Towards an experimental model for exploring the role of touch in anxiety reduction

Joseph P. Hall III*
Dept. of Mechanical Engineering
University of British Columbia

Jeswin Jeyasurya†
Dept. of Mechanical Engineering
University of British Columbia

Aurora Phillips‡
Dept. of Mechanical Engineering
University of British Columbia

Chirag Vesuvala§
School of Computing Science
Simon Fraser University

Steve Yohanan ¶
Dept. of Computer Science
University of British Columbia

Karon MacLean‖
Dept. of Computer Science
University of British Columbia

Abstract

In this paper we investigate the ability of a haptic device to reduce anxiety in users exposed to disturbing images, as we begin to explore the utility of haptic display in anxiety therapy. We conducted a within-subjects experimental design where subjects were shown two sets of disturbing images; once with the haptic creature and once without; as well as a control condition with calming images. Subjects were connected to bio-sensors which monitored their skin conductance, heart rate and forehead corrugator muscle changes; we then used these signals to estimate the subject's arousal, which has been correlated with anxiety level. We observed a significant interaction effect on arousal when subjects held the creature in the presence of disturbing (versus calm) images. The results of this exploratory study suggest that the creature was able to reduce the level of anxiety induced in the subjects by the images. Qualitative feedback also indicated that a majority of subjects found the haptic creature comforting, supporting the results from the bio-sensor readings.

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

1 Introduction

Animals have been shown to lower stress, reduce anxiety [3] and positively influence the mood of their human companions ([1] [6]). Indeed, the presence of a friendly dog may be just as effective as prozac in reducing stress [2]. Because many considerations – allergies, health, living situation, added responsibility, an animal's unpredictability – can make having a companion animal impractical, the emerging field of a "robot therapy" aims to replicate therapeutic benefits of a companion animal in a robotic device ([24] [26]).

Many factors must be addressed for the development of such therapeutic devices. One important research question is the influence of touch in expressing or evoking emotion, which research suggests may play a major role in the effect of animals on anxiety [25]. Our own longer-term research goal is to reproduce the anxiety reduction that has been documented in touch-based interaction with real animals in a robotic creature with richly expressive haptic attributes, in both sensing and display; and if so, to use such a device to implement an active therapy strategy. In particular, we are focused on helping children suffering from anxiety disorders develop successful coping strategies; a 'haptic creature' such as the one we will describe here may be an acceptable vehicle for people of this age. As a first step, we must understand the degree to which a haptically enabled device can influence the affective response of a person interacting with it, how such a response can be measured, and the user's subjective reactions to and acceptance of the device.

Measuring a person's emotional state is a challenge in itself, explored in the realm of affective computing. Biometric sensors have already proven useful for *categorizing* emotion ([19] [8]), and our approach is to use these methods in a related way. Here, we employed the fuzzy inference engine of Kulic et. al [11] to estimate a subject's momentary state of arousal (which has been linked to anxiety level [20]) from several physiological signals, most notably skin conductance and heart rate.

As far as we can tell, this approach of combining haptics and affective computing is unique, and will help develop a greater understanding of the role of touch for expressing or evoking emotion in people. In this paper we propose and begin to validate a lab-based experiment platform for studying this issue, based on the"Haptic Creature" developed by Yohanan and Maclean [29] for studying affect presentation and reception through touch. This semi-zoomorphic device is capable of expressing several emotional states through touch alone (Figure 2).

The following sections will discuss related work, the approach to our study, the haptic creature prototype, the user studies we conducted, our results from these studies, a discussion of our results, and a conclusion.

2 Related Work

While there is little history of systematic study of therapeutic robots with a focus on their touchable attributes, this work draws heavily on psychological studies of human-animal interactions, affect measurement and more general uses of affect in human-robot interaction.

2.1 The Human-animal connection

There has been ongoing research in the physiological responses of humans during human animal-interaction, particularly in comparing this interaction to human-human interaction. Allen et al. [1] investigated the effect of human and animal companions on stressful situations, and found that the presence of a pet dog was better able to reduce a subject's physiological responses to a stressful situation than a human friend. Touch, more than presence, has also been shown to influence emotional state. Vormbrock et al. examined the heart rates and blood pressure of individuals interacting with a dog, and found petting and talking to a canine caused a reduction in these metrics, whereas talking and interacting with humans typically increases these measures [25]. Most recently, research by Coren suggests that it can take as little as five minutes for the presence of a canine to cause signs of reduced stress in a human [2]. While humans can act as calming factors, we feel that replicating

*e-mail:jphiii@interchange.ubc.ca
†e-mail:jeswinj@interchange.ubc.ca
‡e-mail:aurorap@interchange.ubc.ca
§e-mail:cxv@sfu.ca
¶e-mail:yohanan@cs.ubc.ca
‖e-mail:maclean@cs.ubc.ca

typical animal calming behavior haptically is both easier to implement and less prone to ambiguity in interpretation than attempting to reproduce human touch sensations.

2.2 Affect and human-robot interaction

Affect is playing a growing role in human-robot interaction (HRI). Humans communicate with each other via a variety of nonverbal methods, both consciously and subconsciously. Unconscious signals in particular can serve as clues for human intent, allowing a robot to react to a human's state without requiring specific input or volitional attention ([17] [9]). Anxiety has been included in HRI research primarily to improve safety in industrial environments where robots work in close proximity with humans, with the goal of allowing a finer safety limit that allows close physical interactions while blocking those perceived as dangerous [12].

