could be seen and felt as lumps; the pad provides a more cohesive shape.

The heating pad has four settings: none (off), low, medium, and high. We elected to only use none and low (Table 1); in pilots of the device the others proved too warm. It should be noted that once the pad was warm it took a considerable amount of time—several minutes—for the heat to dissipate when turned off. For this reason, we left the warming element off during the user study.

3.7 Response Settings

The Hapticat is capable of producing five distinct responses: *playing dead*, *asleep*, *content*, *happy*, and *upset*. These responses are rendered by selecting a setting for each mechanism from within its respective range (Table 1). Table 2 enumerates the specific setting chosen for each response.

Response	Ears	Breathing	Purring
Playing Dead	Flaccid	None	None
Asleep	Flaccid	Slow	None
Content	Medium	Medium	Slow
Happy	Erect	Medium	Medium
Upset	Erect	Fast	Fast

Table 2: Hapticat mechanism settings for responses

4. USER STUDY

The preliminary observational study was designed to evaluate the effectiveness of the Hapticat in conveying affect through touch. Specifically, we were interested in answering the following questions:

1. Do the actions we have designated to activate the Hapticat's responses match those expected by a user?

2. Can the Hapticat communicate to a user the emotional responses we had implemented?

3. Does the response of the Hapticat initiate any strong emotional response from a user?

The following sections detail the demographics of the participants, the apparatus used, and the procedure of the user study.

4.1 Participants

A total of 13 participants (3 females, 10 males), ranging in age from 20–39, volunteered to take part in the user study. All participants were graduate students in the computer science department. Each received $5.00 as compensation for their participation in the study. Nearly half of the participants reported little to no experience with haptic devices.

4.2 Apparatus

The apparatus for the user study consisted of the Hapticat device presented to the participant sitting in a chair in front of a partition. The device was connected to the haptic actuators located on the other side of the partition such that the participant could not see the experimenters manipulating the device. Since this was a "Wizard of Oz" experiment, it was necessary to conceal these experimenters to maintain the illusion that the Hapticat device was responding independently. The participant was able to see the experimenters when entering the room; however, the participant's back was to the partition so the experimenters were not viewed during the study. At no time was the participant able to see the Hapticat's actuating mechanisms.

One experimenter controlled the lungs while the other controlled both the purring and the ears. The study facilitator sat with the participant in front of the partition. He discretely held a small signaling device—a switch controlling a LED behind the partition—to communicate to the other experimenters when to start the response of the Hapticat. Figure 3 illustrates the user study setup.

4.3 Procedure

The experiment took approximately 30 minutes per participant to complete. It was divided into three parts: mapping actions to Hapticat's responses, observation of affective response, and a questionnaire.

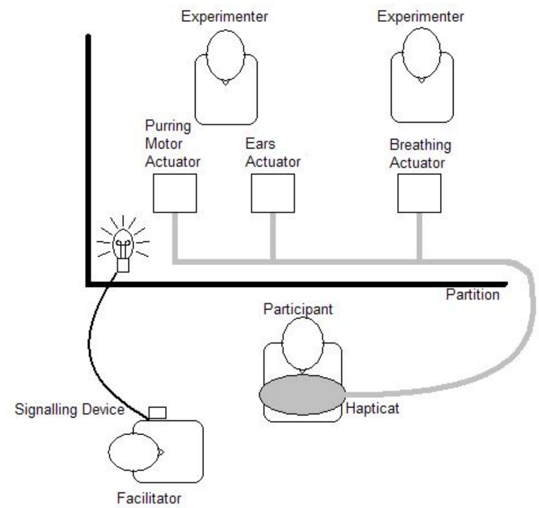

Figure 3: Experimental apparatus configuration

During the first part of the study the participant was asked to look at the Hapticat, which was originally sitting beside her. Without touching or interacting with it, she was asked to answer a questionnaire regarding the responses expected after performing a particular action. The list of actions the participant evaluated was: gently petting, vigorously petting, rubbing ears, pinching body, poking body, hugging, tickling, resting hands on top, shaking, and leaving it alone. The possible Hapticat responses were renderings meant to convey: *playing dead*, *asleep*, *content*, *happy*, and *upset*.

