TAMER: Touch-guided Anxiety Management via Engagement with a Robotic Pet

Efficacy Evaluation and the First Steps of the Interaction Design

by

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Abstract

Anxiety disorders are widespread among children and adolescents, yet the existing treatments are effective for only a small proportion of the affected young population. We propose a novel idea for improving the efficacy of anxiety treatments that relies on affective touch as a therapeutic medium. Building upon the wealth of evidence for therapeutic benefits of animals, our approach utilizes an animatronic pet, the Haptic Creature, as a tool to deliver calming effects. We ground our idea in the framework of social cognitive theory as used in human-animal interaction. We first model the interaction design as a search in a broadly defined interaction space, and then introduce a novel and systematic approach to the interaction design process. We describe our iterative design of a human-Creature interaction that was measurably calming, and share the methodology and results of our two most significant evaluation cycles. Our principal results, from the second study, showed that the interaction with the Haptic Creature, while it is breathing slowly and constantly, produces calming effects as indicated by decreased heart rate and breathing rate as well as the subjective reports.

Preface

The studies described in this thesis were conducted under two ethics approvals. Study 1 with children was conducted with the approval of the UBC Clinical Research Ethics Board (CREB): certificate number H09-02860-A002. Study 2 with adults was carried out with the approval of the UBC Behavioural Research Ethics Board (BREB) certificate number: H01-80470.

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Table of Contents

Abstract ii

Preface iii

Table of Contents iv

List of Tables ix

List of Figures x

Acknowledgements xi

Dedication xiii

1 Introduction 1
- 1.1 Anxiety Disorders: Prevalence and Consequences 2
- 1.2 Anxiety Treatment: Limitations of Current Practices 2
- 1.3 TAMER Approach 3
  - 1.3.1 From Animals to Robots 4
  - 1.3.2 The Importance of Touch 5
- 1.4 Thesis Objectives: Efficacy Evaluation and Interaction Design 6
- 1.5 Contributions 7
- 1.6 Overview of the Thesis Content 7

2 Background and Related Work 9
- 2.1 Anxiety 9
  - 2.1.1 Development and Maintenance of Childhood Anxiety Disorders 10
  - 2.1.2 Treatment of Anxiety Disorders in Children 12
  - 2.1.3 Alternative Techniques for Anxiety Treatment in Children 13
- 2.2 Animal-assisted Activities 14

2.2.1 Animals' Nature and Therapy 14
2.2.2 Animals as Therapeutic Tools 16
2.2.3 Considerations in Utilizing Animals for Therapy . . . 17
2.2.4 Limitations of Animal Therapy 18
2.3 Touch 18
2.4 Robot Assisted Therapy 19
2.4.1 Touch in Robot Therapy 19
2.4.2 The Haptic Creature 21
2.4.3 Empirical Data for Health Benefits of Animal-like Robots 21

3 Approach 23
3.1 Relating Theories of Human-animal Interaction to Robot Therapy 23
3.1.1 Human-animal Interaction Theories 23
3.1.2 Approach: Robot Therapy as Guided by Social Cognitive Theory for Animal-assisted Therapy 25
3.2 TAMER Approach 26
3.2.1 Robot Therapy for Anxiety through Touch 26
3.2.2 Human-centred View in Design 27
3.2.3 Design Requirements 28
3.3 Systematic Approach to Interaction Design 28
3.3.1 Design Space and Attributes 29
3.3.2 Dependency Graph 33
3.3.3 Design Process as Informed by the Dependency Graph 34

4 Assessment of Emotional Response 37
4.1 Measuring Emotions: Background 37
4.1.1 Considerations for Acquiring Self-reports 40
4.1.2 Considerations for Acquiring Biometrics 40
4.2 Measuring Anxiety: Background 42
4.3 Selection of Emotion Measures for TAMER Studies 43
4.3.1 Self-reports 44
4.3.2 Biometrics 46

5 Elicitation of Anxiety in Children 49
5.1 Eliciting Emotional Response: Background 49
5.2 Eliciting Anxiety in the Passive Response Experiment 50
5.2.1 Criteria 51
5.2.2 Development of Anxiety Elicitation Procedure 52

6 Software Apparatus . . . 54
6.1 Stressful Task, Subjective and Performance Data Collection: Clocks Program . . . 54
6.1.1 Purpose . . . 54
6.1.2 Overview . . . 55
6.1.3 Functioning . . . 55
6.2 Robot Control and Physiological Data Collection: TAMER Program . . . 57
6.2.1 Purpose . . . 57
6.2.2 Overview . . . 58
6.2.3 Functioning . . . 59
6.3 Flow Control and Subjective Data Collection . . . 61
6.3.1 Purpose . . . 61
6.3.2 Overview . . . 62
6.3.3 Functioning . . . 62
6.4 Data Processing . . . 63
6.4.1 Purpose . . . 63
6.4.2 Overview . . . 63
6.4.3 Functioning . . . 64

7 Exploring the Possibility of the Passive Response in Study 1 . . . 65
7.1 Motivation . . . 65
7.2 Research Questions . . . 65
7.3 Passive Interaction . . . 66
7.4 Methods . . . 66
7.4.1 Participants . . . 67
7.4.2 Stimuli and Task . . . 68
7.4.3 Measures . . . 68
7.4.4 Experimental Design . . . 69
7.4.5 Setup . . . 70
7.4.6 Procedure . . . 71
7.5 Analysis . . . 72
7.5.1 Physiological Data Selection . . . 72
7.5.2 Statistical Analysis . . . 73
7.6 Results . . . 73
7.7 Discussion . . . 73
7.7.1 Issues with Interaction . . . 74
7.7.2 Issues with Elicitation of Anxiety . . . 74
7.7.3 Issues with Evaluation of Emotional Response . . . 74

8 Design of a Calming Interaction with the Haptic Creature and Its Evaluation in Study 2 . . . 82
8.1 Motivation . . . 82
8.2 Research Questions . . . 83
8.3 The Design of the Tactile Interaction . . . 84
8.3.1 The Human's Expression . . . 85
8.3.2 The Haptic Creature's Expressions . . . 88
8.4 Methods . . . 89
8.4.1 Participants . . . 89
8.4.2 Stimuli . . . 91
8.4.3 Measures . . . 92
8.4.4 Experiment Design . . . 94
8.4.5 Setup . . . 95
8.4.6 Procedure . . . 98
8.5 Analysis . . . 102
8.5.1 Data Verification . . . 102
8.5.2 Physiological Data Selection . . . 105
8.5.3 Statistical Analysis . . . 105
8.6 Results . . . 106
8.7 Discussion . . . 106
8.7.1 Outcomes: Impact of the Interaction on the Emotional Response Measures . . . 107
8.7.2 Implications . . . 113
8.7.3 Critiques of Methodology . . . 115

9 Conclusions and Future Work . . . 121
9.1 Significance of Research Contributions . . . 121
9.1.1 Tactile Interaction Is Calming . . . 121
9.1.2 Modelling the Interaction with Animals Is Promising 122
9.1.3 Working within the Theoretical Frameworks Directs the Interaction Design . . . 122
9.1.4 Dependency Graph is Applicable to Other Design Problems . . . 122
9.2 Future Work . . . 123
9.2.1 Follow-ups on the Second Study . . . 123
9.2.2 TAMER Design . . . 124
9.2.3 Robotic Platform . . . 125
9.3 Conclusion . . . 126

Bibliography . . . 127

Appendices

A Considerations in Designing Experiments Using Biometrics 136

B Issues in the Previous Work in TAMER 138

C Study 1: Documents 141
C.1 Advertisement 141
C.2 Facilitator's Documents 152
C.3 Participant's Documents 170

D Study 2: Documents 179
D.1 Advertisement 179
D.2 Facilitator's Documents 186
D.3 Participant's Documents 198

List of Tables

7.1 Study 1 - summary of participants' information 67
7.2 Study 1 - summary of measures 69
7.3 Study 1 - summary of procedures 76
7.4 Study 1 - descriptive statistics of trials 80
7.5 Study 1 - statistical analysis 81

8.1 Likelihood of gesture on the affect space 86
8.2 Likelihood of the ideal gesture on the affect space 87
8.3 Study 2 - summary of participants' information 90
8.4 Study 2 - summary of human and robot pre-defined contributions to interaction. 92
8.5 Study 2 - summary of measures. 93
8.6 Study 2 - summary of procedures. 99
8.7 Study 2 - summary of data selection. 103
8.8 Study 2 - descriptive statistics of trials 119
8.9 Study 2 - statistical analysis 120

List of Figures

1.1 The Haptic Creature 1

2.1 Animal-like social robots 20
2.2 The Haptic Creature touch sensitive surface 21

3.1 TAMER interaction space 30
3.2 Dependencies among TAMER attributes 34
3.3 TAMER design steps 36

4.1 Thermometer scale 45
4.2 9-point SAM scale 46
4.3 Reduced 6-item STAI scale 46

6.1 Clocks application structure 55
6.2 2-hand analogue clock question 56
6.3 Computerized thermometer scale 57
6.4 TAMER Program structure 59
6.5 The flow control program structure 63
6.6 The structure of signal processing programs 64

7.1 Study 1 - setup 70
7.2 Study 1 - descriptives of absolute self-reported and performance measures 77
7.2 Study 1 - descriptives of absolute biometric measures 79

8.1 Interaction cycle 85
8.2 Study 2 - room setup 97
8.3 Study 2 - descriptives of absolute self-reported measures . . . 107
8.4 Study 2 - descriptives of non-offset biometric measures 108
8.8 Boomerang distribution of affect 112
8.5 Study 2 - sampling distributions of non-offset respiration rate 116
8.6 Study 2 - sampling distributions of non-offset heart rate . . . 117
8.7 Study 2 - sampling distributions of non-offset heart rate . . . 118

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Dedication

To my family,
    Shirin
    Abbas
    Reza
    and ***Zia***,
who help me manage my anxieties.

Chapter 1

Introduction

Anxiety disorders are widespread among children and adolescents, yet the existing treatments are effective for only a small proportion of the affected young population. We propose a novel idea for improving the efficacy of anxiety treatments that relies on affective touch as a therapeutic medium. Building upon the wealth of evidence for therapeutic benefits of animals, our approach utilizes an animatronic pet, the Haptic Creature (Figure 2.2), as a tool to deliver calming effects. Our goal in this thesis work is to provide empirical evidence for the idea that interacting with an emotionally expressive robot, predominantly through touch, can be calming.

In this thesis we describe our iterative design of human-Creature interaction that was measurably calming and share the methodology and results of our two most significant evaluation cycles.

In the following sections we clarify the problem and our approach. We also describe the objectives of the thesis work and its contributions in more details.

Figure 1.1: The Haptic Creature - photo by Martin Dee

1.1 Anxiety Disorders: Prevalence and Consequences

Anxiety disorders are the most common mental disorders during childhood and adolescence. The prevalence of anxiety as reported in several studies is between 2.5% to 5% with increased rate of diagnosis in adolescent population. Although the reported rates vary across studies mainly because different studies have utilized different methods and instruments or have sampled different populations, they all evidence the widespread presence of anxiety [66].

Anxiety disorders severely impact young individuals' lives and development. Anxious children have problems in their relations with their families, teachers, and peers. In fact, studies report that anxiety is negatively correlated with popularity and social competence while it is positively correlated with victimization [66]. Additionally, anxiety disorders trouble sufferers in school activities. Low achievements in reading and mathematics are correlated with anxiety symptoms [30].

The severity of anxiety problems is better pictured by considering the fact that anxiety rarely happens in isolation. Not only do different types of anxiety often coexist, but also anxiety is usually seen overlapping with other disorders. 40% to 60% of anxious children suffer from more than one type of anxiety disorder and they are at 8 to 29 times higher risks of experiencing depression [66].

Anxiety problems continue over time, an issue that compounds the problems of concurrent comorbidity mentioned earlier. A considerable number of anxious children remain anxious during their later years of childhood and even during their adulthood. Not only does childhood anxiety increase the risk of adulthood anxiety disorders, but also it predicts other mental health problems such as depression, externalizing, and substance use disorders [66].

Considering the prevalence of childhood anxiety and its severe consequences that also extend to adulthood, it is important to develop an efficacious treatment for the young population. In the next section we describe the current state of affairs in the area of anxiety treatment.

1.2 Anxiety Treatment: Limitations of Current Practices

Among the available anxiety treatment techniques for children, skill-based or cognitive-behavioural treatments (CBT) have the strongest empirical support. In CBT techniques, children are trained to identify their anxiety symptoms and to apply specific skills when experiencing anxiety in real life situations [66].

CBT techniques provide a significant improvement in anxiety compared to no treatment at all, although their contribution to the overall anxiety state is very small and limited [66]. A closer look reveals that practising some of the core underlying elements requires a high level of cognitive development so is not easily accessible for less developed children [45]. This indeed explains the lower effectiveness of CBT for younger children who have not yet developed the abilities to fully perform CBT components [22].

In the absence of other efficacious options, small and limited improvements offered by CBT techniques are valuable. However, the prevalence and consequences of anxiety raise concerns that call for further research to enhance these techniques. On one hand refining the cognitive and behavioural components of CBT and delivering the treatment by alternative means and on the other hand applying general therapy strategies such as treatment engagement have been proposed to improve the outcomes [66].

The need for more effective anxiety treatments motivated the approach that we introduce in the next section. In this approach we combine affective touch (as an alternative method for treatment delivery) and the principle of therapy engagement to improve CBT's cognitive component. The goal is to make the treatment more accessible for children's developmental capabilities.

1.3 TAMER Approach

Touch-guided Anxiety Management via Engagement with a Robotic pet (TAMER) is a novel idea that explores more accessible pathways for anxiety treatment in children. TAMER is a child-centric approach to the therapy design that builds on the children's natural abilities at the early stages of their development.

This approach, which stems from the body of research in animal assisted therapy and affective touch, can be developed as an integral part of skill-based anxiety treatments to make these techniques more intuitive and thus accessible to children. Moreover, the efficacy measures that TAMER relies on are more objective which provide new means of evaluation for the treatment planning.

TAMER, in its core, comprises a close interaction between a child and an expressive animatronic pet, the Haptic Creature, that responds to the child's patterns of touch and her/his physiologically assessed emotional state. Children are engaged in an affective interaction with the robot, predominantly through the sense of touch as an effective medium for emotional and therapeutic purposes. In this concept, the Haptic Creature is programmed to respond to a child's emotional state as estimated from his or her emotional model, itself continuously obtained from patterns of touch as well as the respiration, heart electrical activity, and galvanic skin response signals.

The Haptic Creature's behaviours, which in the full TAMER concept gradually adapt to the child's idiosyncratic characteristics, will be a series of expressions each contributing to a specific change in emotional state. The expressions are organized in such an engaging sequence that they guide the child to more relaxed states of mind. Aside from their immediate impact, we hypothesize that these calming effects facilitate the process of systematic desensitization, a core component of CBT [45], by providing a tangible context for the child to replace an anxiety stimuli with a pleasant stimuli. In other words, another key part of TAMER concept is that the child should be eventually able to cope with her/his anxieties independently. The TAMER is intended as a learning tool, not a crutch.

In the subsequent sections the evidence supporting TAMER are briefly overviewed. These sections are then followed by the description of the research carried out under this thesis work and its contributions. At the end, the overview of the succeeding chapters is presented.

1.3.1 From Animals to Robots

A number of studies have investigated the benefits of animal-assisted activities (AAA)[1] for children with emotional and behavioural disorders. These investigations report improvements in emotional regulation, behavioural regulation, social skills, and self-esteem in young individuals following AAA interventions [4].

One way to explain the health benefits that animals bring is that animals' patience, affection, attention, and interactivity provides the emotionally disturbed children with an opportunity to change their cognitions of the environment and eventually modify their mal-adapted behaviours [51]. Additionally, the wealth of non-verbal communication through touch and mindbody interaction that happens when interacting with animals reduces stress and help children recover from trauma [98].

[1]For the purpose of arguments here, the term animal-assisted activity is used as an umbrella term for both animal-assisted activity and animal-assisted therapy. However, the author acknowledges the difference between these two techniques.

Despite the benefits of AAA, its integration into treatment settings with anxious children is constrained. Not all children are receptive to animals because of the fears of bites or the potential allergies. Moreover, training animals as therapeutic adjuncts is generally very costly . Usually there are few trained animals available for therapy. Therefore, the access to therapy animals is limited [32].

Maintaining the therapeutic benefits of interacting with animals while addressing its restrictions has inspired the research in the area of robot therapy. Necoro [52], Paro [77], Probo [70], and AIBO [36] are examples of animal-like robots developed over the past few years with therapeutic potentials. Research involving therapy robots, which to date generally rely on facial and audio clues for interaction, illustrates improvements in psychological state in elderly, children with autism, and dementia patients similar to that reported with animals [76].

The evidence for the effectiveness of robot therapy for a number of psychological issues, motivates the idea to develop companion robots to be integrated in anxiety treatment techniques. As with the examples above, the idea leverages the empirical and theoretical supports from the animal research to design robots capable of moderating anxiety.

1.3.2 The Importance of Touch

For an animal-like robot to provide psychological enrichment, it should activate the mechanisms through which interacting with animals works. Therefore, the robot's look and feel, its independent expressions as well as the expressions it represents in response to human's expressions should stimulate the feelings and experiences similar to what people have for a real animal [76].

Research in the area of human-robot interaction for the design of therapy robots has mainly focused on facial and audio clues/expressions, whereas sense of touch has been overlooked despite its importance in the communication of emotion [95]. Although robots such as Paro and Huggable take advantage of touch sensing, they do not rely on the sense of touch as the main medium for facilitating therapeutic goals [6].

Necessity of incorporating affective touch in the design of therapeutic robots becomes clear when one considers the fact that touch is highly influential in communicating and stimulating emotions relative to other senses. Moreover, as several studies report, touch has therapeutic potentials for a variety of psychological disorders such as autism, attention deficit hyperactivity, depression and anxiety. Increased alertness as well as increased active and social behaviours are among the reported benefits of touch in different therapy programs [31].

Another reason for striving to include touch in the design of therapy robots that take the form of an animal is its importance in the context of human-animal interaction. It is empirically supported that touch is the major component explaining the relaxing effects of interacting with animals and that the impact of tactile interaction surpasses those of the verbal and visual interaction [89].

Among all the social robots presented to the research community in recent years, only the Haptic Creature has concentrated on the study of touch as an interaction medium [94]. The Haptic Creature is a cat-sized expressive animatronic pet that sits on a person's lap. It can stiffen its ears, purr, simulate breathing, and sense user's touch [96]. The fact that this robot has been designed for tactile enrichment in interaction makes it an appropriate platform for designing a therapy robot that takes advantage of the health benefits of touch.

Utilizing the Haptic Creature as a promising platform, TAMER draws on the research in AAA and affective touch to develop an accessible technique to be used in anxiety treatment for children.

1.4 Thesis Objectives: Efficacy Evaluation and Interaction Design

At the very early stages of developing TAMER as an approach to the treatment of anxiety, we focused on the following goals in this thesis work:

1. Designing and evaluating relaxing interactions, dominantly through the sense of touch, and thus

2. Providing empirical support for the efficacy of the idea that interacting with the Haptic Creature can produce calming effects.

The literature in human-animal interaction and affective touch informed the design. More specifically, we aimed to design and evaluate both users' and the robot's expressions that result in the reduction of anxiety levels. We investigated appropriate touch gestures on the users' side, and appropriate breathing patterns on the Haptic Creature's side.

We used both subjective self-reports and objective physiological measures for the evaluation of the interactions that we designed.

1.5 Contributions

The main contributions of the research reported in this document are:

1. Conceptualization of robot therapy in the framework of social cognitive theories for health benefits that animals bring
2. Modelling of the interaction design process as a search in a broadly defined interaction space
3. Roadmap for the development of the TAMER idea
4. Design of an interaction that is shown to be calming through subjective and physiological measures
5. Empirical evidence for the efficacy of the TAMER idea

In addition to the main contributions mentioned above, the contextualized emotion patterning captured in the second study is useful in developing models of emotion based on physiological metrics. By contextualized emotion patterning we refer to the context-specific emotional response that is captured by several measures which provide deeper insights about the characteristics of the response, and thus the context. In the future steps of TAMER development, the emotion models will be used in the control of the Haptic Creature's behaviour so it can autonomously interact with the child and calm her/him down. Also, lessons learned from the experiment with children are presented to point out the challenges that require further research. Moreover, these lessons reveal pitfalls to avoid in the future development of the idea.

1.6 Overview of the Thesis Content

Covering the related research on anxiety and areas that TAMER leverages, Chapter 2 backs up the arguments put forth in the introduction Chapter.

The theoretical framework for robot therapy and the systematic approach to interaction design process are covered in Chapter 3 (contributions 1, 2, and 3 above).

Chapters 4 to 6 describe the development of the instruments, methods, and infrastructure that were used in the user studies.

The details of the studies conducted under this work are given in Chapter 7 and Chapter 8. Chapter 7 is focused on the first study in which we tried to clarify the results of an earlier experiment that suggested the potential calming effects of a “passive” form of interaction. By “passive”, we mean that the child is primarily involved in another task and so is not consciously attempting to use the interaction to calm her or himself. The challenges that we encountered at this stage inspired the systematic approach to the interaction design process described in Chapter 3. In Chapter 8, we not only describe the design of a new form of interaction as the first step following the roadmap introduced in Chapter 3, but also report the second study in which we evaluated our newly designed interaction. Our results support the efficacy of this form of interaction to produce calming effects.

In conclusion, Chapter 9 discusses the thesis, its contributions, and the future directions of the research.

Chapter 2

Background and Related Work

The present chapter provides the related background for the TAMER approach. We review the literature in the areas that TAMER contributes to or draws on in order to supply evidence in support of the idea and its rationale:

1. Description of anxiety risk factors informs of the development and maintenance of this childhood disorder - the information that should be considered when designing interactions. Furthermore, the discussion on the available treatment techniques highlights the gaps where integrating the TAMER approach is beneficial.

2. The description of the roles animals play in psychotherapy clarifies the theoretical framework further discussed in chapter 3.

3. The discussion on touch stresses its importance in general affective and therapeutic interactions and in the specific context of animal-assisted interventions.

4. The survey of the related research in human-robot interaction exemplifies the potential of animal-like robots as tools for psychological enrichment and also reveals the paucity of research on affective touch and thus distinguishes the uniqueness of TAMER.

2.1 Anxiety

In this section the development and maintenance of childhood anxiety are reviewed to identify the areas that interventions can target. The currently available treatments and their effectiveness are described next to highlight the need for improvement. The discussion of possible modifications concludes the section.

2.1.1 Development and Maintenance of Childhood Anxiety Disorders

Several factors have been shown to increase the risks of developing anxiety disorders in children: genetic and family influence, temperament, parenting styles, learning, life events, and cognitive factors. Many of these risk factors also contribute to the maintenance of anxiety in children.

Genetic and Family Influence

A set of familial factors contribute to the development of anxiety. It has been shown that childhood anxiety is more common among children whose parents also suffer from anxiety disorders. Although studies of twins have shown moderate heritability for anxiety symptoms, they have consistently indicated that environmental factors, particularly those which are unique to each twin, are more important in the development of anxiety (shared environmental factors such as parents' psychopathology and family socio-economic status are also influential, especially in early years of life) [66].

Temperament

Inhibited and withdrawn temperament is considered as one of the main components that influence the development of anxiety disorders. Temperament is defined in the nosological sense as "an early-identified pattern of responding characterized by consistent inhibited behaviours." In this formal sense, "temperament" refers to one specific character style identified by shyness, inhibition, and withdrawal [66], and will be used as such throughout this thesis.

Temperament in children is characterized by limited social behaviours, overt dependence on figures of attachment, as well as distress, withdrawal, and avoidance when confronting unknowns. For example, children with inhibited personality usually have long delays in approaching or communicating with strangers and keep proximity with their mothers or other attachment figures [66].