Other researchers have used a similar framework for therapeutic goals. Liu et al. [14], used physiological sensors to determine the affective state of an autistic child playing a robot-based basketball game. The game's difficulty was modified in response to the sensor data, and they achieved an 81.1% accuracy in identifying the difficulty level their users found least frustrating. This was an example of robot reacting to a user's affective state, and modifying its own behavior in response. The eventual goal of our own research will be to see how a robot can impact a human's emotional state through *touch*.

2.3 Affect and touchable robots

Affective touch, the ability of a robotic device to either recognize or induce emotional responses from physical touch, has been the focus of many recent devices. For example, emotional responses have been induced by devices that mimic traditional human contact. Bonanni et al. [5] developed a wearable haptic scarf to record and playback affective interaction between users, and were able to produce positive user interactions to simulated touching. Mueller et al. [16] developed the *Hug over a distance* device, a vest with inflatable air bladders that could simulate a hugging motion. The design was intended as a substitute for intimate contact in couples, who found the device initially encouraging, but impractical for use in their daily lives: to recognize the emotional responses of users, specialized devices are necessary.

There have also been forays into simulations of human-animal contact. Stiehl et al. [23] developed the *Huggable*, a robotic teddy bear equipped with somatic sensors, and applied machine learning techniques to determine the emotional state of a user interacting with the robot. Paro [22] is a baby seal robot with touch sensors at various points on its body. It is designed to investigate emotional attachment by humans to robots. Also, Probo [21] is an huggable robot resembling a whimsical elephant-like creature that is designed to provide support for hospitalized children.

However, eliciting a range of emotions in users – rather than simply reproducing human actions – requires more detailed investigation into user interaction strategies. Yohanan and MacLean developed the *Haptic Creature* [28][29] to systematically study affect as communicated through touch. This haptic creature was utilized as the platform for this experiment, as described in Section 4.1. It is a semi-zoomorphic, manually operated robotic device with life-like characteristics that emulate the haptic communication between pets and humans. Yohanan et al. completed preliminary observational studies which showed that the haptic creature was able to generate appropriate affective responses in people interacting with the device. We chose this device for its ability to support touch (as opposed to visual or auditory) interactions as well as ready availability and the flexible use afforded by its manually operated, rather than programmed, nature.

2.4 Measuring human affect

Great effort has been devoted to analyzing physiological sensor data to determine human affective state. It is a nontrivial problem, as different individuals (or the same individual at different times) can react differently to the same stimulus, and the physiological signals have not been fully mapped to emotional state. Rani et al. [18] summarize several machine learning techniques that have been used for this purpose. Here, our sensor platform for this experiment recorded raw sensor readings and employed the fuzzy inference engine of Kulic et. al ([11, 13]) to estimate subject arousal based on a combination of the skin conductance (SC) and heart rate (HR) [9]. This algorithm first looks at SC and its derivative (dSC), basing arousal primarily on SC, but making it slightly higher for a positive than for a negative change in SC. (Thus if SC is increasing and high, arousal is high; whereas if SC is *decreasing* and high, arousal is medium). Arousal is also set to high if HR is very slow or very fast. The placement of emotions on a quantitative scale is based on Russell's circumplex model of affect [20], in which arousal is the strength of an emotion, and valence its positive or negative aspect. Thus "excitement" is classified as strongly positive arousal yet strongly positive valence; anxiety, conversely, has strongly positive arousal in conjunction with strongly negative valence.

3 Approach

Our larger goal is to explore the potential of a touch-centered robotic device to develop transferrable coping strategies in anxiety-prone individuals, particularly young children. An experiment model for this plan needs four elements: a subject group which can validly act as a stand-in for the eventual target group of anxiety-prone children; a controllable means of inducing stress on demand in a manner appropriate for these subjects; physiological measurement of anxiety for the purpose of verification – a measure which might not be needed in a "release" device; and a series of devices of increasing fidelity and controllability through which we hope to reduce experienced anxiety in a manner that will lead to independent coping skills. An interim goal of the research program is to inform the iterative development of this device.

Our immediate research objective was to determine if the physiological data indicated that the subject is at a calmer state while watching the graphic images with the haptic creature than without the creature. Furthermore, to better understand the ecological validity of this experiment model we wished to know three things: (a) if it is possible for us to consistently elevate subjects anxiety level in a controlled laboratory setting, so that we can determine the influence of the haptic creature as an intervention; (b) whether the presence and behavior of the haptic creature influenced this artificially generated anxiety state, using metrics obtained from the physiological readings and qualitative reports from subjects; and (c) potential acceptance of the haptic creature.

For ethical simplicity in early-stage research, rather than using children we began with young adults who were not selected for anxiety-prone history; and induced anxiety in a laboratory environment by asking them to view disturbing images. Physiological sensor data is processed by a fuzzy inference engine [10] which estimates the valence and arousal of the subject, thus giving an objective measurement of anxiety. Young adults clearly will exhibit many differences from young children; for a start, they are likely to have different anxiety triggers (we would not use disturbing images with children), and they could be expected to respond less strongly, or be less engaged by, a "cuddly" toy. However, their basic physiological responses (however triggered) should be similar, and the expectation of lower response to the haptic creature allows us to proceed on a conservative basis without imposing a burden on the affected population we are trying to support.

We initially explored the use of video scenes to induce anxiety. In a pilot test, we attached biosensors subjects who then viewed

Figure 1: A more recent version of the haptic creature currently under construction.