The basic approach for the second portion of the study was observational; however, we also took the opportunity to gather data to compare with our observations. We conducted a within-subjects study with the independent variable being the presence or absence of active haptic feedback. More precisely, when the participant performed an action, the Hapticat either produced an active haptic response or not. Counter-balancing was achieved by seven of the participants receiving the active response in the first set of interactions, while six of the participants received the active response during the second set.

During this part of the study the Hapticat was placed on the lap of the participant. The facilitator asked the participant to perform a specific action (from a subset of the previously mentioned actions). After experiencing the response from the Hapticat, she answered two questions.

The participant was asked what the perceived response of the Hapticat was from the list: *playing dead*, *asleep*, *content*, *happy*, or *upset*. In addition, the participant was asked her emotional response to the Hapticat by reporting a level of agreement to the statement, "I had a positive emotional response to the device". Response to this statement was ranked on a five-point Likert scale: strongly disagree, disagree, neutral, agree, or strongly agree.

The participant was asked to perform each action once without haptic response from the Hapticat and once with active haptic response. The order of the actions was randomized across participants.

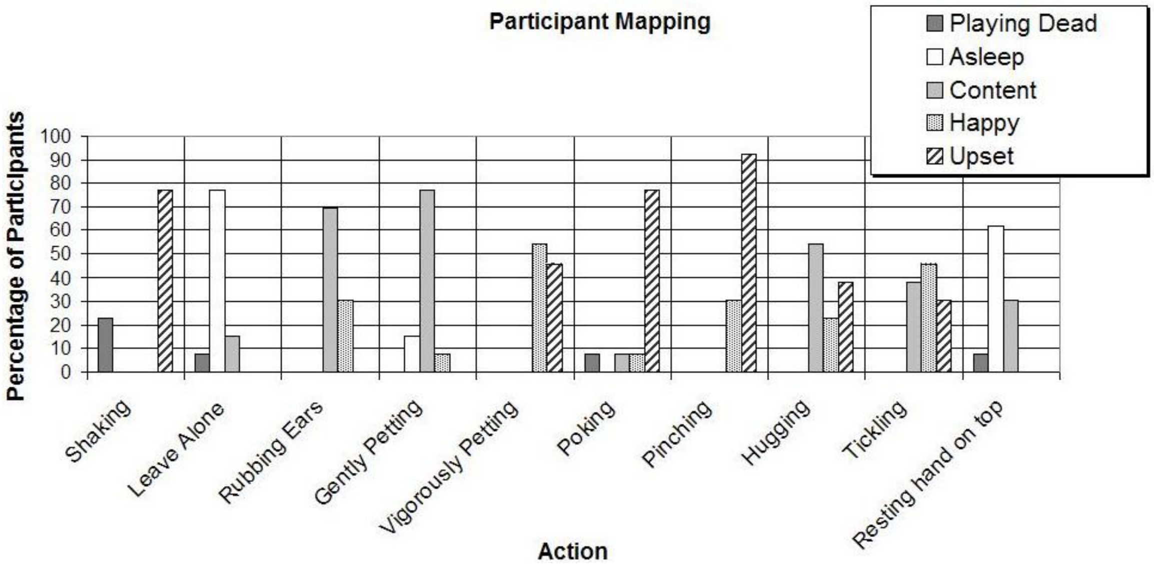

Figure 4: Breakdown of participant mapping of action to response

At no time were participants told that the Hapticat was controlled by the individuals behind the partition. Debriefings with participants afterwards confirmed that they did not suspect this.

During the final part of the study, the participant completed a post-study questionnaire. This questionnaire gathered information regarding demographics, background on pet ownership and interaction with animals, and comments regarding the device and the user study.

5. RESULTS

This section details the statistical results obtained from the user study. As described in Section 4.3, the data gathered are intended for comparison with our observations during the study. The following subsections describe the results in more detail: mapping actions to the Hapticat's responses, communicating the Hapticat's response, and the emotional response of the user.