Inhibited temperament and anxiety are very similar. Several elements of the above description overlap with anxiety symptoms. In fact it is hypothesized that the same underlying construct manifest the two phenomena, although they are distinguished based on their impact on an individual's life. Intense inhibitions share many symptoms with anxiety disorders but do not influence the individual's life in the same way. Once the symptoms significantly interfere with the quality of life, the disorder is diagnosed. Pragmatically, the occurrence time distinguishes the two constructs; anxiety disorders are usually preceded by an inhibited character style [66]. Studies have shown that most children with anxiety disorders have initially had inhibited and withdrawn behaviours [66] and that children displaying high levels of inhibition and withdrawal in the early years of life are more likely to suffer from anxiety disorders in later years of life [66].

It has been argued that it is the "avoidant style of coping" and "effortful control" elements of the inhibited temperament that strongly predict later childhood anxiety. The ties become more evident when considering the children's anxiety as a deficiency in developing the "ability to inhibit attentional focus" toward a source of threat [66].

Parenting Styles

It has been shown that an overprotective parenting style is strongly correlated with anxiety symptoms in children. However, the direction of this effect, i.e. the causality relation, is not clearly known.

In a cross-over study mothers of anxious and normal children interacted with both anxious and normal children who did not belong to them. Both groups of mothers gave more help to anxious children suggesting that child's anxiety state determines the parenting style. In another study, maternal anxiety predicted maternal overprotection which one year later predicted symptoms of child's anxiety. This finding suggests the opposite direction for the effect [66].

The complexity with regard to the role of parenting style is compounded by the interactions that exist between this factor, inhibited temperament and genetic components [66].

Learning

Learning, in the form of conditioning and/or modelling, is one of the mechanisms whereby environment influences a child [66]. Children extend their fears of unpleasant experiences to other environmental stimuli. Once coupled with personality factors as well as the lack of social support, generalizations of this kind increase the risks of developing anxiety [66].

Moreover, observation of parents' behaviours defines the child's approach to the world. Children not only learn their parents' fearful, inhibited, and avoidant reactions toward a stimuli but also generalize it to other situations [66].

Life Events

The role of negative life events in developing anxiety disorders in children is very much dependent on personality factors. It has been shown that the impact rather than the number of the unpleasant events is predictive of anxiety in children. What determines the impact is the child's level of inhibited temperament [66].

Cognitive Factors

As with adults, it has been shown that information processing biases are keys in the maintenance of anxiety in children. Overt attention toward sources of threat, negative interpretation of ambiguities, and exaggerated estimations of danger are cognitive biases associated with anxiety. Although these behaviours are common and natural in early years of life, inability to inhibit them in a reasonable manner in later years of life is characteristic of anxiety disorders. In a study with anxious and non-anxious children age 9 - 14, anxious children showed larger attentional biases to threat. Moreover, the difference between the two groups was positively correlated with age supporting the above conceptualization of anxiety in children [66].

2.1.2 Treatment of Anxiety Disorders in Children

Treatment Objectives

The above description of risk factors suggests the key role of temperament in the development of anxiety. The inhibited personality style not only has strong couplings with constructs resulting in anxiety, but also increases the vulnerability to other risk factors.

While personality factors play a significant role in the development of anxiety, cognitive processes are more salient in the maintenance of the related symptoms. Therefore, interventions that target avoidance behaviours and negative cognitions may prove more effective.

As with other childhood disorders, obtaining successful outcomes is more likely if therapeutic alliance and child's engagement are facilitated during the treatment [66].

Treatment Techniques

Empirical data shows that cognitive-behavioural therapy, which targets behaviours and cognitions, is more effective (than other existing techniques) in improving childhood anxieties.

Although it can take a variety of forms, cognitive behavioural therapy involves training children to identify the physical, cognitive, and behavioural manifestations of their anxiety and to face rather than avoid anxiety stimuli. In other words, the goal is to replace the mal-adapted avoidance and withdrawal behaviours by changing their cognitions of the world [66]. The goal is achieved through verbal instructions, role play, and modelling and is sustained through positive reinforcement [66].

Controlled trials have consistently evidenced the efficacy of cognitive-behavioural programs in improving a variety of anxiety disorders in children. 55% to 60% of children participating in these skill-based programs recover from their anxiety diagnosis while only 30% of those receiving no treatment at all regain their health [22]. Follow up studies have also shown that treatment effects are maintained several years after participation.

Other treatment techniques such as education support sometimes produce outcomes comparable to that of cognitive behavioural treatments [45]. Close scrutiny, however, reveals that these techniques share 65% of the same components suggesting the important role of cognitive and behavioural elements in the treatment outcome. In fact, further experiments have shown the significant decline in the treatment effects once aforementioned elements are totally removed [66].

2.1.3 Alternative Techniques for Anxiety Treatment in Children

It can be inferred from the discussion above that the state of the art treatments are not effective for a considerable number of anxious children (40 - 45%). This exposes a need for developing alternative treatment techniques or improving the current ones [66].

So far the alternative anxiety treatments have focused more on reducing the costs of and increasing the access to anxiety treatment rather than improving it. Different strategies, such as parent as therapist or internet based interventions have been developed that do not rely on the presence of a therapist. In the best case, these produce effects similar to that of the conventional cognitive-behavioural treatments which themselves are only helpful for just over half of affected children who experience them [66].

Although cognitive and behavioural components are evidently crucial ingredients of a change, the underlying mechanisms of the treatment effect are not clearly understood. It has been shown that resources required to practice some aspects of the cognitive-behavioural therapy exceed children's capabilities, especially at younger ages. There is a possibility that alternative ways of presenting these components which better fit children's abilities will be more effective.

Providing a more accessible context for children to practice cognitive and behavioural elements has been the main goal of TAMER. The following sections provide the background for the areas that TAMER borrows from to realize its goal.

2.2 Animal-assisted Activities

In this section, we illustrate different views regarding the mental health benefits of animal-assisted activities. These views form the basis for theoretical frameworks in human-animal relation research and are relevant to TAMER considering the implications of animal-assisted interventions for anxiety therapy.

This section also covers the considerations regarding the integration of animals for therapeutic goals which is of relevance when designing TAMER scenarios.

2.2.1 Animals' Nature and Therapy

"Watching animals at peace may create a coupling of decreased arousal with sustained attention and alertness, opening the troubled child to new possibilities of learning and growth. The child can then experience unconditional love and models of good nurturing, practice caring sensitively for another, and assume mastery tempered with respect."[57]

As illustrated in the above quote, a common trend seen in the literature of human-animal interaction is that animals have the natural potential to calm children down. Moreover, they provide opportunities for retarded young populations to modify their maladapted behaviours and to acquire social skills. This trend is discussed later in Chapter 3 under nature-oriented theories: biophilia and attachment.

Pleasant Distraction

One way to frame the potential benefits of animals is that by diverting attention from anxiety-provoking stimuli and replacing these with the pleasantness of unconditional love and affection, animals help in reducing the experiences of discomfort (in [48] from [73]). Through further self-reinforcement, this substitution facilitates a self-monitored control to replace withdrawal and avoidance (in [48] from[19]), the key risk factors for development and maintenance of anxiety in children.

Numerous studies in the above line of research have tried capturing empirical data for the aforementioned claims. Typically heart rate and blood pressure have been measured, although skin temperature, behavioural manifestations of stress as well as state and trait anxiety have also been evaluated [48].

Nagengast et al. [61] showed that the presence of a dog can significantly reduce physiological arousal and behavioural distress when children undergo physical examination. Later, Tsai et al. [87] examined the effects of animal-assisted therapy on cardiovascular responses, state anxiety, and medical fear in hospitalized children and reported similar physiological and behavioural calming effects.

Children are not the only age group that benefit from interacting with animals. Demello [27] and Shiloh et al. [78] found physiological and behavioural calming effects in adults who interacted with animals after experiencing cognitive and threat stimuli.

Although reports on benefits of animal-assisted therapy are generally positive and encouraging, the methodological disparity among the studies hinders drawing a definite conclusion as to the physiological and behavioural effects of interacting with animals. However, it can be said that in certain contexts and for certain people, animals are able to yield calming reactions.

Social Partners

The other way to view the potential of animals in producing calming effects emphasizes the innate human's need for social interactions and the competence of animals in satisfying this need. By providing non-threatening, non-judgemental, and unconditional attention and affection, animals help the emotionally disturbed children acquire higher and more acceptable levels of social behaviours [48].

Th disordered children's sense of comfort, relaxation, and self-worth improves through the secure relations shaped in the long-term interactions with animals. This in turn helps them gradually alter their behaviour and develop social skills [51].

Research has shown that children find in animals a secure source of love and support that they can rely at the time of stress and emotional complication [86]. In fact, it can be easier for children with social and emotional disorders to relate to an animal than to a human [53].

Bryant [20] found four benefits children perceive in their relation with animals: (1) animals love them for who they are and (2) despite their occasional misbehaviours. Moreover, (3) animals help children feel good and important while (4) they are trustworthy listeners. Based on these reports, Strand [83] argues that the proximity as well as the sense of mastery over the situation that result from interacting with animals help children develop appropriate coping skills.

Moreover, reports suggest that animals as security figures facilitate children's interactions with other people. In a work with a small group of socially withdrawn adults and adolescents significant improvements were reported in social behaviour as the result of interacting with animals (cited in [48] from [39]). Indeed, the catalyst role that animals play in social interaction explains the benefits of using them as therapeutic adjuncts that mediate social relations between the child patient and the therapist [48].

2.2.2 Animals as Therapeutic Tools

The other major trend in human-animal interaction research is focused on the impact of developing working relations with animals as "instruments of change"[48]. This trend is later discussed in Chapter 3 under the tool-oriented theories: social cognitive theory and role play.

Although the two trends introduced here overlap in some aspects, they differ in their definition of animals' role and effect. While the trend introduced earlier relies on natural and instinctive processes to explain health benefits that animals bring, here the emphasis is on learning, in the course of interaction, to modify the cognition of social and emotional stimuli. In this view, animals are "living and interactive tools" that help disturbed children adjust their responses to the world [48].

Instruments of Change

Interacting with animals provides an opportunity for emotionally disturbed children to modify their view of the world. Supportive and direct in their reactions, animals can help young individuals in learning the cause and effect of their behaviours in a constructive manner [48]. Replacing the false associations originally formed with new positive ones improves the internalized emotional control over aversive stimulations.

Within this line of research, interventions are designed to improve the child's beliefs in her/his ability to behave in a desired way and to successfully perform tasks initially feared. The personal achievement additionally helps the child to find her/himself helpful and beneficial [48]. The resulting self-esteem is then reflected as improved emotional regulation and behavioural control (cited in [4] from [64]), the skills required for a successful anxiety management.

Interventions usually happen through observation, modelling, and role play [48] and are extensively used in equine facilitated therapy programs as well as animal training and care-taking therapies.

In a case study with two emotionally disturbed children who participated in dog training therapy sessions, Kogan et al. [46] found that animal-assisted therapy reduced negative comments and distractability, decreased feelings of helplessness, increased feelings of control over self and environment, and improved eye-contact and relationships with peers. In this study, animals were used as metaphors to teach children the appropriate behaviours. Moreover, animal's honest and unambiguous behaviours in response to the child's actions provided an effective learning experience. However, despite this encouraging evidence about a positive impact of animal-assisted interventions, a general conclusion is not straightforward (as previously observed in Section 2.2.1). In the instrumental view, the uncertainty in generalized conclusions is compounded by the paucity of large scale quantitative studies [7].

2.2.3 Considerations in Utilizing Animals for Therapy

The strongest possible inference of the reports in the literature of human-animal interaction is that interacting with animals provides some therapeutic benefits in certain cases. So it is important to understand the context and extent to which animals are beneficial. It helps when designing therapeutic programs that take advantage of health effects that animal produce and is of relevance to TAMER because it leverages these effects.

First, it is commonly seen in the literature that "the pet supplies the child with an opportunity to feel the master of the situation."[51] This is especially beneficial for children suffering from anxiety disorders. Consequently, building upon this characteristic of human-animal interaction increases the likelihood of the effectiveness of the interventions designed for delivering calming effect.

Second, it is important to acknowledge that certain social skills are valued more over the others (cited in [48] from [62]). To achieve long-term therapeutic effects that generalize to other situations it is important to plan therapeutic interventions for a set of valued social skills. The resulting positive feedback reinforces the mastery of the skill and will promote a continued and generalized learning.

2.2.4 Limitations of Animal Therapy

Although animals can be naturally calming, they should be trained for a planned intervention. Not every house pet meets the standards of a therapy animal.

Unfortunately, training an animal to meet the standards for therapeutic purposes does not happen over night and is very costly. Consequently, access to therapy animals is constrained. Moreover, the unpredictability of animals' behaviours restrain their application in certain circumstances regardless of the amount of training [32]. The limits of access and applicability, compounded by the fears of bites, allergies, and transmission of diseases constrain the use of animals for therapeutic purposes.

However, the way animals impact a human's psychological health can be borrowed for developing ideas that are not facing the above limitations. For example, a robot that simulates animal's behaviours can potentially trigger similar reactions in humans. We provide a comprehensive analysis in Section 3.1 in this regard.

2.3 Touch

Touch is unique and highly influential in communicating and stimulating emotions, relative to other senses [31]. It also contributes significantly to human's health and well-being [58].

Studies have shown that touch can result in heightened alertness and thus improved cognitive performance, measured both subjectively and physiologically [31].

Moreover, in a study with abused children, touch not only enhanced children's alertness, sleep patterns, and social behaviours, but also decreased their depressed symptoms. The same reductions were not observed in the comparison group who only listened to children's stories [31].

In another study with a group of children suffering from posttraumatic stress disorder, both anxiety and depression symptoms decreased in the group receiving massage therapy compared to the group who had only watched relaxing videos. Similar results were found in an experiment with psychiatric children and adolescents [31].

It is also argued that while emotionally disturbed children need touch to realize themselves as independent entities [51], they are usually touch deprived due to their fears of contact with other people. Based on this argument and considering the empirical data, providing tactile comfort can significantly improve treatment effects.

Touch also plays an important role in human-animal interaction. Short-term reductions in blood pressure and heart rate have been reported as the result of stroking or petting an animal.

Vormbrock and Grossberg [89] had a group of university students interact with a pet dog visually, verbally, and through touch, each for six minutes. She found significantly reduced blood pressure for tactile interaction as compared with other forms of interaction.

In a laboratory study with normal adults, patting an animal was found to significantly reduce heart rate after participants experienced mild stress levels induced by mental arithmetic, coding or a cancellation task [27]. In a similar laboratory study, reduction in state anxiety was reported as a result of patting animals for two minutes. The same changes were not observed when patting toys with similar tactile characteristics [78].

2.4 Robot Assisted Therapy

Drawing on the benefits of animal therapy, while addressing its constraints, the research in science and engineering has started building animal-like robots that can produce health benefits comparable to that of animals.

Over years a variety of such robots have been developed to serve different therapeutic purposes across a variety of age groups. AIBO [36], iCat [18], Pleo [88], Probo [70], Paro [77], and Huggable [1] are examples of therapeutic robots with the shape of an animal (Figure 2.1).

In this section we review the present state of robot therapy research and highlight the need for incorporating touch in the development of such robots. We then introduce the Haptic Creature as a promising platform for this purpose. Additionally, we illustrate the empirical findings regarding the psychological health benefits of therapeutic robots.

2.4.1 Touch in Robot Therapy

Despite the health benefits of touch and its key role in stimulating emotions, particularly in human-animal interaction, the research on development of animal-like robots has mainly relied on facial or audio clues for communication. This is partly because of the paucity of research in psychology on the characteristics of tactile interaction, and is partly caused by the difficulties in studying touch.

(a) AIBO (b) iCat (c) Pleo

(d) Probo (e) Paro (f) Huggable

Figure 2.1: Animal-like social robots

The Haptic Creature project tries to fill the above gap by introducing a platform for studying affective touch. The proposed platform extensively builds on the wealth of non-verbal communication in the context of interacting with animals ([96] and [97]). The form and focus of the Haptic Creature on touch makes it a promising choice for therapeutic applications such as TAMER.

In addition to TAMER, there are two other robot therapy projects that also take advantage of tactile interaction: Paro and Huggable. Paro, the baby seal robot, has been specifically developed for therapeutic purposes. Covered under an antibacterial and dirt-resistant fur, this robot takes advantage of a plane of tactile sensors to sense user's touch. It is also able to detect light and understand speech [75]. Huggable, a robot in the form of a teddy bear, can see, hear and speak. While feeling the movements and contact on its skin, it can also move its neck, arms, and ears [1]. It is important to note that even in Paro and Huggable, the tactile channel is not the primary interaction medium. In fact, the tactile interaction is not designed. Although these robots detect users' touch, they do not express themselves by tactile clues and aside from a soft skin that feels nice they do not have wide potential for tactile interaction [6].

2.4.2 The Haptic Creature

The Haptic Creature is a lap-size robot that has been developed by Steve Yohanan to study the communication of emotion through touch [94]. The robot resembles a small animal that can breathe, purr, and change the stiffness of its ears (Figure 2.2). It communicates different emotions by changing the depth and rate of its breathing, the symmetry between the inhale and exhale, the strength of its purring, and the stiffness of its ears [96]. Under its skin, a type of soft artificial fur, the robot takes advantage of an array of touch sensors to perceive a person's touch (Figure 2.2).

Figure 2.2: Touch sensors on the Haptic Creature's surface

Studies show that the Haptic Creature can successfully communicate a range of emotions to people [96]. Moreover, a vocabulary of touch gestures that people use to display different emotions to the robot has been identified [97]. Building upon this fundamental knowledge about the communication of emotion through touch it is possible to study the applications of affective touch using the Haptic Creature as a tool.

2.4.3 Empirical Data for Health Benefits of Animal-like Robots

Here we review the result of studies with robots that also take advantage of tactile stimulation. We have limited our review to animal-like robots because of their relevance to our human-animal interaction model, and our own social robot platform (the Haptic Creature). So far, there has been no comparative study, identifying that these types of robots are necessarily more effective than others. The field is very young and it is not unexpected that issues of this kind have not yet been explored.

In a study at a day service center over five weeks, elderly participants reported elevated moods as the result of interacting with Paro. Also, their reactions to stress was improved as measured by urine hormones. In another longitudinal study, weekly interactions with Paro improved elderly's feelings and depression symptoms [90].

Although these studies are encouraging as to the effectiveness of robot therapy to substitute animal-therapy, they suffer from a serious issue: none of these studies incorporate a control group. Thus, there is the possibility that the fact of intervention and not its characteristics is producing the effect. Perhaps increased social communication happening throughout the studies is the main reason for the health benefits. In fact it is not known if the application of a simple toy could produce similar results.

So far, no empirical results have been reported on the use of Huggable in paediatric or elder care although different scenarios have been planned since 2009 [82].

Chapter 3

Approach

In this chapter we introduce two of our main contributions: (1) we conceptualize robot therapy as inspired by animal therapy through the analysis of the mechanisms underlying the beneficial effects of interacting with animals which were laid out in Section 2.2. Our goal here is to organize the body of work presented in Chapter 2 in a manner that can more effectively inform the design of therapeutic human robot interactions that TAMER exemplifies. To our knowledge, such an analysis has not to date been performed. With this framework established, we then describe the TAMER approach in more details. (2) Additionally, we introduce our systematic, dependency-driven approach to guiding our interaction design process, and finally identify the elements of this larger vision which we have accomplished in the scope of this thesis.

3.1 Relating Theories of Human-animal Interaction to Robot Therapy

3.1.1 Human-animal Interaction Theories

According to [48], theories describing mental health benefits of human-animal interaction can be classified in two distinctive categories. In one category, theories are focused on animals' intrinsic attributes that contribute to human's health and well-being. In the other category of theories, animals are viewed as means for cognitive and behavioural change which provide psychological and physiological benefits. Both of these are briefly described next.

Nature-Oriented Theories for Human-animal Interaction

Natural origins for the benefits that animals bring are generally formalized within either of biophilia or attachment theories. Biophilia theory claims that human beings are intrinsically attracted by nature and living things (cited in [48] from [91]). From this perspective, animals, as living organisms, fulfil human's "innate tendency to attend life and life-like processes".

The term "attachment", first introduced by Bowlby [14], refers to "any form of behaviour that results in a person's attaining and maintaining proximity to some other clearly identified individual" to increase feelings of security (cited in [86]). Based on the attachment theory, humans return to their sources of security when encountering complications. As non-threatening, non-judgemental, always-available beings, animals can act as transitional objects[2] that provide safety, improve feelings of security, and mediate social interactions. The secure attachments formed this way in turn influence a wide variety of internalizing and externalizing problems in children and adolescents [60]. In fact, animals help in alleviating anxieties and stresses by providing unconditional love, affection, and attention.

Tool-Oriented Theories for Human-animal Interaction

The instrumental perspective of human-animal interaction is usually formalized within social cognitive theories that describe cognitive and behavioural issues in a framework of three inter-related factors of cognitions, behaviours and the environment [48]. For example in the case of anxiety disorders in children, overestimating threats is usually followed by anxious behaviours which raises parents' overprotection. On the other hand, parents' overprotection increases excessive reactions to normal stimulation and the defective cycle is traversed again. In interventions based on the social cognitive theories, which has less emphasis on forming long-term companionships (as opposed to the interventions building upon biophilia or attachment theories), animals help people see themselves and the environment in a better way. This is accomplished by humans' acquisition of new skills to modify their cognitions of the environment breaking the malfunctioning cycle that results in the disorder.

In therapies grounded in social cognitive theories, patients generally learn to improve their self-esteem, self-efficacy, and internalized locus of control to then make positive changes in their behaviour (cited in [48] from [5]). This is usually achieved through observation, imitation, direct instruction, and/or association-- techniques that can also be used in animal-therapy.

More specifically, animals help disturbed people acquire positive self-perceptions by improving their feelings of self-efficacy, performance achievement, and personal agency. For example, emotionally disordered children

[2] A transitional object is any object, such as a blanket or a soft toy, that comforts the child when s/he is experiencing anxiety.

practice the role of the stronger who manages the situation while interacting with animals. In case of being cuddly, animals can also fulfil the need of these children for physical contact, which is important for them to obtain a sense of independence [51].

Additionally, through modelling and association, animals make it possible for disordered people to recognize the appropriate behaviours and ultimately transfer these behaviours to their interactions with other people. While interacting with animals, mentally disordered patients can better realize the causal relationships between the environmental factors and the responses to them. In their book "Afternoons with puppy" Fine and Eisen [33] illustrate how the process works for a child suffering from attention deficit hyper-activity disorder (ADHD):

"Aaron came to his social skills group early each week so he could get Sasha's undivided attention. ... . Here is a 10-year-old child diagnosed with ADHD, sitting and giggling and smiling as Sasha [a small gerbil] crawls over his legs. So as to not frighten her, he sits calmly-- something that is hard for him to do. He eventually begins to stroke her and tells her how beautiful she is. "You are a sweetheart, Sasha. I love you," he whispers, with a proud smile.

At these times Aaron acts like a different child. Around Sasha he slows down, and she has a calming effect on him. ... . he moves slowly and talks gently. She reciprocates by snuggling and allowing his tender touch. Over the course of the program, I often bring Sasha to Aaron so that he can learn to gauge his own activity level and perhaps be in more control. It is amazing to watch him transform. She immediately helps him regroup, and once he gets to hold her, his activity level is more in harmony with the others. "Holding Sasha is what he needs to have a calmer and more engaged session"."

The modelling and association described above is especially important in the interventions with children suffering from anxiety disorder because they usually fail to recognize the sources of discomfort which has lead to their anxious feelings; in fact they may not be able to identify that they are anxious, making it difficult for them to remedy the situation [51].

3.1.2 Approach: Robot Therapy as Guided by Social Cognitive Theory for Animal-assisted Therapy

In Section 2.4 we illustrated how animals' therapeutic benefits have inspired the development of robots that can substitute for animals when animal-therapy is constrained. In Section 3.1.1, we examined theories that aim to describe the mechanisms by which psychological health benefits derive from certain types of human-animal interactions. Putting these together, we now propose that a social robot might do the same by affording the same interaction mechanisms that theory has identified as helpful with real animals. This is certainly not new - indeed, the idea that animals are good and thus robots acting as animals must also be good has motivated much of the existing therapeutic social robot research to date. The novelty of our approach is to more closely examine *how* it is possible for robots to provide health benefits, as grounded in social cognitive theory. In other words, we outline the possible scenarios for a successful robot therapy which also guide us to decide *what* about human-animal interaction needs to be mimicked.