Figure 2: Hapticat device and also the display of the heating pad and the manual breathing mechanism.

a disturbing scene from the movie *American History X*. While the movie scene did elicit increased skin conductance and heart rate, the response was inconsistent across trials, highly transient and dependent upon an individual's engagement with the video. In most cases, the anxiety peaked for part of the scene but remained at a lower state for the majority of the film. While clearly real, these responses were not sustained or controllable enough for us to use them as a study platform.

Instead, we chose to use a series of images to invoke a more steady, sustained response, in that they maximize the presence of the initial transient and their potential variety allows us more possibility of finding the triggers that work for a particular individual. The International Affective Picture System (IAPS), a relatively standard tool for experiment anxiety induction [7], is a set of static images based on a dimensional model of emotion. The image set depicts both positive and negative scenes such as mutilations, snakes, insects, attack scenes, accidents, contamination, illness, loss, pollution, puppies, babies, and landscapes. The dimensional model categorizes each picture by emotional valence and arousal. For our experiment condition we selected images rated with a low valence and high arousal, corresponding to high anxiety induction; for our control condition, we used independently chosen images which a pilot study indicated were calming.

The haptic creature used for this study is a "Wizard of Oz" type prototype [28]: i.e. a human operator simulates robotic behavior more flexibly than can be attained in early design by automatic control. Its life-like characteristics include a warming element, a purring mechanism, inflatable ear-like appendages, and a pneumatically activated breathing mechanism. The creature's rhythmic breathing and quiet purring reflect typical animal behaviors, while physical warmth has been shown to increase interpersonal "warmth" in social interaction [27]. A more advanced and automated version of the haptic creature is currently under construction 1; the experiments described here will inform this ongoing development effort.

We asked subjects to view two sets of approximately twelve anxiety inducing graphic images, while collecting biometric sensor readings. Subjects viewed one set of images without the haptic creature and one set of images with the haptic creature; and also viewed the neutral images with and without the creature. With the haptic creature, the subject was asked to focus on the screen with the haptic creature in their lap. The haptic creature performed life-like haptic actions such as breathing, purring and providing warmth while the subject watched the graphic images. Qualitative data was collected from the subjects through a pre and post questionnaire.

4 SETUP

4.1 Prototype

The prototype used in the study was a soft robotic haptic creature. The creature had a body which consisted of light brown polyester fleece material, shaped similar to a rugby ball. To maintain a low level of zoomorphism, it had two balloon stiffened ears and a tail, but did not include any other visual animal-like features. The body contains the mechanical components and is lined with small cloth bags filled with polystyrene pellets to give a soft feel to the creature.

The mechanical elements of the creature allow the creature to replicate the purring, breathing and warmth of an actual animal. As mentioned in the approach section, the mechanical elements of the creature are operated manually. The purring mechanism is a 1 watt brushed DC motor with an off-setting weight on the shaft. The motor is connected to an external power supply via a power cord that runs out of the body through the tail. Rotation of the motor shaft results in auditory feedback to the user, as well as a slight haptic feedback.

The breathing mechanism is a closed-air system composed of a latex bladder clamped to plastic tubing that exits the body through the tail. The bladder is inflated and deflated using a makeshift bellows connected to the end of the plastic tubing. The warmth mechanism is a basic heating pad with multiple heat settings. The pad is inserted between the outer shell of the body and the inner lining and the power cord runs out of the body through the tail. Full construction details of the haptic creature are presented in [29].

4.2 Biometric Sensing

Biosensors connected to an encoder were used to observe the stress level in subjects when inducing anxiety. The encoder used was a FlexComp Infinity encoder [4]: a device for real time computerized psychophysiology, biofeedback and data acquisition. The encoder was connected to three different types of sensors and electrodes. Figure 3 shows the three sensors and their typical waveform signal.

The biosensors attached to the subject were:

1. EMG MyoScan-Pro^{TM}Sensor T9401M-60: a pre- amplified surface electromyography sensor. The sensor is connected to the forehead of the subject via electrodes to the encoder and it provides the stress/relaxation biofeedback of the corrugator muscles of the forehead.

Figure 3: From left to right: EKG™Sensor T9306M, EMG MyoScan-Pro™Sensor T9401M-60, skin Conductance Sensor SA9309M, two different types of electrodes a) for the EMG™sensor and b) for EKG™Sensor.

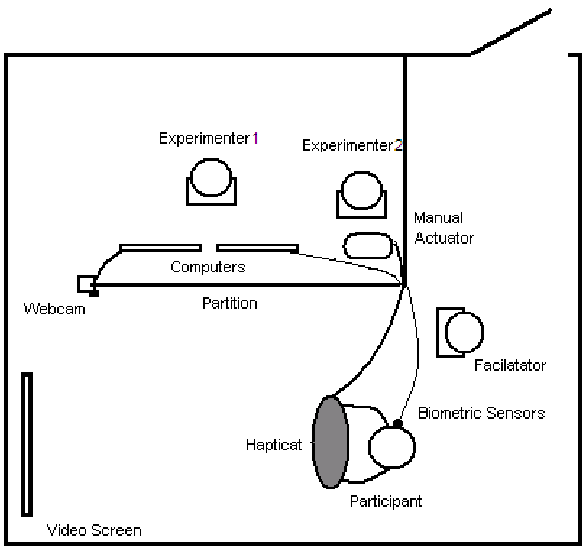

Figure 4: Diagram of the experiment room setup

2. EKG™Sensor T9306M: a pre-amplified electrocardiograph sensor, for directly measuring heart electrical activity. Three sensors attached to electrodes (located on the left and right side of the upper chest respectively, and the belly) are connected to the encoder. The sensor detects and amplifies the small electrical voltage that is generated by the heart muscle when it contracts.