5.1 Mapping actions to Hapticat's responses

In the first part of the study, participants were asked to look at, but not interact with, the device. They were then asked to generate a list of mappings from actions performed to the expected responses from the Hapticat (Section 4.3).

We found that our mapping from the actions to the Hapticat responses generally matched the responses expected by the participants. Table 3 lists our mappings, and Figure 4 charts the breakdown of the participants' responses.

There were four mappings that the participants did not show an obvious agreement with ours: shaking, vigorously petting, hugging, and tickling. In the case of shaking, 77% of the participants expected the Hapticat to be *upset*, while only 33% agreed with our mapping, *playing dead*. In the other three cases (vigorously petting, hugging, tickling), the majority of participants agreed with our mappings, but because of our small sample size we can not definitively say that our mappings were correct. However, looking closer at the demographics of our population, we discovered that the majority of the responses that agreed with ours were from pet owners.

Action	Hapticat Response
Shaking	Playing Dead
Leave Alone	Asleep
Rubbing Ears	Content
Gently Petting	Happy
Vigorously Petting	Happy
Poking	Upset
Pinching	Upset
Hugging	Content
Tickling	Happy
Resting Hand on Top	Asleep

Table 3: Our mappings from action to Hapticat response

5.2 Communicating Hapticat's response

In the second part of the study participants physically interacted with the device. They were then asked to specify which response was being expressed by the Hapticat (Section 4.3).

The participants were able to easily recognize three of the five responses we haptically rendered. For the response of *playing dead*, 85% of the participants recognized our rendering, 77% of the participants recognized our rendering of *asleep*, and 62% of the participants recognized our rendering of *upset*.

There seemed to be some difficulty differentiating between our rendering of *happy* and *content*. When the participant rubbed the Hapticat's ears, our rendered response was *content*; most of the participants recognized the response as being *content* (62%) but 31% stated the response they felt was either *asleep* or *happy*. Similarly, when the participant petted the Hapticat, our rendered response was *happy*; however, most of the participants recognized the response as

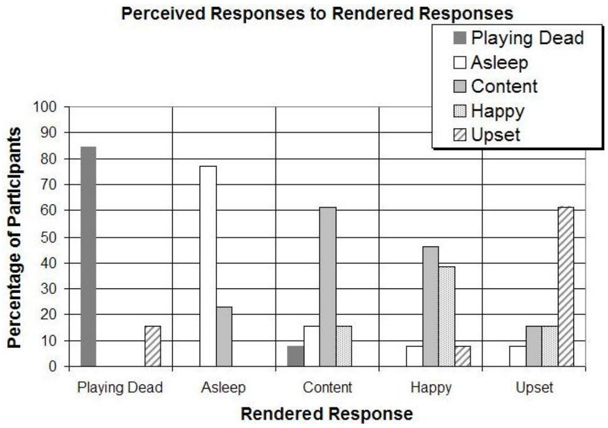

Figure 5: Participants' perception of Hapticat's responses to actions

being either *content* (46%) or *happy* (39%). Figure 5 charts the participants' perception of the device's response.

5.3 Emotional Response

Also in the second part of the study, after specifying the Hapticat's response, participants were then asked to report any change in affect (Section 4.3).

Participants showed a slightly more positive emotional response when the Hapticat responded haptically to most actions when compared to a non-active Hapticat during the same action (Figure 6).

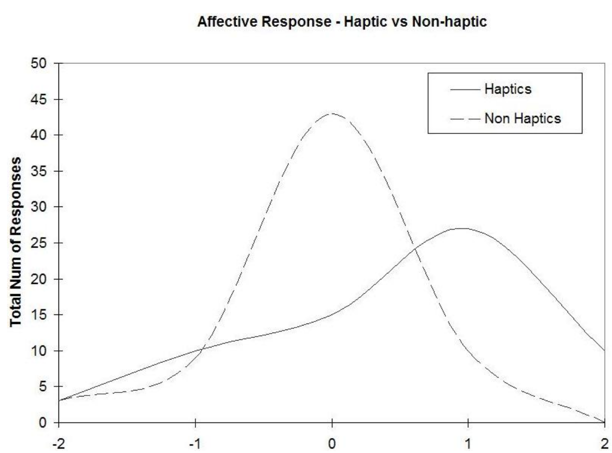

Figure 6: Affective response - Active haptic rendering vs. non-active

In addition, Table 4 shows a comparison of the means for the active haptic and non-active responses during each action (a response of 0 indicates a neutral response).