Social cognitive theory for human-animal interaction seems appropriate when conceptualizing the therapeutic applications involving animal-like robots because it emphasizes the working relationship between the human and an interactive tool that promotes positive changes in behaviour. For example, in therapeutic applications with emotionally disturbed children, robots can stimulate the same emotional responses as animals' to facilitate a self-perception in which children find themselves as increasingly independent and capable of controlling the situation. Through further modelling and association, children can then generalize their experience with (animal-like) robots to other circumstances and gradually modify their originally mal-adapted attitude.

Taking the above view for TAMER helps identify the high level objectives of the approach. Subsequently, it is possible to define the goals of the interaction and its objectives. The following sections clarify this idea.

3.2 TAMER Approach

In the following sections, TAMER is first defined within the framework of social cognitive theory for human-animal interaction. Having its high level goals and design objectives specified, TAMER is then discussed in the space of human-robot interaction approaches. The discussion is followed by a list of key design requirements analysed within a general framework for the development of social robots.

3.2.1 Robot Therapy for Anxiety through Touch

TAMER can be considered as a special case of robot therapy that targets anxiety. Within the framework of social cognitive theory for animal-like robots, TAMER's role can be viewed as helping children acquire the set of skills required for practising skill-based anxiety treatments. In other words, it can be integrated in the cognitive-behavioural treatments as a method to help children modify their response patterns which then improves their coping skills.

Assume this scenario: the child is interacting with the robot while keeping it on her/his lap. The robot displays a range of emotional expressions in response to the child. Once the interplay progresses, the child finds her/himself as the leader of the interaction which improves her/his sense of independence and self-esteem. Moreover, by recognizing his/her own agency in the calming experience, the child can better transfer what s/he learned to cope with her/his feelings in other situations.

Please note that the communication of emotion through touch is key to the above scenario. All the theories describing animals' beneficial impact acknowledge the significance of the non-verbal communication of emotion through touch in the human-animal interaction (please see section 2.3).

3.2.2 Human-centred View in Design

Given our high-level goal of changing the child's emotional state during the interaction we situate our work within the approaches that are common in human-robot interaction for developing social robots.

In [26], Dautenhahn identifies three main approaches in human-robot interaction research: robot-centred, human-centred, and robot cognition-centred. In the first approach, interacting with the social environment makes it possible for the robot to accomplish its design objectives, therefore, the focus is on finding models and architectures of emotion and cognition that facilitate robot's interactions. In the second approach, the successful task completion is defined as the robot's acceptability for humans. Consequently, fulfilling human's perception and interpretations is the key requirement in designing the robot. In the third approach, the robot as an intelligent system makes decisions and solves problems to achieve its goals. Thus, the focus is on developing cognitive robot architectures and intelligent methods.

Like any other human-robot interaction application, TAMER development should ideally utilize a blend of the above approaches. However, in this thesis work the focus is mainly on the second one: human-centred design.

Taking human-centred direction at the initial steps sounds more reasonable given the social cognitive framing of TAMER and its objective of stimulating the mechanisms that underlie the benefits of real animals (Section 3.2.1). By taking the human-centred approach, humans' expectations and interpretations of the tactile interaction are identified. Afterwards, the produced knowledge can foster the idea in the other two directions. In fact, working along the other two directions is not presently a good choice considering the paucity of research on touch and the role it plays in social and therapeutic interactions.

3.2.3 Design Requirements

Another of Dautenhahn's frameworks describes social skills [26] and is helpful in organizing the general requirements of our work that should be addressed when designing TAMER: (1) prolonged and repeated physical and affective contact with humans: by definition, affective touch is the medium for delivering therapeutic benefits. (2) Adaptive behaviours: to comfort humans, the robot should be able to change its behaviours according to human's needs. Biometrics and patterns of touch are currently the robot's main sources of assessing its user's needs and may remain preferable to alternatives in some respects - e.g. vision or wearable sensors are possible but have their own drawbacks. (3) Assistance role: the robot should help the human to calm down and master the anxiety management skills like an animal does. (4) Social interaction: robot should essentially be competent in the social and therapeutic interaction with humans. Otherwise, its goal of stimulating mechanisms underlying animals' beneficial effects won't be accomplished.

3.3 Systematic Approach to Interaction Design

So far we have outlined our idea in the theoretical framework of social cognitive theory, clarified its goals and objectives, and organized the requirements that should be considered in the design. While in our discussions we made the concept more specific, we did not explain, in practical steps, how we can reach the goals within the bounds of the requirements, i.e. how we are going to *solve* the interaction design problem. In fact, it is very complicated to design a therapeutic interaction in the almost unexplored space of robot therapy through touch. There are different dimensions to the interaction and it is unknown how they contribute to our ultimate goal as we found in our early explorations (see Chapter 7). For example, it was not clear to us if robot's behaviours alone produce calming effects or other elements should mediate the impact. We did not know what those elements are (if any) or how they may work within our theoretical framework. Numerous answers exist to these questions. The challenge is to pick the right one.

We now propose an approach to unravel the complications by systematically breaking the problem into pieces in a way that guides our design process. Our strategy has been partly inspired by the dimensional approach to modelling problems often found in engineering, where a system is described by parametrization of model features or dimensions, and partly by the ideas involved in solving Constrained Satisfaction Problems (CSP) in the area of artificial intelligence.

The subsequent sections detail our approach; interaction design is first modelled as a *search problem* in the interaction space, itself parametrized by several dimensions (e.g. robot's behaviours together with the element of user behaviours constitute one dimension). We then describe the design strategy as the application of the CSP variable ordering heuristic to the dimensional model of the interaction.

3.3.1 Design Space and Attributes

It is common in science and engineering to think of a concept as possessing a set of descriptive "attributes". In this view, within the space made up of all the possible cases that belong to that concept, each case is identified with a unique combination of attributes. In other words, each case can be considered as a single point in the multidimensional space defined by the variability inherent in all of the attributes.

As an example consider the Fourier Transform. This method describes a phenomenon as a combination of a set of eigenfunctions. These functions can be considered as the attributes of the space which the phenomenon inhabits. Once the contribution of each attribute (defined by its eigenvalue) has been specified, the phenomenon is fully specified.

Having the target application and its requirements specified, we can apply the dimensional version of system modelling to interaction design problem: we consider the interaction as a concept described by a set of attributes. All the possible interactions defined by their attributes, make up an "interaction space". The design of the interaction is then defined as specifying the contribution of attributes of the desired interaction. In other words, it is a search for an appropriate combination of the attributes which best satisfy the specified goals while meeting the requirements. Hence, the process of finding the "optimal interaction" is transformed into that of finding the best combinations of attributes. This way, it is possible to break an intractable problem into a series of questions that can be answered through experimentation.

As an example, let's work through the interaction design of TAMER. The first step is to specify its goal: to stimulate the mechanisms that eventually result in relaxation. Its requirements include the constraint of interaction predominantly through touch, with the robot in the participant's lap.

Taking the above dimensional approach, one can think of the following attributes to fully[3] describe the interaction that is going to happen (figure 3.1 visualizes the corresponding interaction space).

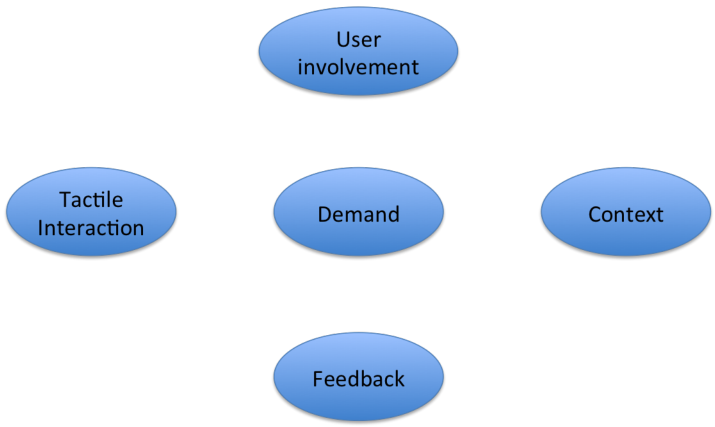


Figure 3.1: The space of TAMER interactions. Each oval represents one of the attributes describing the interaction. In TAMER the following attributes have been defined: (1) tactile interaction: users' and robots expressions through touch; (2) user involvement: the level of users' attendance in the interaction; (3) demand: the resources utilized in the interaction; (4) feedback: the integration of data sources in the flow of the interaction; (5) context: when and how the interaction occurs. Every possible interaction in TAMER consists of a specific parametrization of the above attributes. For example, a *passive interaction* corresponds to this parametrization: minimal user's touch expressions while s/he is not actively participating in the interaction (tactile interaction = finger idly, user involvement = low); the physical, cognitive, and attentional demands are low (demand = low); biometrics are the main source for controlling robot's behaviours (feedback = biometrics only); it is possible for the interaction to occur during the anxiety peak (context = during the effect).

[3]Please note that even if this set of attributes does not fully describe the interaction, the approach is robust enough not to suffer when additional attributes are recognized. it is easily possible to integrate new attributes into this framework.

Tactile Interaction Attribute: Expressions by either the human or the robot. This attribute clarifies what behaviour is demonstrated by either side of the interaction. The expressions (i.e. gestures) available to the human partner include touch gestures they use when interacting with the robot, e.g. stroking, scratching, or hugging. The expressions available to the robot are simply those that the Haptic Creature is capable of making, i.e. all of the possible ways in which it is able to breathe, purr and stiffen its ears. To illustrate, one possible choice of a tactile interaction attribute for producing calming effects could involve the human stroking the robot while the robot breathes slowly at a constant rate.

User Involvement Attribute: The user's attendance to the interaction. This attribute describes how implicit or explicit the interaction is; whether the user is/should be actively involved in the interaction or is just passively influenced by it. It should be noted that we do not mean an instructed or forced set of behaviours when speaking of the user's role in the interaction. In fact, we are specifying the case that affordances and clues of the design should support so that the user is encouraged to display a desired set of behaviours[4].

Depending on the tactile interaction, different levels of attendance can be considered [5]. For example, if our intended interaction is based on two-hand stroking and furthermore, when an experimental context involves execution of specific instructed gestures, implicit involvement (arising through minimal direct attention of the user to the robot) is unlikely to occur. Conversely, when the user is stroking the robot while focusing on another task, implicit (non-attentional) effects are far more likely and can be considered as part of the possible interaction design space.

Demand Attribute: The resources that the interaction utilizes. This attribute indicates the kind of resources involved in the interaction and whether the demands for a specific resource are low or high. Depending

[4]In our early controlled experiments we might explicitly ask users to perform a behaviour of interest. In this context the goal is to test that specific behaviour not that we are imagining the interaction to happen through instructions.

[5]It is also possible to think of the dependency from the opposite direction: not every form of tactile interaction is possible for a given form of user involvement. However, the dependency is more salient in one direction considering the goal of the interaction and its requirements. For example, we can not rely on the minimal user involvement in an implicit interaction if finger idly tactile interaction is not sufficient to trigger calming effects. Awareness of this kind of limitation is our greatest concern.

on the form of expressions a user demonstrates, different physical resources are needed. Additionally, depending on the user's involvement, different cognitive and attentional resources are required. For example, in the case of an implicit interaction while keeping fingers idly on the robot's back, the interaction demands low physical, cognitive, and attentional resources. Therefore, the user's mind can engage in other tasks and s/he can freely use at least one of her/his hands for another task. In contrast, in an explicit interaction while the user strokes the robot with both hands in a specific pattern, there are relatively higher demands for cognitive, attentional, and physical resources.

Feedback Attribute: The data used for estimating the user's emotional state and further controlling the flow of the interaction. This attribute represents the data sources and their integration into the control of the interaction. Currently there are two different sources, each of which can provide information regarding the user's emotions. One is the patterns of touch (touch gestures and their sequence) and the other is the biometrics. The role that each source plays in estimating the emotional state depends on the form of interaction and its demands. Concretely, the form of tactile interaction determines whether or not the touch gestures are available for further interpretations regarding the emotional state, or how they should be interpreted. Moreover, depending on the demands of the interaction, biometrics should be interpreted differently because emotions and cognitions simultaneously influence these measures (please refer to section 4.1.2 for more information; also, section 8.7.1 illustrates the importance of taking this point into account).

Context Attribute: The logistics of the interaction. This attribute describes when and how the interaction should ideally occur; whether the interaction occurs at the peak of the experienced anxiety or afterwards; in either of these circumstances how should the interaction proceed. The appropriate choice for this attribute depends on the form of tactile interaction, users attendance to the interaction, its demands and the integration of data sources for controlling the flow of the interaction. For example, keeping fingers idly on the robot's back while working on an anxiety evoking task can be effective when it is delivered during the anxiety peak. On the other hand, stroking the robot while fully focusing on the interaction can be more effective when delivered after an experienced anxiety.

Every interaction consists of a specific parametrization of the above attributes. For example, a possible interaction is a two-hand stroking (tactile interaction attribute = two-hand stroking) while users are actively involved in the interaction (user involvement attribute = high) and are performing stroking in a certain way (demand attribute (Physical and Attentional) = high) aligned with the robot's behaviour, itself controlled by biometrics (feedback attribute = only biometrics[6]), after a stressful situation (context attribute = after the effect). One can imagine several other interactions, each a different combination of attributes (another example is provided in the caption of figure 3.1).

As can be seen in the above definitions, there are dependencies among attributes[7]. What we choose for one attribute narrows down the choices available to others and so constrains how the interaction works. In the next sections we propose an idea to systematically guide the design process in a way that the progressive narrowing of the interaction space minimally impacts the final design. Indeed, our idea relies on the dependencies to determine the order of choosing optimal parametrizations for interaction.

3.3.2 Dependency Graph

How to efficiently search the interaction space for the combination of attributes that best fulfils the interaction goals? Dependencies among attributes are crucial to be aware of in the search, and indeed can simplify it, because they reduce the possible search space. One can think of these dependencies as constraints among attributes. For example in TAMER, the tactile interaction attribute and the user involvement attribute are constrained by each other. Not every form of tactile interaction is possible for every form of user involvement. In fact, tactile interaction is more constraining considering the goal of the interaction since it is the main medium for delivering the calming effects. If a form of tactile interaction is not relaxing, the choices on user involvement that rely on that form of tactile interaction are not worth considering. This helps to narrow down the search space.

Figure 3.2 depicts the constraining dependencies among TAMER attributes. If the choices of an attribute with regard to the goal of the interaction constrain the choices of another attribute, there is an arrow from the

[6]Since the tactile interaction happens within an expected range of behaviours, touch gestures does not necessarily provide useful information.

[7]It is true that the dependencies are in both directions; if attribute A is dependent on attribute B, B is also dependent on A. However, the goal of the interaction makes one direction more salient than the other (refer to an earlier footnote for an example).

former attribute to the latter. For example, the tactile interaction attribute constrains the user involvement attribute, therefore the arrow is drawn from the tactile interaction to the user involvement. Moreover, by definition, the choices for the demand attribute are directly dependent on the choices for user involvement and tactile interaction attributes. Similarly for the feedback attribute, the form of tactile interaction limits the integration of data sources in the control of the interaction. Moreover, the interpretation of data sources is only meaningful when the sources of demand have been analysed. Finally, before we know in what context the interaction is effective we should know what is afforded when delivering and controlling the interaction.

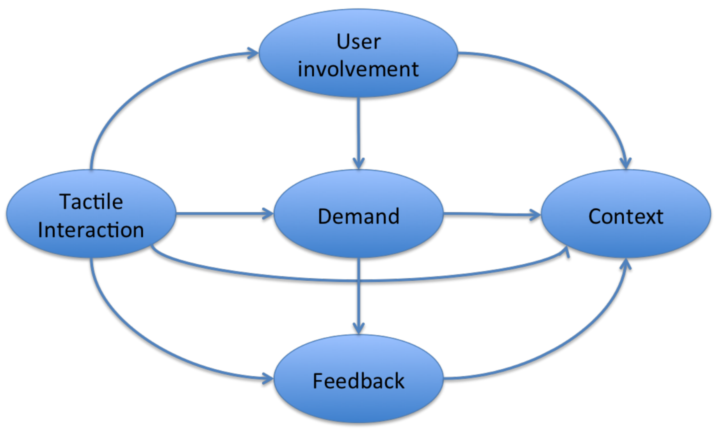


Figure 3.2: The dependencies among TAMER attributes representing constraints and dependencies on the process of designing the interaction. The arrows are in the direction of the more salient dependency between two attributes, i.e. they start from the (more) constraining attribute and end at the constrained attribute.

3.3.3 Design Process as Informed by the Dependency Graph

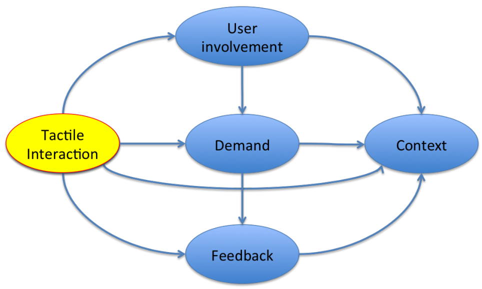
"Variable ordering" heuristic used in Constraint Satisfaction Problems help narrow down the search space. According to this heuristic, the more constraining a variable, the earlier it should be determined. This will hopefully prune larger parts of the search. Consequently, to come up with the appropriate interaction more efficiently, the design process should be started from the more constraining attribute.

According to the above reasoning and the dependencies among attributes shown in Figure 3.2, tactile interaction attribute is the first to tackle in the TAMER design process. Next, comes user involvement, demand, feedback and context respectively (Figure 3.3).

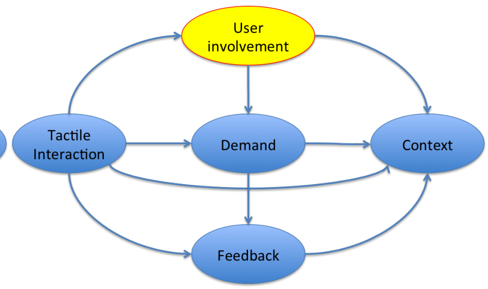
The study reported in chapter 8 is the first step of our design process following the above rationale. The goal of the study is to characterize the emotional response when the interaction is focused on touch. If the study provides evidence for the efficacy of the form of interaction it is testing (stroking), the choices available for other attributes under this form can be potentially integrated into the interaction. On the other hand, if the study does not provide such evidence, all the possible interactions that rely on that form of tactile interaction are removed from the search space.

Moreover, studies testing other forms of tactile interaction will illuminate other regions of the interaction space. Eventually this knowledge will direct the design of TAMER in many different forms.

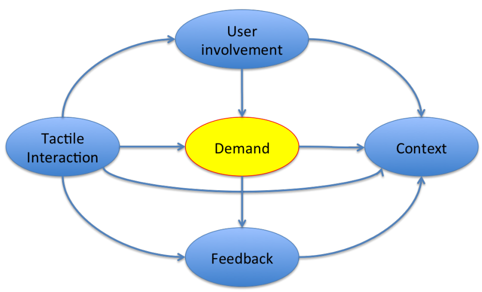
Thinking in the proposed framework prevents haphazard choices that do not facilitate the goal of the interaction. Instead, this framework puts forth a systematic approach for efficiently deciding the appropriate choices. This is very important, especially at the initial steps of developing an unexplored interaction area such as that of TAMER.



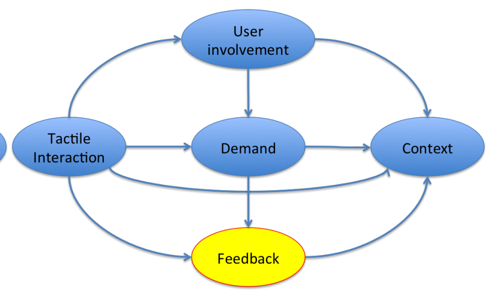
(a) 1^{st}: tactile interaction



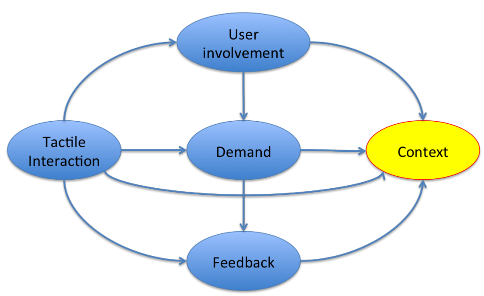
(b) 2^{nd}: User Involvement



(c) 3^{rd}: Demand



(d) 4^{th}: Feedback



(e) 5^{th}: Context

Figure 3.3: The steps of TAMER design process following the variable ordering heuristic. Experimenting on tactile interaction is the first step in the process, because no arrow enters it, while several arrows leave it. The yellow nodes in the subsequent sub-figures indicate the focus of the following steps. A node is chosen for experimentation only if the nodes it depends on have been previously explored.

Chapter 4

Assessment of Emotional Response

This Chapter is the first of the three that describe the preparation of tools required for conducting the studies under this thesis work. In Chapters 4 and 5, we have included some additional background material beyond that in Chapter 2, because this content is secondary to TAMER concept. While the focus of Chapter 2 was on the required background for TAMER, the information supplied in Chapters 4 and 5 are more related to the methodologies for evaluating different aspects of TAMER in controlled experiments. Although unconventional, the author hopes this arrangement of content improves the readability of the document.

In our discussion of the measurement of emotion, we first focus on the assessment of emotional response in general and then move on to the assessment of anxiety as a specific case of emotion patterning. In the two studies reported in this thesis, the first study was an exploratory evaluation that considered children and specifically anxiety, while the second examined more general emotional response for adults with an open eye for indications of anxiety. Thus our anxiety assessment discussion here is more focused on children.

Finally, with this background in place we describe the assessment instruments used in our two studies.

4.1 Measuring Emotions: Background

Although there is no single widely-accepted definition of emotion, Izard [43] has summarized the beliefs of the prominent scientists in the field as the following description:

"Emotion consists of neural circuits (that are at least partially dedicated), response systems, and a feeling state/process that motivates and organizes cognition and action. Emotion also provides information to the person experiencing it, and may include antecedent appraisals and ongoing cognition including an interpretation of its feeling state, expressions or social-communicative signals, and may motivate approach or avoidant behaviour, exercise control/regulation of responses, and be social or relational in nature."

This description embodies the consensual, multi-component model of emotion proposed by [72]. In this model, an emotional response begins with evaluating the significance of the situation. The response is then reflected to a varying degree in three components: subjective experience, physiological functioning, and behaviours (cited in [55] from [35]). Therefore, emotional response can be measured at points where each of these components is expressed: subjective response, autonomic nervous system, and behaviours.

One should consider two steps when measuring emotions. In the first step of measuring emotions one should decide what measures to use. The relevant questions are: (1) what kind of information is desired? and (2) what kind of information does a measure provide?

Related to these questions, we direct the reader's attention to the following findings: the studies investigating the convergence of emotional response in the three experiential, physiological, and behavioural components [21] have found small to moderate correlations among different measures. Based on these results, it has been suggested that each of these components captures a part of the emotional response and therefore, "the more measures of emotion that are obtained and the better they are tailored to the particular context and research question, the more one will likely learn from a particular study."[55].

In the next step, it is important to have an appropriate interpretation of the emotional response. There are two main perspectives regarding the interpretation of emotional responding: dimensional and discrete.

From the dimensional point of view emotional responses are organized along a small number of dimensions. Arousal (intensity of the emotional response), valence (positivity of the emotional response), and approach-avoidance are the dimensions usually encountered in the literature[8].

From the perspective of discrete emotion responding, there are basic emotions each associated with a unique set of experiential, physiological, and behavioural responses. Amusement, pride in achievement, satisfaction, relief, contentment, fear, anger, disgust, sadness, contempt, and shame are considered as basic emotions [28]. Other more complex emotions such as anxiety can then be defined as a combination of these basic emotions [44].

[8] Usually valence and approach-avoidance are considered equivalent, although there are exceptions to this view.

Although the dimensional perspective has stronger empirical support, combining the two can provide more comprehensive description of emotional responding. The choice of what perspective to follow is highly dependent on the response components measured. In the subsequent sections more details are provided with this regard.