3. Skin Conductance sensor SA9309M: measures the conductance across the skin. It is connected to the index and middle fingers of the subject's non-dominant hand.

5 Experiments

5.1 Experimental Setup

The set-up for the experiment is shown in Figure 4. The subject entered the room and sat in a chair facing the video screen. The facilitator then described the experimental procedure and attached the biometric sensors to the subject. Experimenter 1 behind the partition recorded and monitored the sensor readings on one of the computers and also activated the picture slide show on the video screen and monitored the actions of the subject via a webcam on a different computer. Experimenter 2, also behind the partition, activated the haptic creature's actuating mechanisms while the haptic creature was in the subject's lap. The settings for purring, heating and breathing actuation provided by Experimenter 2 were predetermined and held constant for each subject. The subject held the haptic creature for part of the experiment but at no point was able to see the actuating mechanisms of the haptic creature behind the partition. The partition also prevented the subjects from seeing the two experimenters but visual contact of the subject could be maintained by both experimenters through the webcam.

5.2 Experimental Procedure

The experiment took approximately 30 minutes to run for each participant. There were three parts to the experiment, a preliminary questionnaire, two separate slideshow viewings, and a post-experiment questionnaire. Three experimenters were required in each session.

5.2.1 Preliminary Questionnaire

The preliminary questionnaire consisted of general demographic questions, and questions concerning the subject's experience and comfort level with touch based interaction.

5.2.2 Slideshow Viewing

The lights in the room were off for the duration of the slideshow. Once the preliminary questionnaire was administered, the subject was attached to the biometric sensors by the facilitator and asked to sit calmly for two minutes while a baseline measurement of the sensor was gathered, while viewing an image set of three calming natural scenes. The participant was then shown two disturbing image sets, one with the haptic creature and one without; the order of both creature possession and the images within each set were randomly determined. Each set consisted of a two minute slide show of twelve disturbing images. For the set of images with the haptic creature, the participant was first given the haptic creature and asked to sit for two minutes with the creature on their lap, to gain familiarity with the device (shown in Figure 2). A disturbing image set was then shown to the participant, with the haptic creature on their lap. The participant was asked to focus their attention on the screen for the entirety of the image set. While the haptic creature was on the participant's lap, experimenter 2 behind the partition mechanically actuated the haptic creature to provide a breathing and purring sensation. The heating pad within the haptic device simultaneously provided a constant warmth to the participant.

In between the two disturbing image sets, the haptic creature was either given or taken away, and the participant was asked to sit calmly again for another two minutes while new sensor baseline data was gathered. During this secondary baseline they were again shown the same baseline image set of three calming natural scenes. The participant was then asked to view the second disturbing image set. Once this set of disturbing images was completed the biometric sensors were removed and the subject completed the post- experiment questionnaire.

During the experiment, experimenter 2 observed the subject using a non-recording web camera, to identify any noteworthy interaction of the participant with the haptic creature. Experimenter 2 also monitored, recorded and annotated the biometric sensor data. These annotations partitioned the calm and elevated anxiety data regions with and without the haptic creature, for post-experimental analysis.

5.2.3 Post-experiment questionnaire

The final part of the experiment, the post-experiment questionnaire, consisted of questions asking subjects to rate their emotional state during the slideshows and their response to the haptic creature.

6 Results

10 subjects (7 male) aged 20 to 30 took part in the experiment. Subjects were undergraduate and graduate students in computer science and engineering, and were compensated for their time (approximately 30 minutes).

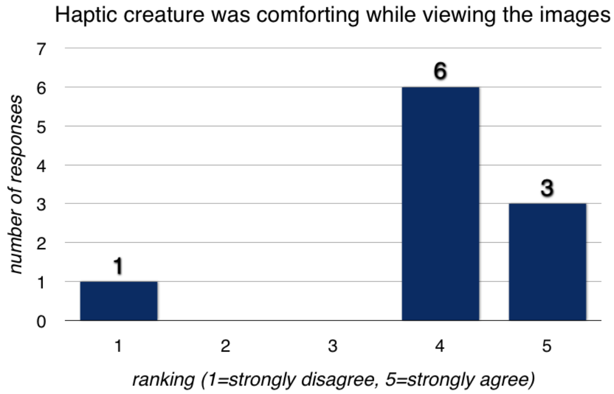

Figure 5: Subjective responses to *comfort* brought about by the haptic creature

6.1 Qualitative Results

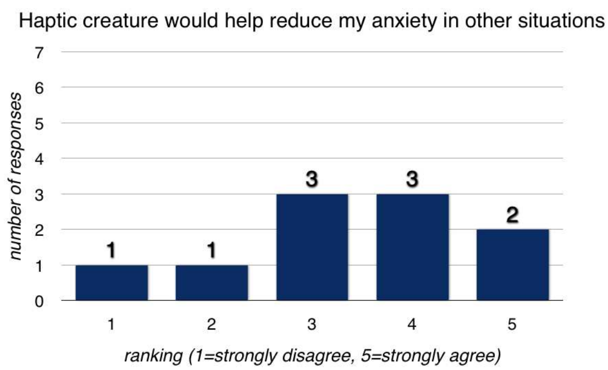

Figure 6: Subjective responses to *anxiety* brought about by the haptic creature

Subjects was asked to fill out a pre-questionnaire for profiling before the experiment and a post-questionnaire soliciting their subjective responses to the experiment conditions after the experiment. We found that 50% of our subjects had access to pets on a regular basis, and (a different) 50% of our subjects often interacted with children.