When participants experienced the haptic rendering of *asleep*, they had a significantly more positive emotional response compared to no active rendering ($t(24) = 5.196, p > 0.05$). Similarly, participants had a significantly more positive emotional response to the haptic rendering of *upset* compared to no active rendering ($t(24) = 0.490, p < 0.05$). However, when looking at a chart of the distribution of participants' emotional responses to the *upset* rendering, we see that this statistical significance is misleading since the distribution of responses was not normal (Figure 7).

Response	Mean	SD	F	Sig	t
Playing Dead	-0.31	0.630	1.1270	0.299	-0.661
Playing Dead†	-0.51	0.555	-	-	-
Asleep	1.15	0.689	5.440	0.028	5.196
Asleep†	0.00	0.408	-	-	-
Content	0.77	0.725	0.004	0.948	3.328
Content†	-0.15	0.689	-	-	-
Happy	0.92	0.954	0.416	0.525	2.372
Happy†	0.08	0.862	-	-	-
Upset	0.08	1.441	10.009	0.004	0.490
Upset†	-0.15	0.899	-	-	-

Table 4: Comparison of mean for active and non-active haptic (†) response

The renderings of *content* and *happy* did not show a significantly greater positive emotional response compared to no active renderings to the same actions at $p = 0.05$, but we observe that the means for both the *content* and *happy* renderings are slightly higher than for no active renderings. The rendering of *playing dead* also did not show a statistically different emotion response compared to no active renderings at $p = 0.05$, but we observe the mean was slightly lower than for no active renderings.

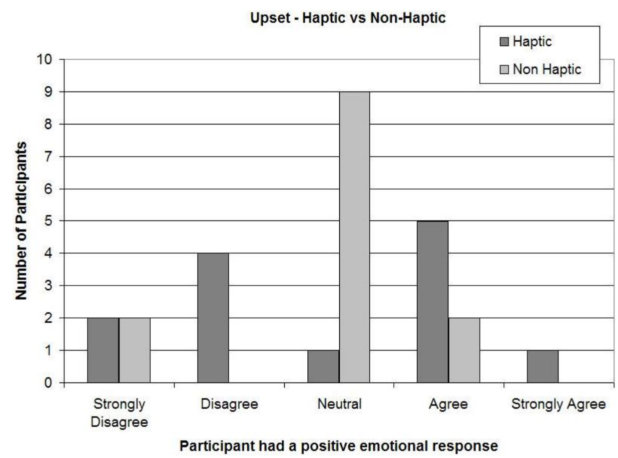

Figure 7: Distribution of emotional responses for "upset" rendering

6. OBSERVATIONS AND DISCUSSION

As described in Section 4.3, the majority of the study was intended to observe participant response to the Hapticat. Our goal was to see if the user had a change in affect while interacting with the device when it rendered active haptic responses. Throughout the study, the facilitator was able to observe the reactions of participants through their posture, facial expressions, and verbal comments. It was particularly interesting to watch their reactions the first time the Hapticat began to respond to their actions. Nearly all exhibited strong positive reactions. One participant began to laugh so hard that tears came to her eyes, and she was unable to report her responses until she took a short break to regain her composure. The vast majority of participants remained genuinely excited and engaged with the Hapticat during the length of the study. However, one participant felt slightly disturbed by the device and commented about this throughout the trials. Whether positive or negative, we were encouraged to observe a change in a participant's emotional state.