We will next cover the considerations for correctly choosing the measures, appropriately interpreting them, and reliably collecting the measures. This content is organized into two subsections: subjective self-reports and biometrics, the two types of measures used in the studies.

Collecting self-reports may seem contradictory to what we described of TAMER. We introduced the ideal TAMER interaction (Section 1.3) as an unintrusive experience, i.e. uncluttered with requests to introspect and report subjective responses. Instead, robot behaviours will be designed to respond based on estimates of user's emotional state estimated from patterns of touch and/or biometrics. However, our studies needed self reports, first to understand the responses themselves, and eventually to validate less intrusive measures[9].

Please note that the definition of emotion, the model of emotion responding, and the following considerations apply to adults as well as children. According to [56], basic motivational systems responsible for activating emotional reactions are phylogenetically old and ontogenetically early, i.e. they are the result of old evolutionary processes but develop during early stages of an individual organism's life. Therefore, it is expected that children share the same underlying mechanisms structuring the emotional response with adults. This assumption has also been empirically supported in [56].

It is worth noting that sharing the same mechanisms does not imply the same response. Emotional responses of two individuals can be substantially different although the underlying mechanisms are the same for both. Similarly, children's emotional responses vary despite the same mechanisms.

[9]The unintrusive measures we plan for the Creature interaction are not yet ready for use. Specifically, it is not possible to use patterns of touch as estimators of emotional state. Aside from the technical issues with touch sensing, the research on the recognition of tactile patterns and mapping them to the corresponding emotional states is still at its early stages ([23], [97], and [34].)

In addition to the fact that having measures of a single component fails to capture the whole emotional response, there are concerns with regard to the reliability of the biometrics - there is no comprehensive model of autonomous nervous system activity for different emotional states. Therefore, there should be another source of data to cross-check the biometric data to be able to reliably interpret them. This additional source can also be used to build appropriate models of emotional response based on biometrics.

4.1.1 Considerations for Acquiring Self-reports

The time when measures are obtained at: It has been argued that the more distant in time the subjective reports are with respect to the emotional stimuli, the less reliable they are (cited in [55] from [68]). Therefore, it is recommended to seek *real-time* self-reports of the current experience as it evolves.

However, real-time measurements are not always possible, in particular where there is a continuous flow of emotions. In this situation the resultant interruption for acquiring the subjective reports as well as the possibly non-natural introspection required may interfere with the natural course of the emotional experience.

The population that measures are obtained from: The populations under study may not be willing or able to provide reliable reports. For example, some people tend to provide socially desirable self-descriptions by falsely claiming positive emotions and denying the negative ones [63]. Even worse is the case for people with alexithmia who have problems understanding and expressing their emotions [55]. A similar case is held with children. Depending on the age group, children may have not yet developed the abilities for conceptualizing and expressing their emotions. It has also been reported that children suffering from anxiety disorders, the main target population for TAMER, have problems understanding their emotions compared to normal children at the same age [84].

The model for emotion responding (dimensional vs. discrete): Empirical research evidence that a dimensional model for self-reports explains a considerable amount of variability in responses, i.e. most self-reported emotions can be distinguished once it is specified where they are located on the dimensions of valence and arousal. Therefore, it is recommended to first examine the dimensional correlates of the subjective reports before conducting any analysis for discrete patterning [55].

4.1.2 Considerations for Acquiring Biometrics

Here, biometrics mainly refer to the indices of autonomic nervous system activity, although in general they can refer to a wider range of measures. The following paragraphs summarize considerations in the use of biometrics for the assessment of emotion.

Autonomic nervous system as a general response system: The main consideration when utilizing biometrics is that the autonomic nervous system serves a number of physiological processes along with emotional response. This system is responsible for the activation of peripheral functions and therefore its measures are affected by a number of other factors such as digestion, attention, and effort [11].

When using biometrics as indices of emotional response, it is necessary to either control for other factors or specify their influence. Triangulating the estimates of emotional response by incorporating other sources of data such as self-reports can also be helpful to clarify the emotional response.

The model for emotion responding (dimensional vs. discrete): The consideration regarding the model for emotional response also applies to biometrics. Although some studies have found that measures of autonomic nervous system activity can distinguish basic emotions (e.g. changes in finger temperature can differentiate anger and fear) [29], there are inconsistencies among these reports. Therefore, it is suggested to take the broader view of dimensionality when conceptualizing the emotional response as reflected by biometrics [21].

There is empirical evidence that most of the variations in the measures of autonomic nervous system activity are associated with levels of arousal, meaning that biometrics are mostly sensitive to the activation of emotion rather than what specific emotion is activated [55]. However, for completely accounting for the differences an additional dimension of valence is also required [21]. In [55] Mauss reasons that this additional dimension is necessary to explain the fact that different biometrics can operate independently and even in opposite directions.

Among the common biometrics, galvanic skin response level shows a linear association with levels of arousal of the stimuli while it is not affected by the levels of valence. On the other hand, blood pressure, cardiac output, heart rate, and the duration of galvanic skin response are also sensitive to valence of the stimuli[55].

Triangulating biometric information: It is usually better to use a combination of several measures to better evaluate the emotional state indexed by autonomic nervous system activity. Different measures are affected by activation of different branches of the system. For example, galvanic skin response level is mainly sensitive to the activity of sympathetic branch of autonomic nervous system while heart rate and heart rate variability reflect the activity of both or either of sympathetic and parasympathetic branches [55]. Having both of these measures helps better evaluating the course of emotional experience. However, it is important to note that the larger the number of the measures, the more likely it is that statistical analyses will result in a type I error unless the Bonferroni correction is applied.

4.2 Measuring Anxiety: Background

"Anxiety seems best characterized as a future-oriented emotion, characterized by perceptions of uncontrollability over potentially aversive events and a rapid shift in attention to the focus of potentially dangerous events or one's own affective response to these events (cited in [79] from [8]).

Anxiety can be thought of as two distinct constructs: state anxiety and trait anxiety [80]. State anxiety reflects current transitional emotional experience, while trait anxiety is a stable personality characteristic. Different measures have been developed for each of these constructs.

When experiences of severe anxiety repeatedly occur, it is considered as a clinical case. It is important to distinguish the conception of anxiety as merely an emotional state and as a clinical case because each should be approached differently when it comes to measurement. In the case of anxiety as an emotional state, assessment is usually organized around transitional properties of the anxiety. In the latter, different measurements are acquired depending on the level anxiety is considered at (i.e. either of symptom, syndrome, or nosology level). That is, for clinical anxiety, instantaneous experience is generally not considered particularly relevant and is not a subject of measurement [79].

As related to the studies reported later in the thesis, the choices for the measurement of anxiety as an emotional state are discussed in this chapter.

For our studies, we consider anxiety as an emotional state rather than a clinical case. As an emotional state, all the models and considerations mentioned above apply to anxiety. Like any other emotion, anxiety is associated with activation patterns on three different components (see Section 4.1): (1) cognitive/verbal response system (subjective experience), (2) the somatic/physiological response system (physiological functioning), (3) behaviour/motor response system (behaviours) [79].

Measurements of anxiety can be interpreted as dimensional or discrete. Within the dimensional model, anxiety is characterized by high arousal and negative valence. On the other hand, within discrete emotion model, anxiety has been defined as a "complex and variable patterning of fear and two or more of the emotions of distress, anger, shame, and positive emotion of interest-excitement."[44]

According to the above definition as well as empirical evidence [44], fear is not the only basic emotion constituting anxiety. However, many researchers usually equate anxiety and fear. This common mistake has not been considered as a serious issue in the literature perhaps because fear is always present in an experience of anxiety [79]. With that in mind, it is not surprising that most of the assessment instruments for anxiety mostly capture the fear component.

4.3 Selection of Emotion Measures for TAMER Studies

In light of the considerations mentioned earlier, we introduce the self-reported scales and biometrics used in the studies reported in this thesis. For the assessment of emotion in general, we employ the dimensional model of valence and arousal. However, anxiety is also measured with specific tools in the hope of capturing the aspects of the experience related to anxiety.

Before discussing the choices made for measures, it is necessary to consider a few points. One point is about the context where the measurement happens. In both of the studies, the effects of interacting with the Haptic Creature are examined in comparison to a reference (the user's response during a particular type of control trial). Each participant would experience these trials in a randomly assigned order. Therefore, it is important to look for reliable measurements of the current emotional state that will reflect the true experience at the resolution of a single trial, where each trial lasts about three minutes.

Another point to keep in mind is the time required to administer the measure - e.g. collect a self report, or allow a biometric measure to equilibrate - which should be short to keep the length of the study within a reasonable range. This is especially important for the studies with children because they usually have a short attention span. Not keeping the study short increases the risks of obtaining unreliable measurements.

In the subsequent sections, the specific choices for self-reports and biometrics are described. Choices of the former are separately discussed for children and adults, whereas the latter is presented as a general case.

4.3.1 Self-reports

Obtaining self-reported emotional experience in addition to biometrics not only provides a broader view of the emotion patterning, but also is required to cross-check the changes in the indices of autonomic nervous system activity. Since assessment of subjective experience provides more reliable answers when made closer to the time of stimulation, these measurements should be made as frequently as possible during the interaction. At the same time, it is important not to interfere with the flow of the interaction. Obtaining self-reports immediately at the end of a trial is a reasonable compromise to both of these constraints. The measurements gathered this way are also valid for verifying biometrics provided that a single biometric data point is illustrative of the whole duration of a trial. This assumption can be made for non-dynamic and reasonably short trials in which a single value is representative of the whole duration.

Study 1 (with Children)

One of our studies was conducted with children, and focused specifically on anxiety. Moreover, the requirement for short assessments was weighted over all the other considerations. Therefore, we collected no dimensional measurement[10], but instead used a single thermometer-like scale [24] to measure subjective anxiety directly[11] (Figure 4.1). This measure was recommended by our clinical paediatrician collaborator based on her awareness of its use in clinical practice, although to the best knowledge of the author no evidence on the acceptability of psychometric properties are available for the measure.

Study 2 (with Adults)

For the assessment of the general emotional response within the dimensional perspective, there are several frameworks which can be used interchangeably [92]. Among these, we chose Russell's circumplex model of current affect. Given that this model is also in use in other studies involving the Haptic Creature ([96] and [97]), the comparison and integration of results becomes easier.

[10] Self-Assessment Manikin scales of valence, arousal, and dominance[15] could have been used for the measurement.

[11] 20-item State Scale of State-Trait Anxiety Inventory for Children[81] was a well evidenced alternative, however, it took longer to administer.

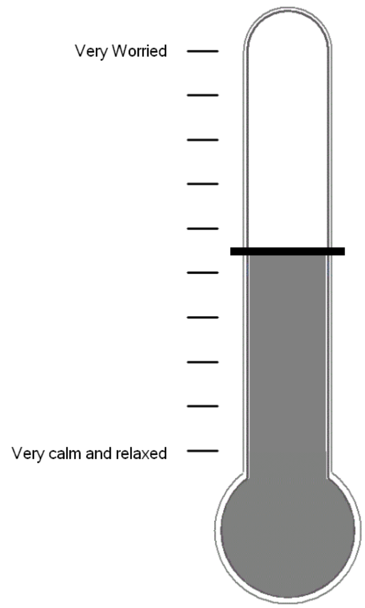


Figure 4.1: 10-point thermometer scale developed to assess levels of anxiety in children. The lowest level represents a very calm and relaxed emotional state while the highest level illustrates very worried state; therefore, the higher the bar, the higher the anxiety. In the computerized implementation of the measure the level of the thermometer was displayed in gray. The default level was set at the middle of the bar. Children were instructed to click at the level that best described their feelings.

As Feldman Barrett and Russell reason, the above 2-dimensional model captures the core affective feeling experienced, however, there are other components involved in a subjective report of emotion which require additional dimensions such as dominance [9].

Self-Assessment Manikin (SAM) scale of valence, arousal, and dominance (figure 4.2) were finally chosen to obtain self-reports of the general emotional experience with adults.

In addition to the dimensional view of anxiety as high arousal and negative valence, the discrete view was also taken into account to more reliably capture the anxiety response. Considering anxiety from the discrete emotions perspective helps in more reliably capturing it. Spielberger's State-Trait Anxiety Inventory which measures the fear component of anxiety [44] has been extensively evaluated and its psychometric properties meet the requirements of the study. To make the study shorter, a reduced version of this scale with acceptable properties was finally used in addition to the SAM scale for general emotional response (figure 4.3).

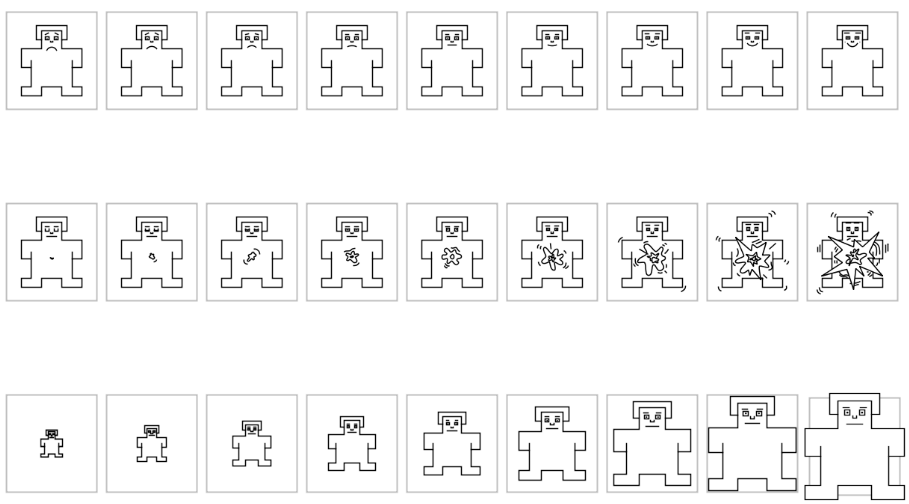


Figure 4.2: 9-point self-assessment manikin scales of valence, arousal, and dominance (respectively from top to button). At the left end of the scales, emotions are respectively characterized as unhappy, calm, and controlled while at the right end of the scales the opposite extremes can be found: happy, excited, and in-control.

	Not at all	Somewhat	Moderately	Very much
1. I feel calm	1	2	3	4
2. I am tense	1	2	3	4
3. I feel upset	1	2	3	4
4. I am relaxed	1	2	3	4
5. I feel content	1	2	3	4
6. I am worried	1	2	3	4

Figure 4.3: Reduced 6-item state scale of state-trait anxiety inventory.

4.3.2 Biometrics

Considering the related literature, availability of measurement equipment, and the previous work on TAMER [40] we decided to look at the following physiological measures: galvanic skin response level, heart rate, standard deviation of normal-to-normal heart rate variability, frequency components of heart rate variability, and respiration rate. Below, we provide the rationale behind our choice of measures and describe the method of measuring them.

In the subsequent sections we introduce specific measures used in each of the studies reported in the following chapters.

Rationale: Collecting the measures of electrodermal, cardiovascular, and respiratory activity provides complementary information on autonomic nervous system functioning in emotion [47].

In the dimensional perspective of general emotional response, galvanic skin response level linearly indexes levels of arousal, while heart rate additionally indexes valence with decreased rates corresponding to increased valence.

The autonomic specificity of anxiety in controlled studies in response to anticipatory threat stimuli (e.g. threat of shock) has been consistently reported as "sympathetic activation and vagal deactivation, a pattern of reciprocal inhibition, together with faster and shallower breathing"[47]. Therefore, in addition to the measures of electrodermal and cardiovacular functioning, measures of respiratory system also index anxiety. Falling in the aforementioned patterning of emotional response to anxiety are increased galvanic skin response level, increased heart rate, decreased standard deviation of normal-to-normal heart rate variability, increased low frequency spectral heart rate variability, decreased high frequency spectral heart rate variability, or increased ratio of low to high frequency spectral heart rate variability, and increased respiration rate.

Method: From previous research in our group, we had access to Thought Technology physiology measurement suite ® [3] for measuring galvanic skin response, heart electrical activity, and respiration. We also used the algorithms introduced in [49] for analysis of galvanic skin response and heart electrical activity signals. We additionally developed our own algorithm for the analysis of respiration. This algorithm is described in more details in Section 6.4.3.

Study 1 (with Children)

All of the measures mentioned above were collected in the study with children except for the low frequency component of the heart rate variability and the ratio of low to high frequency components of heart rate variability. The decision was made because the length of data collections were not enough for reliably calculating low frequency components (please refer to appendix A for more information).

Study 2 (with Adults)

In the study with adults, measures of heart rate variability were excluded from the set of measures described above. Visual inspection of the performance of beat detection algorithm revealed the unreliability of the generated data for calculating metrics of heart rate variability (please refer to appendix A for more information). Although the algorithm did a reasonable job on detecting beats, there was a lot of variability on locating the detected beats; the algorithm lagged the original beat with undeterministic values. Therefore, it was not possible to reliably calculate the inter-beat-intervals for further feature extraction.

Chapter 5

Elicitation of Anxiety in Children

This chapter describes the development of the anxiety elicitation protocol which we used in the study with children. At the beginning, standard methods for eliciting general emotional response as well as anxiety are briefly reviewed. The problem of inducing a predictable moderate anxiety state in a child is challenging, and at the present time we have not yet attained adequate experimental control for this target group. However, in documenting our efforts to systematically approach the elicitation problem we hope to provide future researchers with the essential background on emotion elicitation.

Next, we explain the design of the procedure for inducing anxiety using the Clocks task. The use of Clocks was based on the methodology of the previous thesis work. Therefore, the explanation reports our efforts for generating anxiety within the framework of Clocks.

5.1 Eliciting Emotional Response: Background

Eliciting emotions in laboratory settings is important for studying different aspects of human behaviours. Interacting with confederates, hypnosis, facial expressions, imagery, music, pictures, and films are among the different procedures that have been used for the above purpose [38].

Standardizing the elicitation procedure has also received a lot of attention. A standardized procedure will not only help researchers produce valid results, but also makes it possible to compare the findings across the studies. Examples of these efforts are the development of International Affective Picture System (IAPS) [16] (for children and adults), Gross and Levenson's film set [38] (for adults), and Von Leupoldt et al.'s film set [50] (for children).

As with other topics related to emotion, there are two views with regard to emotion elicitation: dimensional and discrete. In generating the standardized sets mentioned above, IAPS has followed the dimensional view while Gross and Levenson's set is more based on discrete emotions view.

Although interpreting an emotion in research can be done within either of the dimensional or discrete models, elicitation of an emotion does not easily lend itself to these views. In other words, it is possible to interpret the characteristics of an emotion within dimensions of valence and arousal or as a combination of basic emotions. However, the reverse is not necessarily true; eliciting specific amounts of valence and arousal does not generate the targeted emotion. Also, eliciting the exact combination of basic emotions to elicit the desired complex emotion is not easily accessible.

As an example, consider anxiety. Although it can be defined within both dimensional and discrete models, its elicitation is not possible with either the solely dimensional or discrete standard sets mentioned above. Anxiety is more complex than a single response elicited by a single item in IAPS or Levenson's film set. In fact eliciting anxiety has been approached differently in the literature.

The following are the widely used strategies for inducing anxiety: mental arithmetic tasks, reaction-time tasks, Stroop interference tasks, public speaking [12], and emotionally demanding social interactions [25]. It is worth noting that the common ways for eliciting anxiety reported in the literature usually overlap with those of stress. Although it is acknowledged that anxiety and stress are different emotional states, their response characteristics are very similar. Indeed, the focus of anxiety on threat-related cues can activate stress reactions [12] which can explain the aforementioned overlap among techniques to elicit anxiety and stress.

For a specific context of use, standard elicitation procedures should be carefully analysed and be tailored to the requirements of the application. For the research described here, this process was first carried out in a pass for a previous study [40]; we began by using those elicitation techniques in our first study. As we explored our application with children more deeply in this second pass and reviewed the literature more broadly, we uncovered further issues and based on this we would now choose a different path, which we will recommend at the conclusion of this chapter.

5.2 Eliciting Anxiety in the Passive Response Experiment

Although not yet verified, Clocks, as a challenging cognitive task, was assumed to be capable of inducing anxiety. This task, which involves analogue clock reading questions, is a part of cognitive program in Eaton Arrowsmith School for children with learning dysfunctions. Since problem in understanding the relation among concepts is a major learning issue [2], Clocks has been designed to address this problem by improving children's reasoning ability. For example, children learn how hour-hand and minute-hand relate to each other to provide complementary information about the displayed time.

Furthermore, reports from the initial interviews with school staff (conducted prior to the beginning of the research work reported in this thesis) indicated that EAS teachers used the Clocks task specifically to give children an opportunity to practice self-calming strategies in the face of frustration or undue challenge. Together, these attributes suggested it would be a suitable anxiety-induction tool for this group of children. However, as a tool which was generated for pedagogical purposes, Clocks has not been validated in terms of anxiety induction in a controlled research study, and we later learned that the teachers use was indeed more directed at reasoning skills than at deliberate stress induction.

In addition to task cognitive demands, time limit and the loss of incentives were utilized in the development of anxiety inducing protocol. The criteria of such a protocol are discussed first. The chronological steps of the development come next.

5.2.1 Criteria

The most important criterion for eliciting anxiety in the study with children was consistency across trials. In other words, it was important to induce comparable levels of anxiety in different trials so the observed differences among trials can be associated with the intervention, which was the presence or the breathing of the Haptic Creature.

Please note that people have different responses to the same stimulus, so the between-subject differences of the experienced level of anxiety are unavoidable. This, in fact, enforces a within-subject design to mitigate the inconsistencies of induced anxiety at the subject level. However, trial-level inconsistencies are still of concern in within-subject designs. Learning effect is an example of trial level inconsistencies that can be partially addressed with a full counter-balancing scheme among trials.

The other criterion for anxiety elicitation was the physical demands. Please note that children are not able to move one of the their hands which is hooked up with the sensors. This leaves only one hand free assuming that the same sensor-covered hand will be in contact with the robot to feel its breathing.

The third, and rather paradoxical, criterion is engagement. It is against ethical conduct to force children to do something unpleasant. This means that they should voluntarily stay on a task that is not as pleasant.

To satisfy these constraints several procedures were tested. In the next section each of these is described in the chronological order of the development.

5.2.2 Development of Anxiety Elicitation Procedure

Assuming that Clocks induces anxiety, the second main issue regarding the use of this task for anxiety elicitation was learning. Like any other challenging task, there was a possibility that by gaining mastery over time, the task is not as effective in eliciting anxiety. Please note that full counter-balancing can take care of the learning effect as long as no interactions exist between the intervention effect and the learning effect. Since this is not known, it is important to control for learning effect. In the following sections, different approaches to achieve this goal are described.

Level Approach

To counter-act the learning effect it was first decided to adjust the difficulty level to be so high that the learning cannot happen within the limited time of the study or it is negligible. Following this strategy, children were assigned to the easiest level of difficulty that they could not handle (e.g. if a child only knew how to read 1-hand Clocks, s/he was assigned to read 2-hand questions and not 3-hand ones). It was then emphasized that they should do the task as fast and as accurately as they can.

After several pilots it was found that this strategy is not effective especially with young children. Children were engaged neither in the task, nor in the interaction with the Haptic Creature.

The level approach was interfering with the main intervention pathway of calming effect. Instead of getting frustrated, children got bored. Moreover, administration time was much longer than acceptable. These issues necessitated modifications to this approach.

Incentive Approach

Modifications were applied to the previous strategy. In the new incentive approach children were assigned the difficulty level just above their mastery level as was the case with level approach. However, to keep them engaged and on task they were rewarded based on their time and accuracy. More specifically, children were shown a collection of favourite objects (such as candies, cookies, books, etc.) at the beginning. They were then told that by spending more time on the task, or by making more mistakes in their answers they will lose their favourites (the facilitator was removing favourite objects one by one over time. The loss was larger when mistakes occurred).

This strategy was successful in engaging children in the task. However, it made older children excited rather than anxious. Younger children were not stimulated at all as was the case with the previous strategy. Please note that all of the above reports are based on the observational and informal qualitative evaluations.