In the post-questionnaire, subjects were asked to rate their states of anxiety, agitation and surprise on a five-point Likert scale during each image set. A summary of these three emotional responses can be seen in Table 1. In the post-experiment evaluation, subjects were also asked if they thought the haptic creature was comforting, distracting, and/or anxiety reducing while they were viewing the images. Those results are summarized in Figures 5 , 6 and 7.

To test for order effects, we conducted an ANOVA on self-reported comfort, anxiety and distraction for the first versus the second image set seen, regardless of creature presence order. No significant effect of order was seen.

We were also curious whether having pets or babies affected a participant's subjective response to the haptic creature. We carried out an ANOVA on subjective responses to the haptic creature; one from subjects who had pets versus those who did not, and another with subjects who had babies versus those who did not. The results, summarized in table 2, did not show a significant difference.

6.2 Quantitative Results

The data from the biosensors was pre-processed into a less noisy form, examined to determine which images were anxiety inducing,

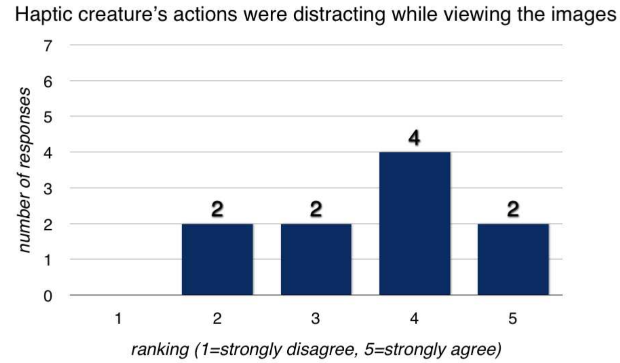

Figure 7: Subjective responses to *distraction* brought about by the haptic creature

Table 1: Likert-scale responses to anxiety, agitation and surprise (1=strongly felt, 5=weakly felt; n=10)

	Creature		No Creature	
State	Mean	Std. Dev.	Mean	Std. Dev.
Anxious	2.3	1.2	1.7	0.6
Agitated	2.0	1.1	1.7	0.7
Surprised	2.8	1.2	1.7	0.7

and finally analyzed for statistical differences.

6.2.1 Signal Processing

Individual biometric signals from each subject were sampled at 256 Hz; a pair of representative *SCRnorm*traces for one subject is shown in Figure 8. Raw signals were processed as in previous experiments with the platform [10]. In summary:

- *SC*: Raw skin conductance traces were low-pass filtered and smoothed, then normalized to the minimum and maximum values over the previous 30 seconds (running window) to produce *SCRnorm*. *SCRnorm* was then differentiated to produce *dSCRnorm*.

- *SC peaks*: For each trial we counted the number of peaks of *SCRnorm* greater than 0.2 for each subject to produce *SCRpeaks*.

- *EMG*: Electromyogram traces were normalized to the minimum and maximum values over the previous 30 seconds (running window), to produce *EMGnorm*.

- *ECG*: To detect changes in the subjects' heartrate as a function of condition, raw electrocardiogram signals were normalized to the baseline heart rate and heart rate variability values

Table 2: Reaction to hapticat (1=strongly felt, 5=weakly felt; n=10)

	Regularly interact with babies		Regularly interact with pets	
Hapticat was...	Yes	No	Yes	No
Comforting	4.4	3.4	4.2	3.6
Distracting	3.4	3.8	3.4	3.8
Anxiety reducing	4	2.8	3.8	3

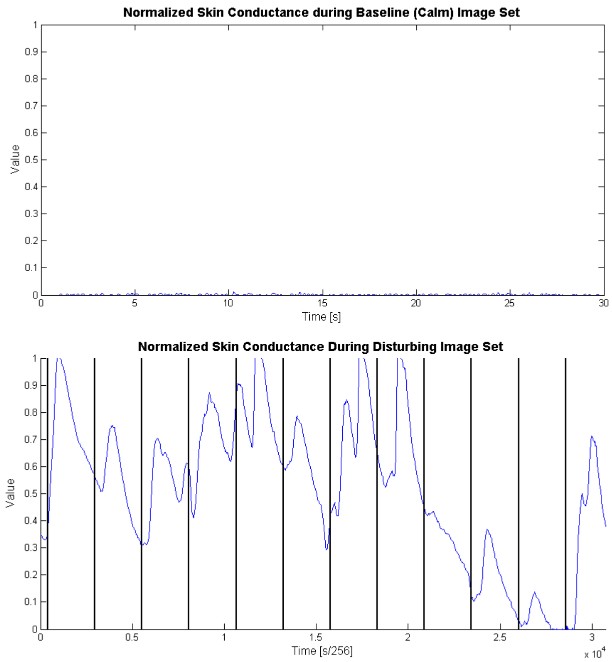

Figure 8: Normalized skin conductance response for shown a calm image set (top, 30 seconds) and a disturbing image set (top, 120 seconds). The vertical line marks the appearance of a new image; in the second figure, data for one full set of 12 images is shown. While there were considerable individual differences amongst responses, these are fairly representative.

taken during the calm-image baseline period of the experiment. This resulted in *HRnorm*; which was further differentiated for an estimate of heart rate acceleration (*HRaccelnorm*).