When mapping the response of the Hapticat to a particular action, we found participants generally agreed with our mappings. It was interesting to see how the participants would respond since we did not reveal the Hapticat to be any particular species. We suspect that participant responses were largely based on their previous experience with animals. An example of this was the agreement with our mappings being strongest for those who are pet owners in the cases of vigorously petting, hugging, or tickling the Hapticat. In the case of shaking the Hapticat, we conclude that we may have incorrectly mapped the Hapticat's response. While we mapped shaking the Hapticat to *playing dead*, our participants thought it would be *upset* instead. Our rationale in choosing *playing dead* was that if one was particularly cruel to a creature, it would react more strongly than being *upset* by effectively "playing possum." Our results clearly show that our participants did not make the same connection. One participant commented that if their pet was so uncomfortable in a situation, it would simply run away. Although our results suggest that our mappings were generally correct, our small sample population indicates that more research will be needed to confirm our mappings for those cases that were not obvious matches.

Our use of the purring, breathing, and ear mechanisms in the Hapticat effectively rendered three of the five responses we defined. There was some confusion between the *happy* and *content* responses. The difference between the renderings was in the speed of the purring, and a half erect or fully erect ear; the breathing of the Hapticat remained the same for both responses. It is possible that the differences between the renderings were too subtle for the participants to differentiate them. Particularly, since there was no training during the study to demonstrate the differences, participants likely had to primarily rely on transfer from their knowledge of the responses of animals. However, we also suggest that the emotion of *content* and *happy* may be too similar for the participants to conceptually differentiate the two. Also, since our sample population is small, more research can be done in the future to confirm our results.

Our participants reported a slightly greater positive emotional response when they felt the active haptic rendering of the Hapticat, rather than non-active rendering (Figure 6). Although we did not find statistical significance in every rendering, all but one caused a greater mean positive emotional response from our participants when active haptics were applied than without (Table 4). Only *playing dead* caused a slightly negative emotional response from our participants. We suggest that when the creature is clearly in an active state, the switching to inactive is interpreted as "dead" as opposed to simply "off", thus eliciting the negative emotional response.

Our results from the user study have been encouraging and suggest that more work can be done to further explore affective touch with the Hapticat. We believe these results stem from realizing our original design goals for the Hapticat: appropriate choices for haptic actuation coupled with an integrated experience. However, we have also observed that human interactions with this animal-like device is much more complex than simply a stimulus-response interaction. There are many factors, such as prior experience with animals and perception of emotion, that complicate the study of human interaction in this context.

7. CONCLUSION AND FUTURE WORK

In this paper we have presented the Hapticat, a device created to study emotion through touch. The inspiration for the device comes from the relationship between humans and animals. A description of the design and implementation of the device was provided. In addition, we documented a preliminary user study. The results show that our action/response mappings for the device correlate with the expectations of the participants. Also, participants were able to recognize three of the five renderings, as well as reporting a noticeable change in their emotional state.

There are three major areas for the Hapticat which we feel warrant further exploration: device enhancements, user studies, and applications.

The device currently requires the coordinated effort of at least two people to effectively render the variety of responses (Table 2) by hand. As a result, we plan to automate the actuation and add various sensors, thus moving away from "Wizard of Oz" mechanisms. At the same time, we also plan to investigate new forms of affordances and actuation. We have the freedom to go beyond simply cat-like features, so we plan to investigate other novel multi-modal interaction. Additional degrees of freedom should allow us to render an even more diverse set of responses from the device.

Leveraging observations from our recent study (Section 6), we would like to conduct additional user studies with a larger set of participants. It would be interesting to correlate variables such as pet ownership and gender with participant behavior. Also, additional studies would be important to validate any actuation enhancements to the device. Additionally, we would like to investigate other emotional aspects, such as the level of "connectedness" individuals have for the Hapticat. The overall goal of further studies is to derive general qualities that may be applied to other affective interfaces.

We would also like to explore application domains for the Hapticat. Borrowing from previous work by Shibata [16] and others, one domain could be in robot pet therapy; using the Hapticat as a surrogate in environments where animals are not normally allowed, such as hospitals and nursing homes. Another possible use is as an intimacy device between individuals. The Hapticat could serve as a proxy for a loved-one in a remote location by expressing their emotional state. One other possible use could be as an ambient display, where the device subtly conveys information haptically to the user.

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