Time Limit Approach

In the next try, children were assigned their mastered difficulty level. It was hoped that it would be easier to keep children engaged without incentives when they were working at their level of mastery. However, time limit was used to increase the tension. Children were told that they had a limited amount of time to work on the task. If they took longer they would lose the set. Accuracy was also emphasized by setting a minimum acceptable level of 90% that if not met, children would lose the set. Moreover, they were told that another (imaginary) child has already obtained a very high (almost elusive) score. Children should have broken that record to achieve a grand prize.

Aside from the visual feedback on the elapsed time, a series of warning beeps were played while children were answering the questions. It was assumed that this audio feedback would exacerbate time tensions.

The final strategy was used in the study. The discussion on its effectiveness will be covered in the section 7.7.

Chapter 6

Software Apparatus

This chapter describes the structure and functioning of the applications that have been developed by the author and Ziaeddin Jalali (author's husband) to conduct and analyse the two studies of this thesis work. These applications are: Clocks Program (coded by Jalali as a partial re-implementation of the Brainex Clocks program in use at EAS), TAMER Program (developed by the author), flow control and subjective data collection (developed by Jalali), and data analysis (developed by author). For each of the four applications, the purpose of development is introduced first, followed by an overview and functional description.

None of these applications are intended for use outside of the current studies. There is no guarantee that these are robust enough to scale to other studies.

6.1 Stressful Task, Subjective and Performance Data Collection: Clocks Program

6.1.1 Purpose

The main purpose of developing the Clocks Program was to induce task-related anxiety on children. This program has been developed to mimic *Brainex Clocks* which is originally a task within cognitive program curriculum offered at Eaton Arrow Smith school for children with learning disabilities. With the permission obtained from School's dean, the Clocks Program was developed to imitate the original application (Brainex Clocks), for the purpose of the TAMER studies.

Clocks Program has the same shape and core functioning of the original Brainex Clocks application. However, it differs from the main application in three ways: (1) its functionality is limited; only 3 difficulty levels have been implemented (1-hand clock questions, 2-hand clock questions, and 3-hand clock questions), (2) a self-report mechanism is integrated into the program control (thermometer scale) such that self-reports are queried at specific stages of the Clocks execution, (3) it has visual and audio feedback on the elapsed time.

6.1.2 Overview

As can be seen in the figure, the Clocks Program has a very simple structure. Once configured for a trial of 25 questions, clock reading questions will be presented one-by-one. At the end, the emotional state is assessed via a dialogue box requesting a self-report.

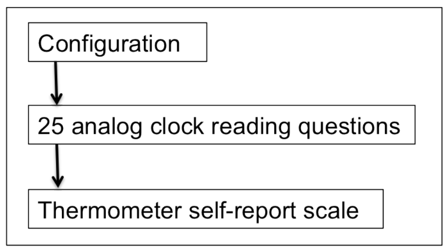


Figure 6.1: The structure of Clocks application.

6.1.3 Functioning

A the beginning of every trial, the Program is configured with the student's ID, the logistics of the trial (if the robot is present, or active), and the difficulty level of questions.

Following the configuration, 25 questions are presented. Figure 6.2 illustrates a 2-hand clock reading question. The answer to the question is entered via keyboard/keypad in the box at the button of the page. The question number as well as the elapsed time are shown at the top left corner of the screen. On the top right corner, the minimum acceptable accuracy is presented.

Feedback on every question is immediately displayed when the answer is entered; a green check-mark appears for correct responses while a red cross-mark appears for wrong ones. The feedback sign lasts on the center of the screen for few seconds and then disappears for the next screen to come up (another clock question or the thermometer scale).

Feedback on the elapsed time is provided through both visual and audio channels. The visual feedback is the seconds passed since the start of the set, whereas the audio feedback is in the form of consecutive beeps. At the

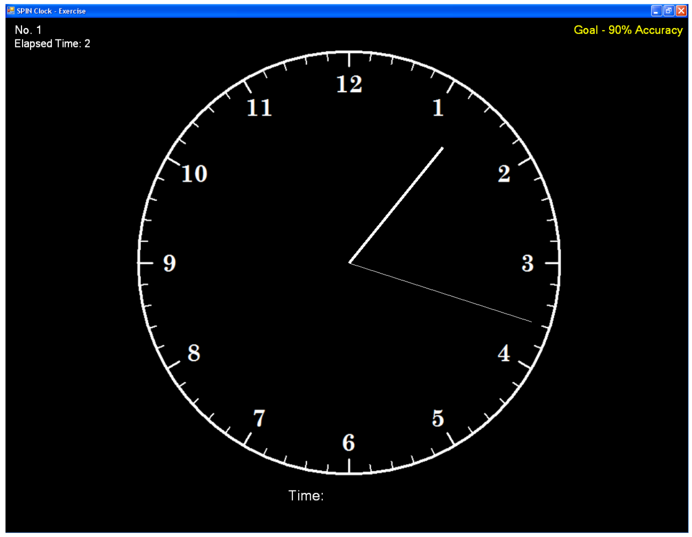


Figure 6.2: 2-hand analogue clock question. The answer should be entered in the box at the button (in front of *Time:*). Question number and the elapsed time are displayed on the top left corner. The minimum acceptable accuracy (90%) is displayed on the top right corner. The feedback sign (green check-mark for correct answers or red cross for wrong answers) appears in the center of the screen immediately after each question. It then disappears when the next screen comes up.

beginning, beeps are sparse, as the time goes by, beeps get faster and faster to signal that not much time is left.

At the end of the set of 25 questions, the subjective experience of anxiety is evaluated with the computerized thermometer scale presented in Section 4.3.1 (Figure 6.3). Once a selection is made on the scale, the student is allowed to see the total time and accuracy of her/his performance.

Delaying the display of the achieved performance helps to collect the true emotional experience during the task. If the time and score are displayed first, the answer to the thermometer is probably affected by instantaneous emotional reactions to the performance.

All the details of the configuration, answers to clock questions, the final score and completion time, as well as the selected level on the thermometer scale are logged in a file for every trial (i.e. there will be a separate file for a set of 25 questions).

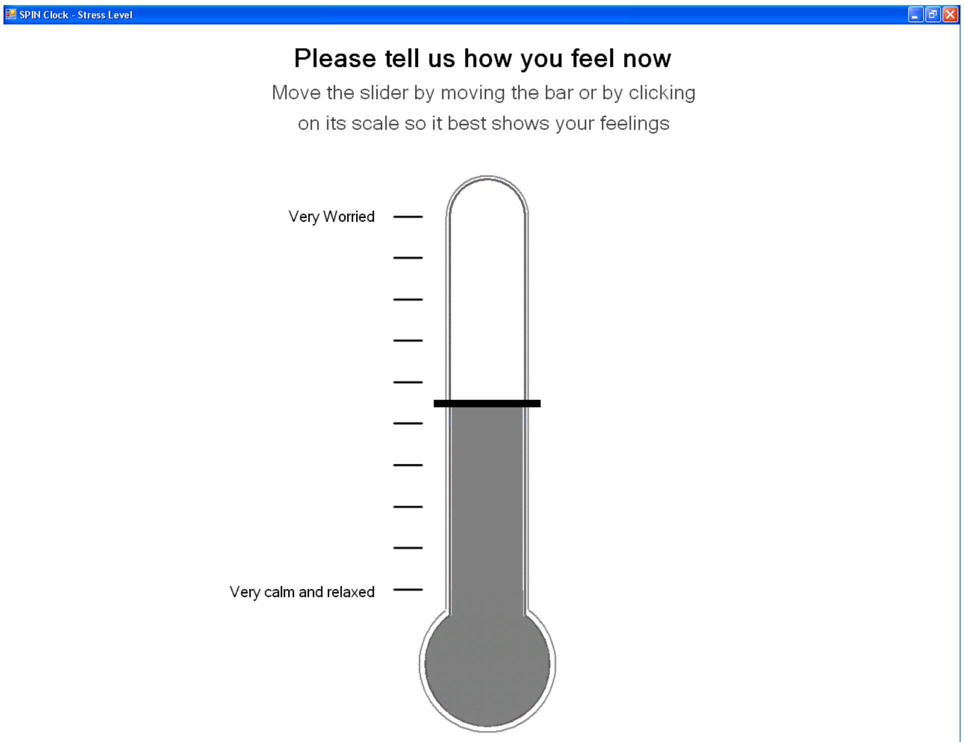


Figure 6.3: Computerized thermometer scale. The horizontal dark bar shows the selected level on the screen. The bar can be continuously moved up and down according to the levels of experienced anxiety, although the value is rounded to the nearest point on the scale of 1 to 10 for further interpretation and analysis.

6.2 Robot Control and Physiological Data Collection: TAMER Program

6.2.1 Purpose

The TAMER Program has been designed for two purposes: (1) collecting the physiological sensor data, and (2) controlling the Haptic Creature. The former is achieved in communication with the Thought Technology physiology measurement suite ® [3] which provides data packets every 175 ms. The latter happens by transmitting position commands over the serial port every 4 ms, a rate that ensures a smooth breathing especially in cases when the robot is mirroring participants (with the configuration of Tought Technology encoder currently in use, the respiration sensor samples participants' breathing at the rate of 256 Hz which is equivalent to about 4 ms).

It is worth mentioning that there are two other applications developed for the same functionality as above. One is the Process Data application which was used in the previous studies on TAMER[40] as well as the initial pilots of the current thesis work. This application was unstable and its failure to reliably and smoothly control the robot's breathing necessitated a replacement.

The other application is Tubes[85] which is an infrastructure developed with the purpose of integrating the standalone applications that are used in user studies. Tubes was shaped around the author's idea to have a platform more reliable than Process Data by integrating Yohanan's robot control application[93] and Kulic's physiological sensing application[49]. This simple idea was further developed by TAMER group and in its current implementation, Tubes has much wider capabilities (please refer to Tubes documentation for more information on the program[85]).

Although Tubes sounds very convenient to use, it was still in final stages of development and validation as we embarked on the present work. To avoid delays in the course of studies caused by the potential issues of the untested software, TAMER Program was developed[12].

6.2.2 Overview

Figure 6.4 provides an overview of the structure of TAMER Program. There are four main steps as illustrated in the figure: reading data, buffering it, sending position command to the robot, and storing data. A class has been defined for each of these steps. Please note that the step of buffering data is only required if robot's behaviours are controlled based on the raw physiological data in real-time (e.g. in mirroring mode where the Haptic Creature mirrors human's breathing).

There are two threads in the Program. The one surrounded by a blue box, the collection thread, is mainly responsible for data collection (reading and logging sensor data). The other one, the control thread, which is surrounded by a red box, is only responsible for communicating with the Haptic Creature.

Except for hand-shaking flags, the two threads does not share any resources if the robot is behaving on its own (e.g. in leading mode where the

[12] The author is unaware of the current status of Tubes and its verification test.

Haptic Creature is breathing at a constant rate). However, as exemplified above for the mirroring mode, the robot's behaviours sometimes depend on physiological data. In this case a buffer is shared between the two threads.

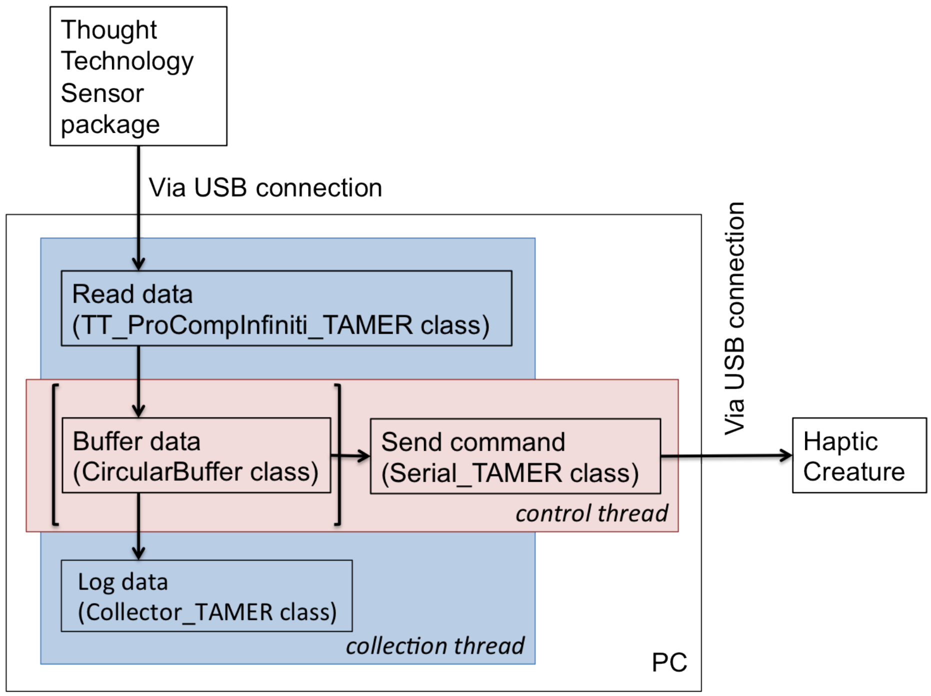


Figure 6.4: The structure of TAMER Program. The blue bounding box represents the thread responsible for data collection off the Though Technology suite (collection thread). The red bounding box represents the thread responsible for the serial communication with the robot (control thread). The arrows represent the direction of data flow.

6.2.3 Functioning

As referred above, TAMER Program supports different modes of operation such as mirroring or leading. Despite the differences among these modes, they all share the following functionality[13]:

[13] Additional details to help the next student who may want to use the code: the common steps described above are implemented in the *TAMER* function with calls to the following functions, each corresponding to one of the steps: (1) *startTT* and *restartTT*, (2) *Baker_controller*, (3) *handle_message* and *empty_msg_queue*, (4) *TimerRoutine*, and

(1) Establishing connection with the Thought Technology suite: In the first step, the COM environment is initialized to make it possible to communicate with Thought Technology sensor suite. Next, connection with the suite is established and configured. The configuration consists of (1) assigning data units for each sensor (e.g. microvolt for heart electrical activity data collected by ECG sensor), and (2) setting internal buffers of Thought Technology suite to keep the sensor data.

In the final setting, higher precision data units were preferred over lower precision ones. Moreover, the internal buffers were adjusted so the data is sent as frequently as possible.

(2) Initializing the robot control thread: After the connection for data collection has been successfully established a separate thread is initialized for communicating position commands to the robot via a USB connection (the control thread). After setting up the serial connection on a hard-coded port, the control thread initiates a timer with an appropriate expiration interval to smoothly control the robot's breathing. In setting the timer, it is important to note that there should be at least a delay of 500 ms between the creation of the serial connection and the first command transmitted to the robot.

Please note that the Program has been designed in such a way that it is not possible to get the robot working in the absence of biometrics sensors; at least one sensor must be connected for the execution to proceed. However, it is possible to work with sensors in the absence of the robot. This design decision was made to reduce the errors of the study setting and to ensure that the interaction period is always captured. This restriction should be noted when rerunning the application.

(3) Collecting data: Once the Thought Technology encoder has stored enough data on its buffers, it sends out notifications to the host computer via USB serial communication. In a loop executed by the data collection thread these notifications are handled and the data is logged. In modes where the robot's breathing is dependent on human's instantaneous breathing, the respiration data is first stored in a buffer and is logged afterwards. The respiration buffer is also accessible to the control thread that sends commands to the robot. To get reliable functioning, data protections have been implemented for the buffer.

(5) *wrapup.*

The loop mentioned above continues as long as the data collection is in progress. During this time it is possible to mark the files at a desired moment by pressing the button ‘m’.

Please note that data collection step happens in parallel to robot control step and the numbering of the steps used here is only for the readability of the present content (one thread is responsible for data collection and another for robot control; the two threads are run in parallel).

(4) Controlling the robot: Depending on the operation mode, the appropriate position is calculated and sent to the robot on the serial port. For example, in the mirroring mode of operation, the next valid value on the respiration buffer is mapped to an appropriate value within the robot’s breathing range. This value is then transmitted as a position command to the robot. As another example, in the leading operation mode, the next point on the linear trajectory of inhale (linearly increasing) or exhale (linearly decreasing) is sent on the port.

There is also a catch-up procedure devised to prevent sudden jumps when the first command is communicated to the robot. The catch-up procedure basically prohibits the transmission of position commands until the current position of the motor is reached, i.e. the stream of command is blocked until it *catches* where the robot is presently at.

(5) Stopping the data collection: Pressing ‘q’ on the keyboard will stop both data collection and control threads and the flow of the program is reset to its initial state (i.e. step 1 above).

In return to the initial state, the COM environment is not destroyed. Therefore, its initialization in the first step won’t be required the next time. In other words, the COM environment should be initialized once per execution of the Program.

6.3 Flow Control and Subjective Data Collection

6.3.1 Purpose

The flow control program is a program designed to automate the procedure of the study with adults. This program performed the following three tasks: (1) managing specific steps of every trial, (2) communicating prompts to participants, and (3) collecting participants’ subjective emotional experience.

Ideally TAMER Program should have been integrated into this flow control program. When integrated, the data collection would be automatically synchronized with rest of the steps within a trial. Due to time constraints the integration was not implemented. In the existing implementation, the flow control program advanced participants through experimental stages, while the facilitator manually set the TAMER Program by observing participants' progress. The manual synchronization did not affect the study and its results because associated errors were handled during data analysis (please see section 8.5.2 for more information).

6.3.2 Overview

An overview of the functioning of the flow control program can be found in figure 6.5. As can be seen in the picture, the program operates under two different modes: one handles the trials where the Haptic Creature is present, and the other deals with baseline trials where the robot is not present.

Each cycle of the program handles a trial in either of its modes; it is not possible to change the mode of operation in the middle of a trial.

The data from subjective report steps are logged into a single file for every execution of the program.

6.3.3 Functioning

When the program is loaded, a file name is obtained where the self-report data will be logged. The program starts at a blank black screen, the start screen. Depending on the trial, by clicking at different points of the start screen, a different mode of operation is selected: clicking on the top right corner will take the baseline branch; clicking on any other point except for the top corners will take the other branch. Please note that at any step except for the subjective report step, clicking on the top left corner will terminate the execution of the program.

In both modes, *Moving square* and *Blank screen* steps are included and timed for 60 sec and 75 sec respectively during study trials. In *Moving square* step, participants are asked to watch a square which randomly moves on the screen and changes its color. The purpose of this step is to neutralize participant's emotions. In *Blank screen* step, participants are asked to interact with the robot if it is present. Otherwise, they do not do anything.

To enter the subjective reports, participants use a mouse and click on the provided scales shown on their screen. Whenever ready, they can submit their reports which brings them back to the start screen.

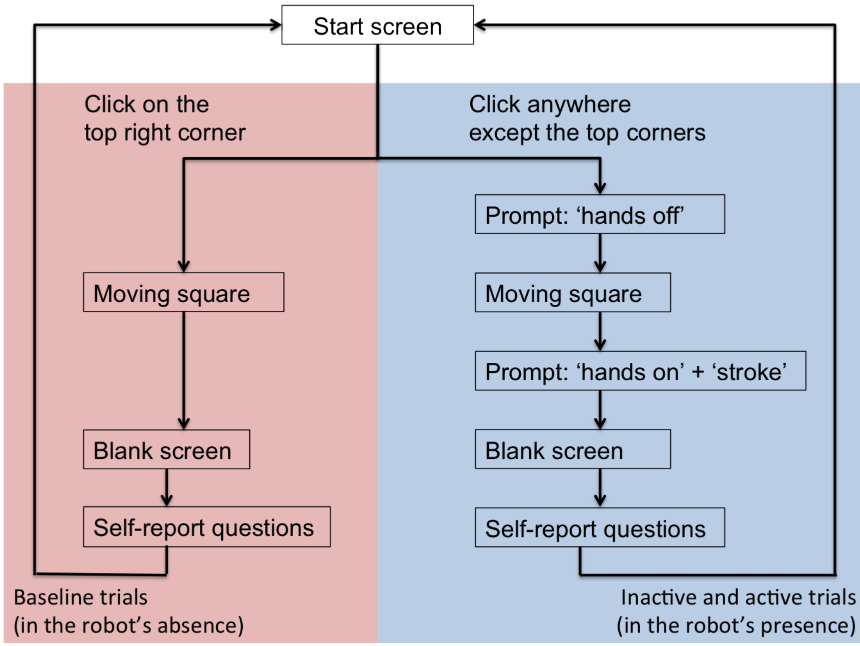


Figure 6.5: The structure of the program to control the flow of the experiment.

6.4 Data Processing

6.4.1 Purpose

The main purpose of the set of programs developed for processing data files was to convert them into a format for further automatic analysis and feature extraction. For self-reports, these programs were as simple as scripts for generating tables of values for statistical analysis in SPSS. These won't be covered here.

For physiological data, the purpose was to pull out the appropriate chunks of data for feature extraction and then extracting the features. Please note that all of these steps are off-line, i.e. are performed after data is collected.

6.4.2 Overview

The overview of signal processing programs can be seen in figure 6.6. Usually raw data files are analysed by a custom C++ program and appropriate parts are extracted (window selection step). These parts are then passed to a MATLAB script that filters the raw data to remove the noise off the content and finally computes the features.

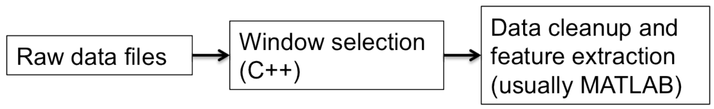


Figure 6.6: The structure of signal processing programs. Window selection step extracts the sections of interest in the raw data file for further processing. The cleanup and feature extraction step is where the actual biometric measures are calculated.

6.4.3 Functioning

Among the steps above, only the functionality of the last step will be explained here. The details of the implementation of the window selection step are covered under each study separately because there are study specific considerations which should be accounted (see Sections 7.5.1 and 8.5.2).

For extracting galvanic skin response level, the implementation followed the descriptions in [49].In processing the data of heart electrical activity, the Q-R-S detection algorithm and C++ implementation of it by [42] were used to detect heart beats. Inter-beat-intervals were then calculated based on the detected beats. This information was then passed to a MATLAB script for calculating heart rate and heart rate variability features. The considerations for implementing the feature extraction procedure are summarized in the Appendix A.

For extracting respiration rate, mean normalization as well as a low-pass filtering at cut-off frequency of 0.004 Hz was first applied to data. Zero-crossing within sliding windows were then used to count the breaths.

Following the considerations described in Section 4.3.1, all of the above features were calculated for the whole duration of a trial.

Chapter 7

Exploring the Possibility of the Passive Response in Study 1

The current chapter describes the details of the first study with children. The goal of this study was to verify some of the earlier results which were confounded by methodological issues (see Appendix B). We first summarize our motivation for re-running a past study. We then review the research questions and describe the modified experimental methodology. We conclude the chapter by presenting our results and discussing them.

7.1 Motivation

There is a considerable amount of anecdotal evidence suggesting that a human can unconsciously benefit from interacting with animals. The past study by [40] suggested a similar possibility with the Haptic Creature, although it was confounded by methodological issues. Since the unconscious effects were very desirable from the clinical practice point of view, we decided to re-check such a possibility.

7.2 Research Questions

Following the rationale of the previous study we assumed that participants would start following the robot's breathing by their own breathing. Under a stressful situation, synchronizing the breathing rates would relax the person provided that the robot's breathing rate was set to that of the person at rest.

Within the so called *robot* ***leading*** *the person* scenario described above, we asked the following questions:

1. Do the Haptic Creature's movements correlate with the changes in the child's biometrically measured emotional state when his or her cognition is busy with a demanding cognitive task?

2. Do the movements contribute to robot's calming effects (if any) beyond its presence alone?

3. Is there any change in the Haptic Creature's effects over a short period of time?

4. Do self-assessment responses reflect the biometric estimates of emotional state?

7.3 Passive Interaction

At the time of the experiment, there is no access to participant's idiosyncratic breathing rates at rest [65] to then adjust the robot's breathing rate based on that.

In tackling the above challenge, we conducted a series of small pilot studies. These pilots revealed that participants can only perceive the difference between two breathing rates when the two are apart by more than 35% of the range of breathing rates at rest. More specifically, for the range of breathing rate from 12 bpm to 30 bpm in normal people at rest [74], only the breathing rates which are more than 2.8 bpm different will be perceived.