The fuzzy inference engine described in [10] was then used to calculate a continuous estimate of arousal (*Arous*) based on these processed signals, as mentioned previously.

6.2.2 Data Segmentation

We found that while the biometric as well as self-reported results from all subjects suggested that they responded strongly to some images, subjects differed widely in terms of which images produced those reactions. Since we wish to detect anxiety when it occurs, rather than attain an average response by all subjects across all images, it was appropriate to focus on the high-response data segments chosen by subject.

Therefore, for each image set, we needed an objective measure by which to choose the most anxiety-inducing images and corresponding measured responses for each subject. Because *SCRnorm* showed the highest-amplitude and fastest-rising sensitivity to image changes, we used the five images per subject per condition with highest initial *SCRnorm* response peak; i.e. the five images with the highest *SCRnorm* response peak with the creature present and five images with the highest *SCRnorm* response peak when it was absent for each subject.

6.2.3 Statistical Analysis

In our statistical tests, we used the means of the physiological data during the display of the high-response images; as well as mean physiological sensor data for the 30 seconds of the baseline data taken with the creature and without. These data for each subject were then compared in a repeated measures, two-factor within-subjects ANOVA analysis. This revealed significant interaction effects from creature presence and images for both *Arous* ($p < .05$) and *HRnorm* ($p < .05$). As there were significant interaction effects, we make no assessment for main effects.

7 Discussion

We will frame our discussion around several guiding questions regarding the suitability of this platform for its intended purpose, and the results found in this first use.

7.1 Did the intervention produce a physical response?

Disturbing images produced a peak in measured skin conductance response (*SCRnorm*) at the appearance of the image (Figure 8). The initial peaks of each response occur immediately after each new image is presented, making it likely that the sensed change was produced by the image appearances.

The magnitude of the responses showed variation across both images and subjects: almost all subjects responded to at least 5 images with a jump in *SCRnorm* of 20% or more. None had a notable response to all twelve images, as would be expected from the content of the images. There was no order-related trend in which images produced an *SCRnorm* response. Therefore it is likely that the content of the images was the primary motivation of response; and the subjects did not appear to become acclimatized to the appearance of disturbing images for the duration of the session. An ANOVA test showed no significant order effect between self-reported emotional states induced by the first and second image sets.

Thus, we conclude that the images did generate a physical response that was consistent over the testing period. The specifics of the response, in particular the specific images which elicited more extreme responses, varied by subject. The measurable aspect of the response was transient rather than sustained, but its regular and predictable timing gave adequate experiment control.

7.2 Did the creature mitigate physiological response?

Prior work [9] led us to predict that mean *SCRnorm*, *dSCRnorm*, *EMGnorm*, and *HRnorm* as well as *Arous*would be higher during the disturbing image set. The analysis results support an interaction effect between images and creature presence for both *HRnorm* and *Arous*; in addition, a smaller (nonsignificant) trend in the same direction was observed in *SCRnorm* and *dSCRnorm*.

We saw stronger effects in the inferred arousal measure than in the direct measures because, gathering information from multiple sensors, it is more sensitive. Taking the temporal mean of the physiological data can cause the transient signals caused by anxiety to be lost. The fuzzy inference engine for predicting arousal allows for a more sensitive analysis of physiological state, taking into account multiple biometric signals as well as temporal effects. Thus while the changes in each physiological measure may be small, they are combined to form a significant change in arousal. It is evident from the data that the effects of the anxiety induced by these images is represented by very small, albeit detectable, changes in the biometric sensor data.

Thus, significance in the biometric data at this level is an encouraging result, given our relatively small sample size of 6 individuals in this exploratory study. Additional subjects will be needed to generate greater power in future investigations.

The self-reported user surveys of emotional state are consistent with the interpretation that the haptic creature had an effect on emotional state: mean surprise rating (an indicator of the shock experienced) was lower with the haptic creature than without (Table 1), along with ratings of anxiety and agitation. The haptic creature may have also brought out greater differences between individuals. *Without* the haptic creature, subjects reported more consistent (lower standard deviation) levels of anxiety, agitation and surprise in response to the disturbing images than when it was present. *With* the creature, levels were lower overall; but more varied (Table 1).

7.3 Was mitigation attributable to anxiety reduction?

Having seen some definite indications of influence of the haptic creature on physiological signals (namely *Arous*), we turned to subjective responses for additional insight into the how subjects actually experienced its presence. While we hypothesized that the mitigation occurred through a positive emotional response of the sort we receive from the presence of a real animal or of a friend, other possibilities exist.

7.3.1 A Distraction...?

In the context of this experiment model, we anticipated that users might find the haptic creature distracting. While this might temporarily reduce anxiety, such a reduction would be more likely to arise out of decreased attention to the source of anxiety rather than an emotional response to the creature. Distraction may be appropriate in some anxiety-provoking situation, but as a coping mechanism this is a limited answer: consistently turning away from an anxiety-inducing situation will in general lead to new and possibly greater problems; and furthermore, the distraction might soon become annoying itself.

Several subjects claimed that having the haptic creature with them was distracting (Figure 6), but the trend was less clear than for the comfort rating. It is also likely that some subjects found the entire experience of the haptic creature unusual and hence distracting, and that their subjective reporting of distraction would be decreased after spending more than the two minutes of baseline (calm image) time with the creature. A larger sample size and more extended interaction is thus necessary to determine if this effect is significant, perhaps with a more engaging task to determine a functional level of distraction.

7.3.2 ... or a Comfort?