Accordingly, any value within 35% of the measured respiration rate will produce comparable effects. Therefore, reducing the value by 35% of the range of 8 bpm will be a safer option; it is comparable in terms of the participants' perceptions while it is likely closer to the true rest rate.

7.4 Methods

The goal of the study was to examine if the Haptic Creature was capable of changing the physiological signals when it was active breathing compared to the time it was inactive or the time it was not present at all. We were interested to know if the interaction affects participants' emotions while they are busy working on a challenging task and are not informed of the characteristics of the breathing (as related to their breathing). Subsequent sections describe the study in details.

Recruitment	
number of participants	recruited: 16
	analysed: 15
inclusion-exclusion criteria	Eaton Arrow Smith student
	between 7 - 17 years of age
	Clocks proficiency level above 1-hand
method of recruitment	through school staff
Demographics	
gender mixture	9 females, 5 males
age	range ($min - max$): $10 - 17$
	distribution ($mean \pm std$): 13.7 ± 2.3

Table 7.1: Study 1 - summary of participants' information.The values reported in this table (ranges, means, and standard deviations) are based on 14 participants whose data was valid for analysis.

7.4.1 Participants

The main target of the TAMER idea are children with anxiety disorders. However, it is very costly to work with this group of children for the purpose of efficacy evaluation. Instead, a group of children at high risks of experiencing anxieties are a more economical subject pool.

Students of Eaton Arrow Smith school had previously participated in the studies assuming that they were an accessible high risk population[14]. This assumption was also followed in the current study mainly because no other option was available. However, students' status on the anxiety spectrum was assessed to evaluate the extent to which this assumption held.

Another advantage of working with this group of children was their familiarity with the Clocks task which was chosen to induce anxiety. Training other children to work with the task takes a lot of time and energy. Also coming up with a consistent training protocol is very challenging. Moreover, keeping other children motivated and engaged on Clocks was really hard as we found through our pilots[15].

Although it is more common in the literature to work with children within a small age range (e.g. 9 - 13), Eaton Arrow Smith students were recruited from the wide range of 7 - 17 because the whole pool was rather

[14]Eaton Arrow Smith school is located on UBC campus, very close to ICICS building

[15]Please note that the choice of Clocks task was never revisited.

small, and we thus recruited from the entire population.

To recruit participants, the invitation letter as well as the consent and assent forms were distributed among children by school staff. To be able to work within the anxiety elicitation protocol, participation was restricted to those students who worked at a difficulty level of Clocks higher than 1-hand.

Only 19 forms were returned, out of which three withdrew before the onset of studies[16]. Among the 16 participants (10 female), data of 15 was valid for further analysis (10 female). The recruited pool came from a relatively normal age distribution and was more representative of adolescents rather than young children (range = 10 - 17, mean = 13.7, standard deviation = 2.3). The table above summarizes the information of participants.

7.4.2 Stimuli and Task

In all the study trials children were working on the challenging cognitive task (Clocks) within a limited amount of time and thus were presumably stressed. In two of the three trials the Haptic Creature was present, and in one of these two it was also breathing at 35% of the range slower than participant's breathing rate measured at the initial baseline collection.

Participants worked on the Clocks within the time limit approach (see Section 5.2.2). That is, they were assigned to the hardest difficulty level that they had mastered. However, they were asked to do it in a much shorter amount of time.

7.4.3 Measures

The main indicators of anxiety level were biometrics. To cross-check the validity of these measures, subjective reports of experienced anxiety were also collected. As discussed in Chapter 4, this cross-check is valid only when obtained immediately after the course of a non-dynamic and reasonably short condition.

Respiration rate (RR), heart rate (HR), heart rate variability standard deviation (HRV-SDDN), heart rate variability high frequency component (HRV-HF), and galvanic skin response level (GSR-L) were the biometric measures of experienced anxiety while a 10-point thermometer like scale measured subjective levels of anxiety (please see sections 4.3.2 and 4.3.1 for more information).

[16] Two had left the school and one was no longer interested in participating.

Measure	***What Measured?***	***Metrics***
Self-reports - at the end of each trial		
Thermometer scale	subjective experience of anxiety	
Biometrics - during each course of interaction		
respiration signal	autonomic nervous system (ANS) response	rate (RR)
heart signal	ANS response	rate (HR)
		variability (HRV-SDNN)
		variability (HRV-HF)
GSR signal	ANS response	level (GSR-L)
Clocks Performance measures		
Completion time	time on 25 questions	
Accuracy	accuracy on 25 questions (number of correct answers)	percentage

Table 7.2: Study 1 - summary of measures. RR: respiration rate, HR: heart rate, HRV-SDNN: heart rate variability standard deviation, HRV-HF: heart rate variability high frequency components, GSR-L: galvanic skin response level.

In addition to measures of anxiety, performance measures on the Clocks task were also collected to provide better insights on the effects of the interaction on participants' behaviours.

Biometric signals were continuously recorded during trials. The recording durations were all longer than a minute but were not fixed and varied based on participants' mastery level on the task. Self-report measures were collected upon the completion of task in each trial.

7.4.4 Experimental Design

To investigate the proposed research questions we planned the study with three trials: NO (the Haptic Creature was not present), INACTIVE (the robot was present but was not breathing), and ACTIVE (the Creature was present and was breathing). In all the trials we induced stress on participants by asking them to work on the Clocks task.

Comparing ACTIVE and INACTIVE would answer the first research question (if the robot's breathing can change participant's emotional state). On the other hand, comparing INACTIVE and NO would answer the second research question (if breathing is effective beyond the robot's presence alone).

We also collected an initial baseline to account for the effects of participants' physiological idiosyncrasies in the emotional response collected in each trial. We collected a second baseline to explore the immediate emotional state following the interaction.

7.4.5 Setup

Figure 7.1: Study 1 - setup. The facilitator is behind the two screens of the laptops. On the right laptop the facilitator is able to configure the Clocks program and monitor the participant's performance on it while on the left laptop, the facilitator sets up the data collection and robot control. The child keeps the robot on his laps with one hand on the robot's back and the other hand entering clocks through a keypad.

Figure 7.1 illustrates the setup of the experiment. The facilitator was present in the room to configure applications and set up data collection.

Children were working on the Clocks task in a setting very similar to the settings of their school work; the monitor and keyboard had the same size and form of those children usually work with. Moreover, they were sitting on the same kind of chair that they sit on during their daily work on Clocks. These considerations were taken into account to control for the potential effect of unfamiliarity on children's performance on the task.

Throughout the study children wore a set of head-phones that played pink noise to filter out the environmental noise as well as the noise generated by the robot's breathing.

From their side, children were video recorded. The video records were mainly intended to capture the unexpected events and interactions through out the experiment for further analysis.

The experiment platform consisted of the physiological sensing package, the TAMER Program (described in Section 6.2), and the Haptic Creature. The sensing package included Thought Technology (TT) respiration, ECG, BVP, and GSR sensors and the TT proCompInfinit encoder, which communicated with the host computer (Intel laptop with 2.4 GHz processor running Windows 7) via optical cable and USB. At 175 ms, TAMER Program gathered and logged sensor data, and used it to control the Creature's movements. The Creature was Baker, a version of the Haptic Creature that had only the breathing mechanism working at the time.

7.4.6 Procedure

Participants were introduced to the setup and instructed on procedures, then walked through the full experiment steps for familiarization (table 7.3). Data collection and short informal interviews followed the demonstration step.

As a part of introduction, children were hooked up with sensors. They were also reminded of the few differences between the Clocks task they work on in the experiment and the original task. More specifically, they were instructed that they would work on a level they have already mastered although they should finish it within a shorter time. Also they were instructed to wait for facilitator's prompts to get started or to move on to the next series of questions. In the instructions, children were also reminded of the importance of being accurate and that they should not move their bodies.

The demonstration step was almost identical to the data collection step to avoid any surprise during the data collection. For data collection, each participant was asked to work on Clocks in three different trials: (1) the Haptic Creature was not present (NO trial); (2) it was present but was not breathing (INACTIVE trial); (3) it was present and was breathing (AC-

TIVE trial). The breathing rate was set to 35% of the range slower than participant's respiration rate measured during initial baseline. Trials were presented in a fully counter-balanced order to participants. There was a time gap of a minute between each two consecutive trials to let participants settle down after the transition to a new condition.

One baseline collection preceded and one followed the three trials. During baseline collection, participants were asked to watch an emotionally neutral video to focus their attention and to minimize their body movements.

The Clocks task consisted of a series of 25 analog-clock-reading questions, which should have been answered within a limited amount of time and with accuracy +90%. The time limit was determined based on the participants' skill level (64 seconds for 2-hand level whereas 74 seconds for 3-hand level). The questions were all from the same difficulty level for a participant, although they differed among participants; every participant was assigned to the hardest difficulty level that s/he had mastered.

Administering the full protocol took about 60 minutes. 40 minutes were devoted to introduction and demonstration, 15 minutes to data collection with no continuous collection longer than 2 minutes, and 5 minutes to interviews.

7.5 Analysis

Before conducting statistical analysis, the reliability of the physiological data files for further feature extraction was verified. The details of these preprocessing and further statistical analysis are explained below.

7.5.1 Physiological Data Selection

Appropriate chunks of each data file were extracted and visually inspected to make sure that the quality was acceptable for reliable calculation of features: the last three seconds of all files were discarded to account for the facilitator's delay in synchronizing the data collection with completion of the task. Following the guidelines described in appendix A, the last 60 seconds of the remaining data was used for calculating features.

Through visual inspections, three galvanic skin response data files were removed from further analysis. The rest of the files were used for assessing the autonomic indices of anxiety.

7.5.2 Statistical Analysis

Biometrics were first offset with respect to the first baseline to account for the idiosyncrasies among participants, i.e. every score was transformed to baseline - raw value. The normalized values were then separately analysed using repeated-measures analysis of variance.

Eight different measures were calculated: respiration rate, heart rate, heart rate viability standard deviation, heart rate variability high frequency component, galvanic skin response level, task completion time, task accuracy, and self-reported level of anxiety. Bonferroni correction was applied to α-level to avoid sample specific results due to multiple measurements, i.e. α was adjusted to $\frac{0.05}{8} \simeq 0.006$.

Sphericity, the necessary and sufficient condition for a valid F-test, was checked for all the measures using Mauchly's test. All the measures passed the test.

7.6 Results

Table 7.4 summarizes the descriptive statistics of the raw and offset data. Table 7.5 represents the results of repeated measure ANOVA. Figures 7.2 and 7.2 visualize means for non-offset (or absolute) values of self-report, performance measures, and biometrics. SPSS 11.5.0 has generated descriptive and F statistics.

The null hypothesis cannot be rejected for any of the eight measures. However, the medium to large effect sizes for some of the measures (self-reported anxiety, time, RR, HRV-HF, and HRV-SDNN) suggest that by increasing sample size there are chances of detecting the difference among trials.

7.7 Discussion

Unfortunately the above results are not conclusive. We can neither infer that the interaction has been ineffective, nor do we have consistent evidence for its effectiveness.There are three categories of factors that each possibly explain the results: interaction, elicitation, and evaluation. The next sections discuss each of these categories separately.

Taking the approach introduced in Chapter 3 will direct the interaction design and evaluation while addressing these issues during the design process. The study reported in the next chapter is the first step of following such an approach.

7.7.1 Issues with Interaction

We assumed that while participants' cognition is fully loaded with a demanding task, they would unconsciously start following the robot's breathing with their own breathing. We did not inform in advance of taking this action. Also we only enforced minimal tactile interaction with the robot as a stimulation.

At the presence of a demanding task, it is too much to expect that there are enough resources available for an uninformed process to take place, especially when such a process is not analogues to any other experience (mimicking an animal's breathing is not something that natually comes to one's mind) and there is not much input to activate it (the tactile interaction is minimal).

Given the success of the Haptic Creature to change people's emotional state in other studies [96], not seeing a difference associated with the robot and its behaviour is probably because the passive form of interaction is not very effective. However, this conclusion cannot be made given the other issues present in the study.

7.7.2 Issues with Elicitation of Anxiety

There is no way to make sure that the Clocks task has successfully induced stress. There is no reliable baseline to compare the NO condition against as a representative of the task only effects.

Even in case of having reliable comparisons in hand, it was not possible to attribute the changes to anxiety especially with the emphasis on autonomic nervous system metrics. The Clocks task involves other factors such as attention and mental effort which independently affect biometrics.

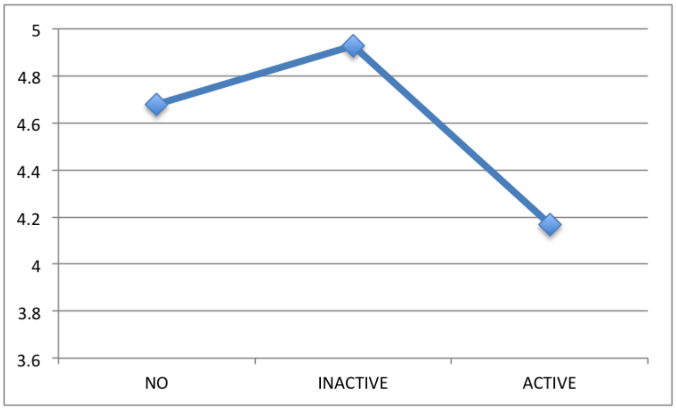
7.7.3 Issues with Evaluation of Emotional Response

Neither self-reported experience of anxiety, nor biometrics provided valid measures of the emotional experience. As mentioned before, biometrics were affected by a number of other factors such as attention and mental effort. The existence of these extraneous factors could have surpassed the possible effect of the interaction.

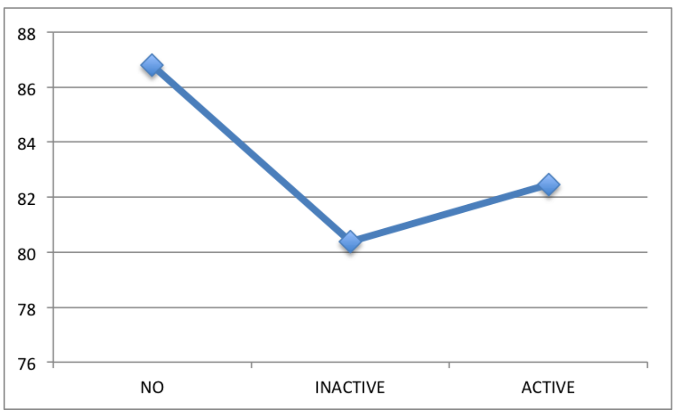
Also, trials were so dynamic that not a single value is representative of the whole duration. Perhaps analysis of signals for more transient patterns is more appropriate for evaluating emotional response. However, these instant by instant analysis cannot be checked with unobtrusively obtained subjective reports.

Step	***Time***	***Description***	***Considerations***
introduction	~10^{min}	high level overview of the goals and steps of the study	
Instructions	~15^{min}	familiarization with thermometer scale, sensors, the Haptic Creature, study trials, Clocks with time limit, considerations in the study	
Demonstration			
baseline	2^{min}	neutralizing	
NO	~2 ^{sec}	the robot is not present	counter-balanced with INACTIVE and ACTIVE
INACTIVE	~2 ^{sec}	the robot is present but is inactive	counter-balanced with ACTIVE and NO
ACTIVE	~2 ^{sec}	the is breathing at 35% slower rate	counter-balanced with INACTIVE and NO
Data Collection			
baseline	2^{min}	neutralizing	
NO	~2 ^{sec}	the robot is not present	counter-balanced with INACTIVE and ACTIVE
INACTIVE	~2 ^{sec}	the robot is present but is inactive	counter-balanced with ACTIVE and NO
ACTIVE	~2 ^{sec}	the is breathing at 35% slower rate	counter-balanced with INACTIVE and NO
baseline	2^{min}	neutralizing	
interview	~5^{min}	overall response to the interaction, thoughts, and suggestions	

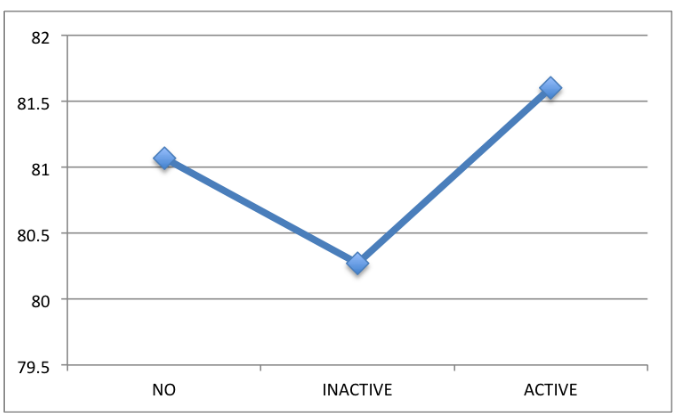
Table 7.3: Study 1 - summary of procedures. During NO, INACTIVE, and ACTIVE trials participants were working on the Clocks task at the difficulty level assigned to them.



(a) Self-reported anxiety on 10-point thermometer scale (bpm)

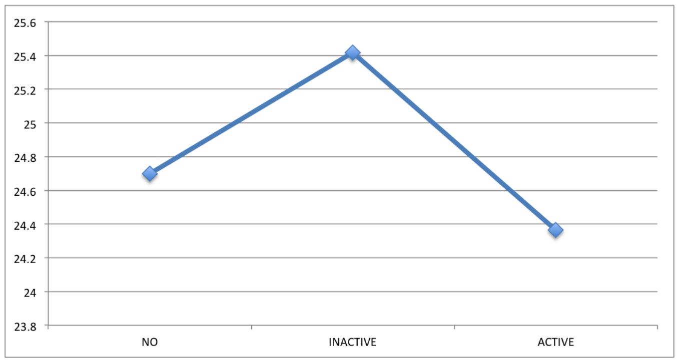


(b) Task completion time (seconds)

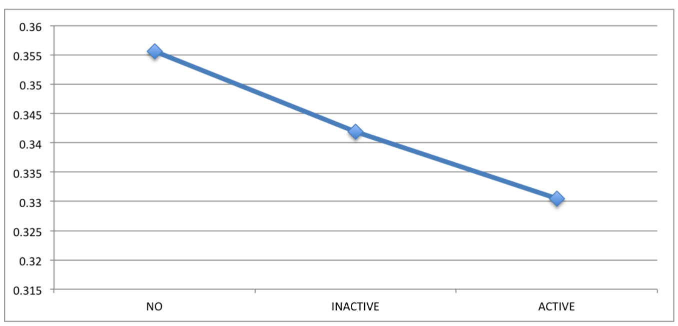


(c) Task accuracy (% of correct answers)

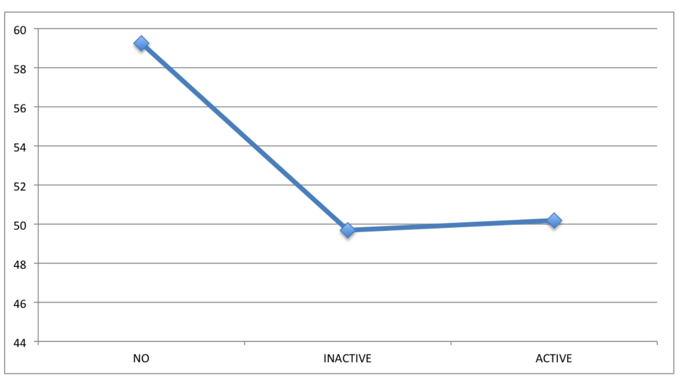
Figure 7.2: Study 1 - means for non-offset (or absolute) values of self-reports and performance measure for NO, INACTIVE, and ACTIVE trials.



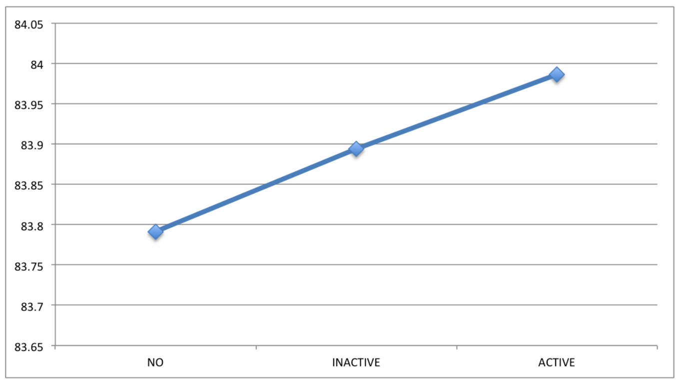
(a) Respiration rate (bpm)



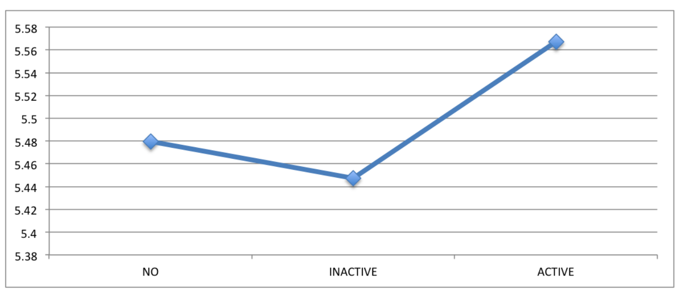
(b) High frequency component of heart rate variability



(c) Standard deviation of heart rate variability (milliseconds)



(d) Heart rate (bpm)



(e) GSR level (micro Siemens)

Figure 7.2: Study 1 - means of non-offset (absolute) values of biometrics in NO, INACTIVE, and ACTIVE trials (only during interaction period). The high frequency component is calculated as the proportion of power in high frequency band to the total power thus is unit-less.

Absolute (offset) values								
Groups:	Baseline 1		NO		INACTIVE		ACTIVE	
Metrics:	mean	std	mean	std	mean	std	mean	std
Thermo (15)			4.68	2.53	4.93	2.44	4.17	2.38
Time (15)			86.80	31.74	80.37	28.22	82.46	32.47
Accuracy (15)			81.07	11.76	80.27	9.97	81.60	9.77
RR (15)	20.20	2.62	24.70	2.05	25.42	2.55	24.36	2.30
HRV-HF (15)	0.35	0.07	0.36	0.09	0.34	0.08	0.33	0.08
HRV-SDNN (15)	56.37	21.02	59.24	28.91	49.67	37.42	50.18	38.64
HR (15)	78.19	12.31	83.79	10.63	83.89	12.62	83.99	12.23
GSR-L (12)	3.87	2.20	5.48	2.59	5.45	2.73	5.57	2.75
offset values								
Groups:			Δ_{NO}		$\Delta_{INACTIVE}$		Δ_{ACTIVE}	
Metrics:			mean	std	mean	std	mean	std
Thermo (15)								
Time (15)								
Accuracy (15)								
RR (15)			-4.50	3.21	-5.22	3.87	-4.17	2.36
HRV-HF (15)			0.00	0.13	0.01	0.13	0.02	0.12
HRV-SDNN (15)			-2.87	39.66	6.70	45.55	6.19	46.82
HR (15)			-5.60	5.56	-5.70	4.99	-5.79	5.02
GSR-L (12)			-1.61	0.84	-1.58	0.77	-1.70	0.86

Table 7.4: Study 1 - means and standard deviations of the collected metrics during different trials. Δ sign represents the offset values with respect to the baseline (i.e. $baseline - value$ of either inactive and active trials). Thermo: self-reported anxiety on the 10-point scale, Time: completion time (seconds), Accuracy: the percentage of the correct answers, RR: Respiration Rate (breaths per minute), HRV-HF: normalized high frequency component of heart rate variability, HRV-SDNN: standard deviation of heart rate variability (milliseconds), HR: Heart Rate (beats per minute), GSR-L: Galvanic Skin Response Level (micro Siemens). For biometrics, mean values only represent the baseline/interaction period. The number enclosed in parentheses in front of each metric is the number of data points that have been used to derive the mean and standard deviation of that metric.