Most subjects did not in fact seem to find the creature annoying, at least during this brief exposure; the response was generally positive. When we asked subjects whether they found the haptic creature *comforting* during the slideshow, 9/10 either agreed or strongly agreed (Figure 5). In comments, many specifically commented on the creature's warmth as comforting, and several mentioned its simulated breathing. Some indicated that they found the gentle breathing of the creature pleasant; interestingly, a few volunteered that this caused them to become more aware of their own breathing. Although we did not record respiration rate in this study, this is an important observation: a focus on breathing is often used in therepeutic calming techniques.

Finally, we received net-positive but varied response to the proposition that the haptic creature might reduce anxiety in stressful situations other than that of viewing disturbing images. This is further indication that individuals may vary in their receptiveness to this type of anxiety mediation, to be addressed with further investigation.

7.4 Indicators of receptiveness

We explored correlations between subjects' response to the haptic creature and the presence of pets or babies in their lives. While we did not find a statistically significant difference, subjective ratings suggested that individuals with pets got slightly more comfort from the haptic creature than people without pets (See Table 2). In addition, qualitative comments from users indicated that the women in the study were more receptive to the haptic creature than men, although the sample size in the experiment was extremely small.

Based on the standard deviations of individual responses, it seems that individuals with pets gave more consistent comforting-ratings for the haptic creature than people without pets. This might be an indication that pet owners are more used to interacting with a small creature (either artificial or real) via petting and touching, or that the haptic creature was consistently treated like a real pet. We surmise that pet owners may be more inclined to recognize the haptic creature as a pet, based upon their previous experiences, whereas those who are not familiar with pets will lack a comparison and therefore have a more varied in their emotional response to the creature. It is also possible that non petowners may have an inherent dislike of animals or animal associations, and therefore showed a less positive response to the creature.

Individuals with and without babies also showed no significant correlation in subjective comfort responses (Table 2), but the mean comforting-rating from people without babies was one point lower than individuals with babies (3.4 versus 4.4). Similarly, when asked whether the haptic creature would reduce anxiety in other situations, people without babies tended towards neutrality while those with babies seemed more optimistic (mean = 2.8 versus 4.0). People with babies also found the haptic creature slightly less distracting (3.4 versus 3.8). Could people with babies have treated a small, haptic creature on their lap as a baby? More investigations are needed to identify a clear link between these two factors.

8 Conclusions

Our primary goals in this experiment were to (a) validate a platform for exploring the ability of an animal-like proxy to impact anxiety responses to stressful situations; and (b) through data obtained here, make a preliminary assessment of this approach to the larger objective of helping anxious individuals and particularly children produce coping mechanisms for everyday situations. We did this by subjecting 10 subjects to 2 graphic image sets; once with the haptic creature on their lap, and once without. Subjects were connected to biosensor readers, which read their skin conductance, heart activity rates and forehead corrugated muscle changes; and provided subjective information about their responses to the creature's presence.

A close look at the data allow us to conclude tentatively that the method used to elicit anxiety (sequences of disturbing images) did succeed in the sense of producing transient arousal (one aspect of anxiety, predicted by SCR). Furthermore, we observed an influence on these levels even with the simple initial prototype of the haptic creature. As such, this experiment model will be helpful in initial explorations. Our experiment has also demonstrated where the model must be further developed for later stages of development.

In general the quantitative data gathered from the biosensors showed changes, some significant, which supported our hypotheses that the creature could reduce anxiety levels in difficult situations in most individuals. Specifically, its presence was associated with a reduction in both the mean and normalized skin conductance values, the normalized derivative of skin conductance value, number of response peaks and derived arousal levels of the subject. Subjective data from users did not show statistical significance, but trended towards positive effects that were consistent with and helped to interpret the physiological data. Several features of this version of the creature were singled out by some subjects for effectiveness; specifically, warmth and breathing. Thus, this work has served to confirm the potential of this direction, while identifying several areas of focus for next steps.

9 Future Work

In continuing this research, we will improve both the experiment model and the creature itself. We used disturbing images as stimuli in our research's early stages, in which we have employed adults as early proxies for the children we ultimately wish to support. However, issues of overly transient response direct us to seek alternatives to disturbing images as experimental stimuli sooner than later. With each alternative, we will need to re-explore the sensitivity of the suite of sensors we examined here, in particular with more sustained but less extreme stimuli. The creature itself is already being rebuilt in a less robotic form which we anticipate will be more appealing to both adults and children, as well as more expressive and with the ability to sense and interpret how it is being touched. Based on user comments, we will focus in particular on behaviors aimed at modulating the subject's breathing patterns and perhaps heartrate.

We believe that young children will be the audience with the most to gain from our research: they may be most malleable in learning anxiety coping strategies, given support; and a responsive, engaging and attractive haptic creature is more likely to be an effective vehicle for children, who are more experienced with cuddling, petting and hugging soft toys and using these actions as responses to stressful situations.

REFERENCES

[1] K. Allen, J. Blascovich, J. Tomaka, and R. Kelsey. Presence of human friends and pet dogs as moderators of autonomic responses to stress in women. *Journal of Personality and Social Psychology*, 61(4):582–589, 1991.

[2] . N. S. Amy O'Brian. Dogs prove more effective than pills. *Canada.com*, Dec. 2008.

[3] S. Barker and K. Dawson. The Effects of Animal-Assisted Therapy on Anxiety Ratings of Hospitalized Psychiatric Patients. *Psychiatric Services*, 49(6):797, 1998.