Self-reports and Performance					
	Thermo	Time	Accuracy		
mean square	221.27	161.23	6.76		
mean square error	170.17	44.08	57.80		
F	2.06	3.66	0.12		
df	(2,28)	(2,28)	(2,28)		
p	0.15	0.04	0.89		
η^2	0.13	0.21	0.01		
power	0.39	0.63	0.07		
Biometrics					
	RR	HR -HF	HRV-SDNN	HR	GSR-L
mean square	4.33	0.002	434.65	0.14	0.50
mean square error	2.76	0.002	106.73	9.20	0.16
F	1.57	1.01	4.07	0.02	0.29
df	(2,28)	(2,28)	(2,28)	(2,28)	(2,22)
p	0.23	0.38	0.03	0.98	0.75
η^2	0.10	0.07	0.22	0.001	0.03
power	0.09	0.21	0.68	0.05	0.09

Table 7.5: Study 1 - statistical analysis comparing offset NO, INACTIVE, and ACTIVE trials. Description of the terms used in the table: mean square: variations associated with between group differences; mean square error: variations associated with within group differences; F: F statistic; df: degrees of freedom; p: significance level; η^2: effect size ($\eta^2 \approx 0.01$: small effect, $r^2 \approx 0.06$: medium effect, $r^2 \approx 0.14$: large effect).

Chapter 8

Design of a Calming Interaction with the Haptic Creature and Its Evaluation in Study 2

In this chapter we detail the design of a calming interaction as the first step following the rationale introduced in Section 3.3. We also describe the second study which aimed at evaluating this interaction and will discuss the overall contributions to the TAMER project.

The chapter starts with a discussion emphasizing the need for understanding tactile communication in human-robot interaction. It then introduces the research questions and highlights the relevance of their answers to TAMER. Next, comes the approach taken for interaction design and its theoretical support. The chapter continues by describing the experimental methodology (participants, measures, setup and procedures) and data analysis. We conclude with experiment results and discussion of its interpretations and implications.

8.1 Motivation

We hypothesize that interacting with animal-like robots can bring about health benefits comparable to that of real animals, given our framing of it within the theories describing the beneficial impact of real animals (see Section 3.1.2). Indeed, preliminary experiments with such robots suggest that they can produce psychological effects similar to those produced by animals[76].

Although early research suggests that social robots may be able to provide a psychological enrichment that is particularly helpful when real animals are inaccessible, more research is needed to rigorously confirm the therapeutic value, and also to expand the potential impact. In particular, interaction design is crucial: we must identify the human-robot interaction components that effectively stimulate human's emotions to then utilize these components as pathways for delivering therapeutic interventions with robots.

Given the literature that provides evidence for the importance of touch and its health benefits, especially in the context of human-animal interaction, touch is one of the essential components to research in developing therapeutic robots (Section 2.3 contains a comprehensive review).

As illustrated in 2.4, with the exception of Yohanan's Haptic Creature, HRI research has overlooked the sense of touch as such a component. At this time, we are aware of no report clarifying the role and characteristics of tactile communication of emotion as a mediator for therapeutic goals. Although some robots such as Paro and Huggable sense user's touch and react to it, they do not rely on the tactile interaction as the main communication medium.

8.2 Research Questions

Utilizing the Haptic Creature as a promising platform, in this study we are characterizing the effects of the interaction, predominantly through the sense of touch, on the user's emotional state to understand whether an animal-like robot can simulate animal effects. We are examining the efficacy of the interaction to change the emotional state; or, more specifically, to alleviate anxiety. In our investigations we seek answers for the following questions:

1. What form of tactile interaction will best facilitate the desired change in emotional state?
2. How does the interaction chosen above impact objective and subjective measures of emotion?
3. Does the impact imply relaxation?
4. What are the possible mechanisms that could potentially cause these changes?

The results of this study will provide the fundamental evidence for TAMER and ground the further development of a therapeutic interaction. In other words, positive answers for the above questions would produce empirical support for TAMER by validating the underlying assumption that the tactile interaction, in the context of human-robot interaction, can effectively cause a desired change in the emotional state. Additionally, as discussed in Section 3.3, the results bring insights to the interaction design process with regard to the forms of interaction that can potentially have comforting impact.

8.3 The Design of the Tactile Interaction

Our goal is to design an interaction with the Haptic Creature such that it can produce effects which are empirically similar to that of animals in reducing anxiety. At our initial steps, we narrowed down our design to a specific form of interaction that we hypothesized as capable of producing the desired impact.

For the maximal impact to occur, we hypothesized that both sides should contribute their share. More specifically, humans should cooperate with the robot that tries calming them down. Based on this hypothesis, it is important to design both human's and robot's behaviours.

As already proposed by Yohanan and MacLean [94] the interaction with the Haptic Creature can be decomposed into four states, and the transitions among them. States (illustrated by four cells in Figure 8.1) refer to the expression of an emotion or the recognition of it by a human or the robot. Transitions in Figure 8.1 are of two types: horizontally, they indicate the relation between an emotion displayed by one side and the emotion recognized by the other side. Vertically, they describe the internal changes that result from the communicated emotion. The advantage of this model is that it makes it possible to isolate each component of the interaction to then study it independently.

Within the model mentioned above and based on a larger, more general research investigating the internal transitions caused by the interaction [93] (the arrow surrounded by a red rectangle in Figure 8.1), here the focus is on a smaller, more specific case of the human transitioning from a less to a more calm emotional state (i.e. one instance of states $3 \rightarrow 4 \rightarrow 1$ in Figure 8.1) and designing the other elements of this model so as to make that occur.

Following the rationale introduced in [94], we envisioned the interaction as a sequence of human's expressions/gestures and the robot's expressions that occur in parallel. The goal was to design a form of interaction in terms of the expressions on either side which made the desired transition possible. We built on the specifics of the emotion display by either the Haptic Creature or human reported in [96] and [97]. Additionally, we utilized the research in human-animal interaction to justify our final model. Details for this process come in the subsequent sections.

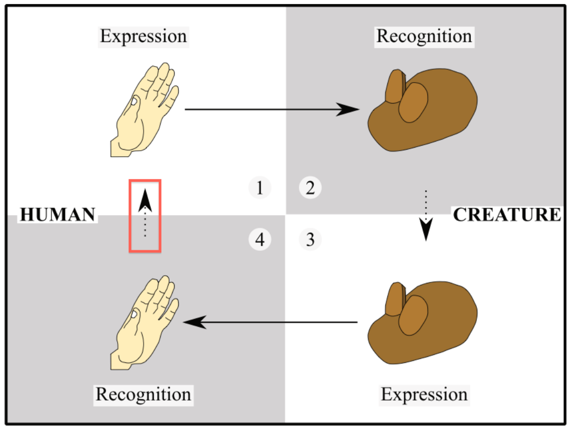


Figure 8.1: The cycle of interaction with the Haptic Creature [97], © 2011, Springer Science and Business Media.

8.3.1 The Human's Expression

As mentioned above the goal was to find a form of expression on the human's side that contributed to a calming interaction. In other words, we were looking for a human gesture that when performed facilitated the process through which the robot's behaviours were calming. To the best of our knowledge, there is no research documenting how performing different touch gestures can alter a person's emotional state. However, as with facial expressions there might be a bidirectional relation between the emotional state and the way it is expressed [29]. That is to say that not only do emotions have specific behavioural indications, but also those behaviours can trigger their associated emotions.

In [97], Yohanan and MacLean report how humans express their feelings by means of touch gestures. Based on these reports, we selected a few gestures for our interaction that are normally performed when humans feel calm and relaxed (low arousal, high valence) hoping that when performed, these gestures would mediate the transition into their associated emotional states.

Please note that previous literature neither approves nor disapproves the above assumption. However, there is a possibility for a bidirectional relation between an individuals' touch gestures and the associated emotional states they elicit in the same individual in a way similar to facial expressions.

<u>Stroke</u>

Arousal \ Valence			
	2.97	3.50	3.40
	3.07	3.93	4.13
	3.47	3.73	4.33

Pat

Arousal \ Valence			
	2.80	3.50	3.37
	2.63	3.73	3.87
	3.07	3.01	3.83

Contact

Arousal \ Valence			
	2.90	2.37	2.00
	3.70	4.57	3.10
	4.40	4.60	4.63

Cradle

Arousal \ Valence			
	2.77	2.80	2.60
	3.10	3.23	3.70
	3.53	3.80	3.93

Hug

Arousal \ Valence			
	2.77	3.60	3.87
	3.37	3.00	4.30
	3.63	3.57	3.47

Massage

Arousal \ Valence			
	2.43	3.53	3.27
	2.47	3.27	3.43
	2.73	3.17	4.03

Hold

Arousal \ Valence			
	3.13	3.00	3.37
	3.37	3.83	3.80
	3.53	3.60	3.80

Scratch

Arousal \ Valence			
	2.80	3.33	3.50
	2.80	3.27	3.40
	2.63	2.63	3.67

Rub

Arousal \ Valence			
	2.67	3.70	3.80
	3.07	3.47	3.97
	3.03	3.03	3.70

Finger Idly

Arousal \ Valence			
	2.67	2.70	2.33
	2.73	3.80	2.90
	3.30	3.07	3.73

Table 8.1: Every 3 by 3 block above is a valence-arousal map (as per Russell's 2-D affect model [92]) showing how participants in [97] reported they would use that gesture. Specifically, each cell of each map depicts the likelihood (*1: Very Unlikely to 5: Very Likely*) that participants would use that gesture for an emotion lying in that region of the valence-arousal map. Valence increases horizontally, while arousal increases vertically (bottom up); shading darkens with higher likelihood. Data is reprinted with permission from [97].

Ideal Gesture

Arousal \ Valence			
	1.00	1.00	3.00
	2.00	3.50	4.00
	2.00	4.00	5.00

Table 8.2: The valence-arousal map of an ideal gesture for the desired human expression.

Table 8.1 shows where on the valence and arousal coordinates of affect each of these gestures[17] is more likely to occur. The criteria for selecting a gesture were:

- Having high occurrence for expressing higher valence *and* lower arousal; intuitively, the darker the associated valence-arousal map is toward the lower right corner, the better.
- Having low occurrence for expressing lower valence *or* higher arousal; intuitively, the brighter the associated valence-arousal map is around all corners except the lower right one, the better.

Following these criteria, we selected three gestures: *stroke*, *massage*, *finger idly*. *Massage* gesture did not seem appropriate given the breathing structure of the robot; the structure is not strong enough to simulate breathing even when under a relatively small external force. Between *stroke* and *finger idly*, *stroke* had much higher occurrence for very high valence and very low arousal, therefore it was selected. Our choice of stroking was also supported by the evidence from human-animal interaction research [41].

The most intuitive way for performing the stroking gesture, as afforded by robot's form and shape, is to move hand(s) over its back shell where it is breathing. However, we had to look for other ways of performing the gesture to deal with several constraints. First, the breathing mechanism was so fragile that it stopped working properly for external forces as small as the hand weight. To avoid this, participants would need to observe instructed constraints about the heaviness of their stroke. This wasn't necessarily a good solution because it made the interaction unnatural.

The second constraint associated with back-shell stroking was the limited possibility of actively involving both hands in the interaction. As evidenced

[17] These gestures are the first ten most frequently used gestures reported in [97].

by a series of pilots, participants felt more comfortable when they were able to interact with the Haptic Creature with both of their hands.

To address these constraints we further constrained the *stroke* gesture beyond the definition provided in [97]. In this form participants had one of their hands fixed on the side of the robot's back shell in a way that they could feel the breathing without exerting any forces on the breathing mechanism. They leaned one hand on their lap while also in contact with the robot's breathing parts. To do so was both natural (as observed in pilots) and did not require extra care with regard to the amount of applied force to the mechanical structure. With the other hand, they would stroke over the Haptic Creature's body.

In addition to addressing the above constraints, this form of stroking could help in collecting cleaner data when physiological sensors were hooked up to the stationary hand, as motion tends to add artifacts to the data. In another series of pilots, we compared this form and the original more intuitive one. We found that participants were subjectively comfortable performing it as much as they were performing the original way.

Since we had not planned any other tasks in our study protocol, using this modified form that involved two hands rather than a single hand was also affordable. That is, in comparison to the study with children, participants did not need their hands to do another task while interacting with the robot.

8.3.2 The Haptic Creature's Expressions

The Haptic Creature's expressions refer to its physical acts to convey an emotional state. Our choice of the Creature's expressions should be compatible with our choice for that of the human so it is more likely for the intended effect to take place. We chose a gesture on the human's side that is usually performed when in relaxed emotional states. We also know that humans expect the robot to mirror their own emotional state [97]. Therefore, it is reasonable to assume that human's transitioning to a calmer state is reinforced if the robot is assigned to express its relaxed emotional state.

For the interaction to work in the way envisioned above, it is important to make sure that participants recognize the robot's expressions. This has already been illustrated in [96], which reports the ability of the Haptic Creature to communicate specific emotions.

The rendering parameters in pleasant-deactivated state (i.e. high valence and low arousal on the affect space) of the robot as reported in [96] were initially chosen. However, through pilots the breathing rate parameter was adjusted to the rate of 20 breaths per minute in a saw wave form (rather than a sine wave form). The adjustments were based on participants' reports that this form of breathing was more relaxing.

8.4 Methods

The goal of the user study was to characterize the impact of interacting with the Haptic Creature, in the context of a specific interaction, to know if it can produce relaxing effects similar to that of animals. Subsequent sections describe the study in details.

8.4.1 Participants

Although the immediate target of TAMER is children, this study focused on adults. Working with adults precludes direct generalization of results to children. However, we accepted this limitation because our main goal was to show the possibility that the benefits of human-animal interaction and affective touch extended to tactile human-robot interaction. We wanted to understand whether or not our models for non-verbal, tactile communication of emotion with robots, built upon the literature in human-animal interaction, were effective.

Whether directly generalizable or not, we can use insights gleaned from adults to refine our models and in turn, design new child-robot interactions which we can then examine directly for greater effectiveness. Working with children proved infeasible to find this missing piece: the absent empirical evidence that through touch, robots can stimulate emotions in a similar way as animals do. The child population was not as accessible as adult population. Moreover, research with children was replete with methodological challenges not relevant to the main purpose of the study (please see section 7.7).

Detailed recruitment criteria and the rationale behind it as well as a report on final recruitment are presented below. Table 8.3 summarizes this information.

Recruitment Criteria and Rationale

The study was advertised through fliers, mailing lists, and online classifieds to recruit normal adult participants, aged 19 to 50. To minimize the amount of extraneous variations, participation was restricted to English native speakers (those whose first learned language is English), preferably from North America, who had no prior experience with the Haptic Creature. The language restriction, in particular, was imposed to account for the nuances

Recruitment	
number of participants	recruited: 52
	analysed: 38
inclusion-exclusion criteria	normal adults (between 19 - 50 years of age)
	native English speaker
	no prior experience with the Haptic Creature
method of recruitment	fliers, mailing lists, online classifiers
Demographics	
gender mixture	all women
age	range ($min - max$): $19 - 45$
	distribution ($mean \pm std$): 23.8 ± 6.6
attitude toward pets (PAS score)	range ($min - max$): $58 - 117$
	distribution ($mean \pm std$): 97.6 ± 12.3

Table 8.3: Study 2 - summary of participants' information. Not the data for all participants were used in the final analysis (For more details please see section 8.5.1). The values reported in this table (ranges, means, and standard deviations) are based on 38 participants whose data was valid for analysis.

of interpreting instructions for self-report scales (which were prepared in English) and to facilitate the subjective expression of emotions on those scales. No prior screening was done to evaluate participants' mental health state or language proficiency. However, their participation in previous experiments was checked based on their names and email contacts.

Recruitment Report

52 participants, all women, were recruited for the study, however, data for 38 of them was valid for analysis (please see Section 8.5.1 for more details). The recruited pool was quite young (range = 19 - 45, Mean = 23.8, standard deviation = 6.6)[18] because advertisements were mostly by means more accessible to the campus community.

It was very difficult to recruit anything close to a gender-balanced pool due to interest in the subject matter, so we chose to focus on women for this

[18] These values and all the other ones reported here are based on 38 participants whose data was valid for analysis.

study so as to generate more conclusive results for the sample[19]. This single-gender sample does not capture the full variability of the target population. Consequently, the results are not generalizable to a wider group. However, the generalizability doesn't seem unlikely since previous investigations has shown that interpretations of the Creature's expressions are independent of gender [96].

Attitude toward pets measured by Pet Attitude Scale (PAS) [59] showed high interest in animals among participants (range = 58 - 117, Mean = 97.6, standard deviation = 12.3). This was not unexpected given the voluntary participation; it is more likely for those interested in animals to have had enough motivations to participate in a study with a "furry robot" as it was described in the recruitment documents (Appendix D).

8.4.2 Stimuli

As discussed earlier in Section 8.3, tactile interaction with the Haptic Creature can be decomposed into the human's expression/gesture and the robot's expression. As discussed in Section 8.3, for the goal of anxiety reduction, we identified an appropriate form of expression on both sides.

In order to evaluate our design to know if interacting with the Haptic Creature through touch can produce effects similar to that of animals, we fixed the human's expression and changed the robot's expression from a completely inanimate state to a state where it simulated an animal's breathing. While it was also possible to vary human's expressions, we decided not to do so. In our exploration of this untouched interaction design space, we tested one thing and kept others fixed to understand that thing very well. For the same reasons, we did not at this time examine the impact of true interactivity, where the Haptic Creature responds to (i.e. alters its behaviour) the humans touch. The robots pre-programmed motion did not change during its "active" trials.

We asked participants to perform a two-hand stroking gesture (rationale discussed in 8.3.1) as a compromise between complete subject freedom, and a consistent, experimentally tractable movement that has been found to be reasonably natural; stroking was the most likely gesture that participants chose overall when interacting with the Haptic Creature [97], suggesting it is generally a natural choice.

[19]Although adult male participants did not show much of interest in the study, we have received strong interest from young and adolescent boys in the Haptic Creature. Therefore, we do not have a reason to anticipate a similar kind of participation bias with child participants.

The Haptic Creature off (no expression) and the Haptic Creature breathing at the constant rate of 20 breaths per minute constituted the variety of robot's expressions (see Section 8.3.2 for the rationale on the choice of breathing characteristics).

Contributor	***Contribution***
participant	feeling the breathing with one hand
	stroking with the other hand
robot	off in inactive trials
	breathing at 15 $^{\text{breath/min}}$ in active trials

Table 8.4: Study 2 - summary of human and robot pre-defined contributions to interaction.

Keeping it on their laps, participants interacted with the Haptic Creature with one hand fixed on the side of the robot's back to feel the breathing and the other hand stroking over its body. In active trials, the robot displayed the breathing expression while in inactive trials it was off. Table 8.4 summarizes this information.

8.4.3 Measures

Two types of measurements captured participants' emotional experience: subjective self-reports and objective biometrics. Each of these measures informed of emotional experience at a different level providing a deeper understanding about the characteristics of emotional response to the interaction (please see Chapter 4.1 for a discussion on manifestations of emotion).

The criteria for the selection of specific self-report scales or biometric measures and the logistics of their collection are described in the subsequent sections. Table 8.5 provides a summary of this information for a quick review.

Self-reports

As described earlier in Section 8.2, the goal of the study was to characterize the emotional influence of the tactile interaction with the Haptic Creature and examine whether that influence was consistent with a state of increased relaxation. Therefore, a measure was required to obtain the general emotional response (in terms of valence, arousal, and dominance) and another to more specifically evaluate the level of anxiety. Both of the selected measures

Measure	***What is Measured?***	***Metrics***
Self-reports - after each course of interaction		
SAM	general emotional response; localizing the response on Russell's affect circumplex	valence
		arousal
		dominance
STAI-6	anxiety level (level of comfort)	reduced 6-item scale
Biometrics - during each course of interaction		
respiration signal	autonomic nervous system (ANS) response	rate (respiration rate)
heart signal	ANS response	rate (heart rate)
GSR signal	ANS response	level (GSR level)

Table 8.5: Study 2 - summary of measures.

should be valid for measurements as close as three minutes apart which is the estimated duration between two consecutive measurements in our study. Both of the selected measures should satisfy the general assessment criteria described in 4.3, i.e. they should be valid for measurements as short as threes minutes apart.

Self-Assessment Manikin (SAM) scales of valence, arousal, and dominance were used to evaluate general emotional response. Measures of valence and arousal localized the emotional response on Russell's affect circumplex while the dominance scale provided additional information to distinguish emotions falling closely in the circumplex regions (for a comprehensive review on emotion assessment instruments please see Section 4.3.1). The psychometric properties of these measures have been evaluated in [15] and meet the required criteria for the study.

A short-form (6-item) state scale of State-Trait Anxiety Inventory (STAI), from now on referred to as STAI-6, was used to record the subjective levels of anxiety. While producing scores similar to the full-form of the STAI, STAI-6 is faster to administer. The reliability and validity of this measure has been evaluated in [54]. As related to the criteria for this study, the test has acceptable concurrent validity.

SAM and STAI-6 scales were administered after each trial of the study, i.e. either after a baseline collection or after an interaction period with the Creature in an inactive or active trial. The approximate time between each two consecutive administrations was three minutes. Both scales were computerized and presented to participants on a screen, where they could enter their answers by mouse clicks.

Biometrics

As unobtrusive means of assessment that can be obtained without interrupting the natural flow of the interaction, three biological signals were collected: heart electrical activity signal, respiration signal, and galvanic skin response signal.

Out of these signals, three features were extracted as indicators of autonomic nervous system activity during the interaction: GSR level (GSR-L), heart rate (HR), and respiration rate (RR) (please refer to Section 4.1.2 for a review on autonomic nervous system indexes of emotions). These features were calculated for the whole trial and thus do not represent the transient characteristics of the response, i.e. they do not capture the temporal characteristics of the response[20]. As suggested by the literature, all of the above measures, when increase, indicate anxiety (see Section 4.3.2 for more details).

All the biological signals were collected continuously during a trial in the study. As will be explained in more details in Section 8.4.6 and 8.5.2, each trial lasted for about 135 seconds of which the first 60-second period was devoted to neutralizing. The last 60 seconds was used for extracting the three features above while accounting for the delays of manual synchronization of data collection with the onset and end of trials (more details in 8.5.2). Thought Technology (TT) respiration, ECG, BVP, and GSR sensors recorded respiration, heart, and GSR signals respectively, i.e. four data files were generated for every participant in each trial.

8.4.4 Experiment Design

We planned the study to examine if the interaction that we designed could change a user's emotional state. We envisioned two trials in our study. In one, the Haptic Creature simulated an animal's breathing (active trial) while in the other one it was in an inanimate state (inactive trial).

In our study, we also incorporated an initial baseline collection to account for the possible effects of participants' mood in their ratings on subjective measures and the idiosyncrasies in the biometric measures. A second baseline was also included at the end to explore the overall reaction to the interaction with the robot.

[20] The temporal characteristics can be separately investigated for more in-depth understanding of the emotional response.

In our within-subject experimental design, we collected four self-reported measures of emotional experience at the end of each trial for each participant. Additionally, respiration, galvanic skin response, heart electrical activity, and blood volume pulse signals were continuously captured during a trial. From these signals, three[21] biometric measures were extracted to represent the emotional experience for the whole duration of a trial (a single value for each trial).

To thoroughly clarify the steps of the study for participants and thus avoiding any odds that would inflict the subjective and physiological responses, we included a practice session into our experimental design which was identical to the main study session except that it was shorter.

The practice/study session was started by a baseline trial and followed by either inactive or active trials. During baseline the Haptic Creature was off participants' sight and was then handed in for inactive/active trials. The order of presentation for active and inactive was decided randomly following a fully counter-balanced assignment criteria.

8.4.5 Setup

The details for the study setup will be explained in the following sections (Figure 8.2 provides an overview).

Arrangement

Figure 8.2 illustrates the arrangement of the study room. The facilitator was present throughout the study to administer the experiment. However, a partition separated her from participants to minimize the potential impact.

On one side of the partition, the facilitator was setup with two computers: one to control the data collection and to direct robot's behaviours; the other to control the flow of the trials and to communicate with participants. On the other side of the partition, participants faced a screen where they received prompts on and completed the self-report questions using a mouse.

Since environmental factors affect emotional experiences [69], utmost care was taken to make the setup as friendly as possible to help participants feel comfortable and natural in the study environment. Any source of strong emotional stimulation could have masked the emotional impact of interest. Providing participants with a comfortable seat and making the

[21]Heart electrical activity and blood volume pulse signals provide similar information. They back up each other; if one of them fails the data captured by the other can be used.

study room more bright by using light colors for equipment were among the considerations with this regard.