[4] Thought Technology.

[5] L. Bonanni, C. Vaucelle, J. Lieberman, and O. Zuckerman. Taptap: a haptic wearable for asynchronous distributed touch therapy. In *CHI '06: CHI '06 extended abstracts on Human factors in computing systems*, pages 580–585, New York, NY, USA, 2006. ACM.

[6] G. Collis and J. McNicholas. A theoretical basis for health benefits of pet ownership. *Companion Animals in Human Health*, pages 105–22, 1998.

[7] T. Ito, J. Cacioppo, and P. Lang. Eliciting Affect Using the International Affective Picture System: Trajectories through Evaluative Space. *Personality and Social Psychology Bulletin*, 24(8):855, 1998.

[8] K. Kim, S. Bang, and S. Kim. Emotion recognition system using short-term monitoring of physiological signals. *Medical and Biological Engineering and Computing*, 42(3):419–427, 2004.

[9] D. Kulic and E. Croft. Estimating Intent for Human-Robot Interaction. In *IEEE International Conference on Advanced Robotics, Coimbra, Portugal*, pages 810–815, 2003.

[10] D. Kulic and E. Croft. Anxiety detection during human-robot interaction. In *Intelligent Robots and Systems, 2005.(IROS 2005). 2005 IEEE/RSJ International Conference on*, pages 616–621, 2005.

[11] D. Kulic and E. Croft. Physiological and subjective responses to articulated robot motion. *Robotica*, 25(01):13–27, 2006.

[12] D. Kulic and E. A. Croft. Real-time safety for human-robot interaction. *Robotics and Autonomous Systems*, 54(1):1 – 12, 2006.

[13] A. Lanz and E. Croft. ON LINE-AFFECTIVE STATE MONITORING DEVICE DESIGN. 2007.

[14] C. Liu, K. Conn, N. Sarkar, and W. Stone. Online Affect Detection and Robot Behavior Adaptation for Intervention of Children With Autism. *IEEE Transactions on Robotics*, 24(4):883–896, 2008.

[15] C. Liu, K. Conn, N. Sarkar, and W. Stone. Physiology-based affect recognition for computer-assisted intervention of children with Autism Spectrum Disorder. *International Journal of Human-Computer Studies*, 66(9):662–677, 2008.

[16] F. F. Mueller, F. Vetere, M. R. Gibbs, J. Kjeldskov, S. Pedell, and S. Howard. Hug over a distance. In *CHI '05: CHI '05 extended abstracts on Human factors in computing systems*, pages 1673–1676, New York, NY, USA, 2005. ACM.

[17] R. W. Picard. *Affective Computing*. The MIT Press, Cambridge, Massachusetts, 1997.

[18] P. Rani, C. Liu, N. Sarkar, and E. Vanman. An empirical study of machine learning techniques for affect recognition in human–robot interaction. *Pattern Analysis & Applications*, 9(1):58–69, 2006.

[19] P. Rani, J. Sims, R. Brackin, and N. Sarkar. Online stress detection using psychophysiological signals for implicit human-robot cooperation. *Robotica*, 20(06):673–685, 2002.

[20] J. Russell. A circumplex model of affect. *Journal of Personality and Social Psychology*, 39(6):1161–1178, 1980.

[21] J. Saldien, K. Goris, B. Vanderborght, B. Verrelst, R. V. Ham, and D. Lefeber. Anty : The development of an intelligent huggable robot for hospitalized children. In *9th International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines*, September 2006.

[22] T. Shibata, T. Mitsui, K. Wada, A. Touda, T. Kumasaka, K. Tagami, and K. Tanie. Mental commit robot and its application to therapy of children. In *Advanced Intelligent Mechatronics, 2001. Proceedings. 2001 IEEE/ASME International Conference on*, volume 2, pages 1053–1058. IEEE/ASME, July 2001.

[23] W. Stiehl, J. Lieberman, C. Breazeal, L. Basel, L. Lalla, and M. Wolf. Design of a therapeutic robotic companion for relational, affective touch. *Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on*, pages 408–415, Aug. 2005.

[24] W. Stiehl, J. Lieberman, C. Breazeal, L. Basel, L. Lalla, and M. Wolf. The Design of the Huggable: A Therapeutic Robotic Companion for Relational, Affective Touch. In *AAAI Fall Symposium on Caring Machines: AI in Eldercare, Washington, DC*, 2005.

[25] J. Vormbrock and J. Grossberg. Cardiovascular effects of human-pet dog interactions. *Journal of Behavioral Medicine*, 11(5):509–517, 1988.

[26] K. Wada, T. Shibata, T. Saito, and K. Tanie. Robot assisted activity for elderly people and nurses at a day service center. In *Robotics and Automation, 2002. Proceedings. ICRA'02. IEEE International Conference on*, volume 2, 2002.

[27] L. Williams and J. Bargh. Experiencing Physical Warmth Promotes Interpersonal Warmth. *Science*, 322(5901):606, 2008.

[28] S. Yohanan, M. Chan, J. Hopkins, H. Sun, and K. MacLean. Hapticat: exploration of affective touch. In *ICMI '05: Proceedings of the 7th international conference on Multimodal interfaces*, pages 222–229, New York, NY, USA, 2005. ACM.

[29] S. Yohanan and K. MacLean. The Haptic Creature Project: Social Human-Robot Interaction through Affective Touch. In *Proceedings of the 2nd AISB Symposium on the role of virtual creatures in a computerised society*, 2008.