Although participants were explicitly asked to interact with the Haptic Creature mainly through touch, a horizontal rigid sheet extended the desk over the participant's lap to occlude their view of the Creature as they interacted with it (Figure 8.2).

During the study, the Haptic Creature was either placed on its cushion to the right of the participants and out of their sight (during baseline) or on participants' laps while they were interacting with it (during inactive or active trials). The long power and USB cables were contained within robot's tubular furry tail where visible to participants.

Equipment

Thought Technology (TT) respiration, ECG, BVP, and GSR sensors were used at appropriate body sites for collecting the corresponding signals (see Section D for details on sensor placement). Signals were communicated to the TT ProComp Infiniti® encoder [3] which transferred them to the host computer (Intel laptop with 2.4 GHz processor running Windows 7) via optical cable and USB for a later post processing.

A 18.1" LCD monitor was used as a communication medium to provide participants with prompts throughout the experiment and to present them the self-report questions of emotional experience. A computer (Intel laptop with 2.4 GHz processor running Windows 7) controlled this communication. Please note that two different computers were used in the study; one for data collection and robot control and the other for communication with participants and acquiring their self-reports.

The version of the Haptic Creature utilized in this study, Baker, had only the breathing mechanism functioning. The most updated description of its structure and available functioning can be found in [10].

A video camera was constantly recording participant's upper torso and face for two reasons: (1) to verify that participants correctly follow the study instructions (Section 8.5.1), (2) to have another source for evaluating emotional experience (i.e. facial expressions) to triangulate with other sources.

Software Apparatus

At 175 ms, a custom C++ program gathered and logged sensor data and controlled the breathing of the Haptic Creature. Please refer to Section 6.2

Figure 8.2: Study 2 - room setup. 1. facilitator's seat: during the trials the seat was completely behind the partition and invisible to the participant. 2. participant's seat. 3. office partition: this partition separated out the facilitator and the participant. 4. a white thick sheet of paper: this sheet covered the robot when participants kept it on their laps to minimize the possibility of visual interaction with the Haptic Creature. 5. participant's screen. 6. video camera. 7. Though Technology encoder. 8. the Haptic Creature and its cushion: during the baseline trials robot together with the cushion were placed on the ground out of participant's sight.

for more details about the program. On a different machine, as mentioned earlier, another custom program controlled the flow of trials by managing the steps and communicating the appropriate instructions to participants via prompts on a screen. It also collected participants self-reports for further analysis.

Ideally the two programs should be automatically synchronized so the data collection starts when a trial starts and it continues until the trial continues. Unfortunately due to time limits for the thesis work, the synchronization was not implemented and the task was done manually by the facilitator. However, this has not affected the results by using appropriate parts of data (for more detail see Section 8.5.2).

8.4.6 Procedure

Participants were first introduced to the goal of the study and received instructions about the measures and steps they ought to expect in the study. They were then walked through all the possible trials during the practice session to became familiar with the study. Next, participants provided their demographic information and then moved on to the study session. At the end they were interviewed.

Every action taken and every instruction/prompt given during the study was evaluated against the following criteria to make sure the study would yield valid and reliable outcomes (Please refer to chapter D for the facilitator's scripts as well as the instructions administered to participants):

- Providing a setting, as natural as possible, for examining the hypotheses
- Clarifying all the steps of the study for participants through thorough instructions
- Avoiding any bias in response induced by instructions (Hawthorne's effect)
- Collecting noise-free data
- Applying an effective stimulation at an appropriate time
- Measuring the response at the right time (i.e. when the stimulation exists; neither missing nor over collecting data)
- Making stimulation and measurement consistent (both between and within participants) to have deterministic effects that can be attributed to the stimulation
- Controlling for other factors that can potentially change the emotional state (audio or visual stimulations as well as environmental factors).

A single session required 45-60 minutes. In the following sections procedures for each of the main parts of the study will be described. A summary of this information can be found in Table 8.6.

Step	***Time***	***Description***	***Considerations***
introduction	~7^{min}	high level overview of the goals and steps of the study	
demonstration	~10^{min}	familiarization with scales, sensors, the Haptic Creature and interaction with it, study trials; considerations in the study	
Practise session			
baseline	20^{sec} 20^{sec}	neutralizing baseline	
robot inactive	20^{sec} 20^{sec}	neutralizing interaction	counter- balanced with active
robot active	20^{sec} 20^{sec}	neutralizing interaction	counter- balanced with inactive
demographics questionnaire	~8^{min}	age, gender, attitudes towards pets	
Study session			
baseline 1	60^{sec} 75^{sec}	neutralizing baseline	
robot inactive	60^{sec} 75^{sec}	neutralizing interaction	counter- balanced with active
robot active	60^{sec} 75^{sec}	neutralizing interaction	counter- balanced with inactive
baseline 2	60^{sec} 75^{sec}	neutralizing baseline	
interview	~5^{min}	overall response to the interaction, thoughts, and suggestions	

Table 8.6: Study 2 - summary of procedures.

Introduction to the Study

Figure 8.2 displays the room arrangement at the beginning of the study. Upon participants' arrival, they were directed through the setup. Participants then provided their consent to participate. Next, the facilitator explained the goals of the study at the very high level. While it was important to make the steps clear, instructions should not have directed participants to a specific response.

The general structure of the study, i.e. trials, robot's expressions and measurements, was also described. When appropriate, written instructions were provided (details in Appendix D).

Demonstration

Following the introduction, the intended interaction was fully demonstrated to make sure that the stimulation is consistent across participants. Detailed instructions were provided for stroking interaction: the speed and pressure of the human's gestures (as described in [97]), the orientation of the Haptic Creature on the laps, and the positioning of hands on it. Within the defined interaction, adjustments were made according to participants' preferences (e.g. whether they preferred to stroke with their dominant hand or non-dominant hand).

Next, participants were hooked-up with the sensors and received a thorough description of each trial. The considerations regarding the study steps and data collection were also clarified to avoid extra noise in the data. More specifically participants were asked to minimize their visual contact with the Haptic Creature and to avoid unnecessary movements and speaking while data collection was in progress (details covered in chapter D).

Practice Session

To get acquainted with the steps, participants walked through a short version of all different trials: baseline, inactive, and active. It was important to reduce the odds of unexpected cases during the study session since this could have distorted the physiological measures and even the self-reported emotional experience. The short practice session could also reduce the effects associated with the novelty of the platform (e.g. the initial arousal resulting from not knowing what the robot can do).

Each trial started with a neutralizing period during which participants watched a video[22] to move them toward a neutral emotional state. The neutralizing video was planned to eliminate the possible effects from one trial into the next, which ensured a consistent stimulation across trials. For both inactive and active trial, the Haptic Creature was on the participants' laps, however, it was off all the time. To ensure minimal interaction, participants were instructed to keep their hands on their sides and not in contact with the robot. For the sake of consistency, this was enforced during the baseline as well.

Following the neutralizing period, either the baseline period[23] or interaction period[24] started. During both of these periods participants' screen was off (blank black screen). At the beginning of the interaction period, participants were prompted on the screen to put their hands on the robot and start stroking. For an active trial, the Creature was turned on at the beginning of the interaction period and remained active until participants entered their self-reports.

Physiological signals were collected from the onset of the neutralizing period to the end of the baseline/interaction period. However, the moments at which the neutralizing period finished and baseline or interaction period started were marked as accurately as possible by the facilitator based on her observation of study progress. At the end of each trial participants reported their emotional experience on the provided scales (SAM and STAI-6).

Throughout the practice session, participants wore a set of ear muffs to mask the noise generated by the breathing mechanism working (they had the ear muffs throughout all the session for the sake of consistency although it was really needed only in active trial). The length of both neutralizing and baseline/interaction periods during practice session was set to 20 seconds to keep the study short and to prevent any response saturation.

Demographic Questionnaire

Following the practice session, a questionnaire for acquiring participants demographic information as related to the study was administered (see chapter D). The resulted time gap would help participants to become more comfortable in the environment. Also, it would let the effects of previous exposure to the interaction wear off before the starting of the main study session.

[22]A square randomly moving on the screen and changing colors. This video was designed according to the reports in [38].

[23]For baseline trial

[24]For inactive or active trial

Study Session

The Study session was almost identical to the practice session except for the fact that it was longer and was followed by a second baseline collection.

The neutralizing period lasted for 60 seconds while both the baseline and interaction periods lasted for 75 seconds. These times were long enough to ensure that manifestations of emotion would appear at different levels while they were short enough that participants were not bored. The upper limit of 75 seconds for the interaction period was decided through pilot studies. The lower limit of 60 seconds was chosen because the valid assessment of some biometrics requires at least 60 seconds of data collection (see section A for details).

Interview

Following the study session, sensors were removed and participants were interviewed within a semi-structured setting about their experience interacting with the Haptic Creature (questions can be found in Appendix D). Among other things, they were asked to describe their feelings during the interaction. This was important to fill in the gaps where self-reports and biometrics cannot fully capture the situation. Moreover, participants' descriptions would provide insights on how they saw the interaction affecting them. This information can probably direct the next steps of the interaction design.

8.5 Analysis

Data collected during the study session were analysed through several steps. First, the validity of the data for further analysis was verified. Following that, only for physiological data, appropriate chunks were extracted for further processing and feature calculation. Finally, statistical analysis was conducted to evaluate the hypothesis. The details for each of these steps are explained below.

8.5.1 Data Verification

In the data verification process we screened out invalid data points. Two main stages can be defined in this process. In the first stage we decided whose data was valid for further analysis (coarse exclusion) while in the second stage we verified different sources of data for each participant (detailed exclusion). This process was necessary to make sure that the data we were relying on captured the intended stimulation; not less, not more. The facilitator performed all the levels of verification while she was blind to participants' responses; she was not aware of participant's self-reports or biometric measures while examining videos or raw physiological signals.

The subsequent sections detail the selection process. Table 8.7 summarizes this information.

Criteria	#	***Associated ID's***	***Source***
Study-level Verification			
visual contact	4	ID19, ID31, ID41, ID42	video records
falling asleep	3	ID03, ID34, ID35	video records
equipment failures	5	ID09, ID10, ID12, ID36, ID43	facilitator's notes
dishonesty	2	ID27, ID48	personal information
Participant-level Verification			
noisy respiration signal	1	ID14	RESPIRATION files
noisy heart signal	8	ID01, ID02, ID11, ID45, ID47, ID49, ID50, ID51	ECG files
noisy GSR signal	2	ID15, ID51	GSR files

Table 8.7: Study 2 - summary of data selection.

Coarse Exclusion

Video records of participants during the study were reviewed to make sure that every participant had followed the instructions, i.e. to make sure that they performed the stroking gesture without looking at the robot and that they did not fall asleep during any of the trials. Data of four participants were dropped because they had visual contact with the robot during the interaction. Another three participants were dropped because participants either fell asleep (two participants) or were very sleepy throughout the interaction (one participant).

Although no prior screening was done to check participants' eligibility for the study, the personal information they had provided prior to their participation was matched with that they provided after as a way to verify their qualification for the study. Unfortunately, it was found that two participants were dishonest about their eligibility so their data were dropped[25].

Data of four participants were dropped because of the robot's failure to breathe during the active trial. Another data point was removed from further analysis because of outside disruptions.

After all this process, 38 valid data points remained for further verification (at participant-level) and analysis.

Detailed Exclusion

Self-reports were valid for all the data points which passed the coarse exclusion verification. So the detailed exclusion verification only dealt with the physiological signals.

Data records of respiration, heart, and galvanic skin response (GSR) signals during baseline/interaction periods of study session were visually checked to make sure the noise levels fall within acceptable ranges for feature extraction procedures to reliably calculate features [26][27]. Total number of 608 files for 38 participants were checked[28].

After the visual check, data for one participant was removed from further respiration analysis (i.e. 37 data records were used for extracting respiration features). Eight of the original 38 data records were eliminated from further feature extraction of heart signal[29]. Visual inspection of GSR signals resulted in the elimination of two out of 38. Please note that at the detailed exclusion level, the elimination of one source of data for a participant (e.g. respiration) did not cause the elimination of other sources of data

[25] One had previously participated in a study with the Haptic Creature and had used a different email address to contact the facilitator, however the email address she provided at the end of the study matched an earlier one. Another one described herself as 18 years old on the demographic questionnaire, an age which our ethics approval excluded.

[26] For respiration and heart signals, the calculated features were checked on the raw data. If the feature extraction algorithms' accuracy in beat detection was not acceptable, the data file was dropped. That is to say that if breath counts (for respiration signal) or detected beats (for heart signal) were far from accurate, the data was dropped .

[27] If the record for a specific signal was noisy in any of baseline 1, inactive or active trials, all the records of that signal were dropped to avoid the complications of dealing with missing data in statistical analysis. For example if for participant ID00, the respiration signal was noisy only in baseline 1, the respiration data for that participant was completely discarded for further analysis

[28] There are 4 sensor files per each participant: RESPIRATION, GSR, ECG, BVP; each participant completed 4 trials in the study session: baseline 1, inactive or active, and baseline 2. So total number of $38 \times 4 \times 4 = 608$ files needed to be reviewed.

[29] only based on ECG data. Although both BVP and ECG files were checked, the decisions were only made based on ECG files for the sake of consistency

for that participant provided that different sources were analysed independently. As as example, assume that IDXX's respiration file during inactive trial is corrupted. We drop all IDXX's respiration files during baselines and active trials. However, we keep ECG, BVP, and GSR files if they meet the required quality for further processing.

8.5.2 Physiological Data Selection

The last 60 seconds of the baseline/interaction period were used for extracting physiological features. To account for the facilitator's delay in synchronizing data collection at the end of each trial, the last second of data files were discarded and were not included in the 60-second window mentioned above.

The utilization of the last 60-second window (of the 75-second data collection) for analysis ensures an equal length of data used for feature extraction which is important when performing statistical analysis [13]. Moreover, there is a possibility of transient response at the onset of the emotional stimuli [41], which is not of interest in the current study. Given the short duration of the transition discarding the first 15 seconds of data would be more than enough to capture the steady state response only.

8.5.3 Statistical Analysis

To examine the effects of the interaction with the robot under the inactive and active trials, the first baseline collection was used to offset each participant's data[30]. Self-report data were offset to account for the potential distortion in participants' ratings by their mood; physiological data were offset to account for the idiosyncrasies in individuals' responses [65][31]. The statistical tests were then performed on the offset data that reflected the change with respect to the baseline (i.e. all the offset scores were computed as $baseline - rawvalue$).

Given the within-subject design of the study, dependent sample t-test was used to compare the offset data in inactive and active trials. Since the sample sizes in both groups are equal[32] and larger than 20 [37], the statistical

[30]the offset will be illustrated by a "Δ"sign.

[31]Please note that both of these offsets will be cancelled out in the formulas of the specific statistical test used here; however, it is a good practice to perform the offset.

[32]See "Detailed Exclusion"under 8.5.1: by "equal"we mean that the full analysed dataset contains the same number of observations for a given sensor (e.g. GSR) for all conditions, since for a given participant, an observation for that sensor corrupted for one condition is also removed for that participants' other conditions. However, each sensor

test is robust to the violation of both normality and homogeneity of variance assumptions. Therefore, none of these were checked for the data.

Since seven metrics are collected in the study (four self-report metrics and three biometrics), Bonferroni correction was applied to the α-level of 0.05 for the statistical tests to account for the problem of capitalizing on chance [37]. Therefore, all the metrics are tested against 0.007 significance level.

8.6 Results

Table 8.8 summarizes the descriptive statistics of the raw and offset data. Table 8.9 represents the result of t-test analysis. In tables $\Delta_{Inactive}$, Δ_{Active}, and Δ respectively represent $baseline - inactive$, $baseline - active$, and $\Delta_{Inactive} - \Delta_{Active}$. Δ values can also be derived as $active - inactive$. Therefore a positive Δ means active value is larger than the inactive one, while a negative Δ means the opposite way. Figures 8.3, and 8.4 to 8.7 visualize means for non-offset (or absolute) values of self-reports and biometrics. SPSS 11.5.0 has generated descriptive and t statistics as well as the graphs, while G*Power 3.2.1 has generated the effect size metrics and power.

In summary, among the seven measures analysed for the study (four self-reported and three biometrics), four showed a statistically significant difference between inactive and active trials. In the active trial when the robot was breathing, valence (SAM-V) significantly increased ($t(37) = 4.88$, $p < 0.001, 99.3\% CI = [0.45, 1.71], d = 0.79$), state anxiety (STAI-6) significantly decreased ($t(37) = 3.45$, $p = 0.001$, $99.3\%\ CI = [-2.16, -0.20]$, $d = 0.56$), heart rate (HR) significantly decreased ($t(29) = -2.95, p = 0.006, 99.3\% CI = [-2.47, -0.02]$, $d = 0.54$), and breathing rate (RR) significantly decreased ($t(36) = -3.00$, $p = 0.005$, $99.3\%\ CI = [-2.16, -0.20]$, $d = 0.49$). These results as well as their implications will be discussed in the next section.

8.7 Discussion

The discussion is organized in three sections. Calling back the hypotheses, in the first section, we examine and interpret our results in light of our hypotheses. In the second section, we discuss the implications of our findings. We then conclude the section by considerations regarding the generalizability of results.

may have a different number of observations in the full analysed dataset, due to detailed exclusion.

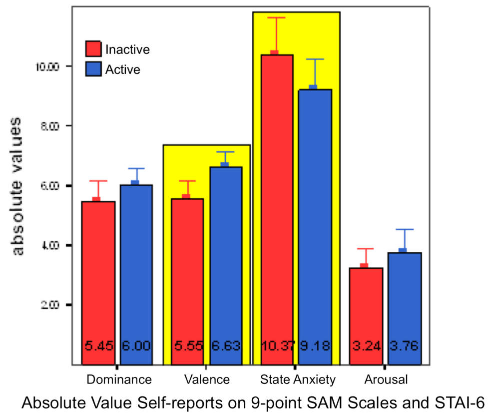
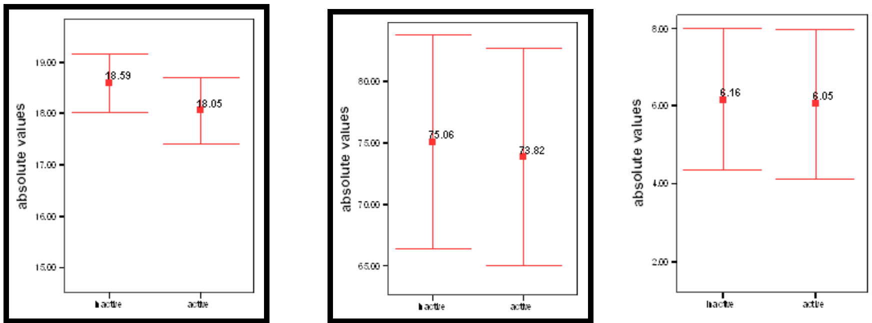


Figure 8.3: Study 2 - means for non-offset (or absolute) values of our four self-report measures for inactive and active trials for 38 valid data points. The number at the bottom of each bar shows the mean value represented by that bar. Error bars illustrate 99.3% confidence intervals. Red bars represent inactive trials while blue bars represent active trials. From the left, paired bars respectively depict means for SAM-D (dominance), SAM-V (valence), STAI-6 (state anxiety), and SAM-A (arousal). The bars surrounded by a yellow box represent significant difference.

8.7.1 Outcomes: Impact of the Interaction on the Emotional Response Measures

Consistent with our hypothesis, subjective and biometric measures of valence and anxiety changed indicating more relaxed emotional states (i.e. valence became more positive and anxiety went down) when participants were stroking the robot and it was breathing at rest. The change is best associated with the robot's behaviour which altered from not breathing (inactive) to breathing (active). The association, however, cannot yet be interpreted as causation because robot's expressions and participant's expressions may be both necessary for the effect to take place. Further experiments are required to examine the causality by looking into the main effects of human expressions and robot expressions as well as the effect of their combination.

It is worth noting that not only are the results significant, but also of practical value. We direct reader's attention to effect size metrics which show large to very large effects for all the measures that have turned out significant [37]. Since effect sizes are independent of the sample size, we can



(a) Respiration rate (bpm) for 37 valid data points

(b) Heart rate (bpm) for 30 valid data points

(c) GSR level (μSiemens) for 36 valid data points

Figure 8.4: Study 2 - Means of non-offset (or absolute) values of our three biometric measures in inactive and active trials (only during interaction period). Error bars illustrate 99.3% confidence intervals. The bars to the left represents the inactive trials while the ones on the right represents active trials

argue that the significance is not purely the product of the relatively large sample size of our study.

One might argue that the above changes are small in magnitude compared to exercise-related changes. To answer the argument we should first notice that there is no exercise component here; subjects are at rest and the changes are only explained by affective influences. Additionally, the stimuli were subtle and participants usually started at a neutral emotional state (although not controlled). So the fact that we saw any change is of great interest. However, further investigation is needed to corroborate this with magnitudes of physiological changes deemed practically important in clinical practice.

In the next sections we interpret the relation between our measures and the underlying response systems to better understand the characteristics of the emotional transition caused by the interaction. Additionally, we relate the results to our understanding of anxiety. We also illustrate the connection between emotional response and the robot's behaviours. From these discussion we infer two main points: (1) Our measures are nicely lined up indicating the interaction increases valence without affecting arousal (the first two sections). (2) The presence of the robot does not seem to produce a specific self-reported emotional response (as opposed to autonomic responses brought about by handling the robot) while its breathing makes people happier and more relaxed (the third section).

Significance and Insignificance Are Both Meaningful

When discussing the results it is important to consider both the measures that turn out significant and those that do not. Measures of arousal, dominance, and GSR-L were not significant. Is there any meaning to that? In other words, is there any explanation that describes both the significant and insignificant results?

With respect to the dominance metric we suspect that by increasing the sample size, there are high chances of getting this metric as significant in a direction consistent with anxiety reduction. We support our argument by pointing to the dominance effect size, which is medium (actually close to large), and the low power of its statistical test.

Regarding the GSR-L metric, there is the possibility that in contact with the robot's fur, participants' palm and fingers may have become sweaty and this may have masked the variations associated with the emotional response. However, it is very unlikely that it was the case; the resolution of measurements was set high to capture low amplitude changes. Considering this along with the fact that the sweaty palms were equally likely to happen in both inactive and active trials, the variations caused by the emotional response should have been detected.

Earlier in 4.1.2 we noted that GSR-L is linearly associated with levels of arousal. Unchanged GSR-L and subjective arousal points to an interesting aspect of the interaction: the interaction does not affect the arousal component of the emotional response. To complete the picture also consider the fact that heart rate decreases when the valence increases. Therefore, it can be concluded that the interaction has affected valence without affecting arousal.

To obtain more insights about the nature of the emotional response, it is helpful to examine the underlying response systems. At the behavioural level, unchanged arousal and increased valence suggest that the interaction has successfully activated the appetitive response system that yields to approach behaviours [33].

[33] Definition of appetitive response systems (extracted from [71] page 44): "... complex behaviours can be reduced to combinations of two distinct classes of action tendencies- approach and avoidance... . The theories hold that appetitive motivation and the approach behaviours that follow from it are managed by what various theorists termed behavioural activation system, ... This is a regulatory system that organizes the approach of diverse

At the autonomous functioning level, it has been shown that galvanic skin response levels are controlled by the activation of sympathetic system while heart rate is controlled by the activation of both or either of sympathetic and parasympathetic systems [47]. Considering the results of the study, it can be inferred that the interaction has not stimulated the sympathetic system while it has activated the parasympathetic system. This is very interesting because the activation of parasympathetic branch of the autonomic nervous system is associated with the relaxation response while the activation of the sympathetic branch is associated with stress response [67]. In other words, not only at the experiential level but also at the autonomic functioning level, the results are consistent and indicate improved relaxation.

The fact that the measures of different response systems are nicely aligned and all indicative of calmer emotions make a stronger case for our conclusions. Moreover, it supports the appropriate choice of measures which have successfully addressed the requirements of the study.

Measures Are Consistent

When interpreting the results it is important to consider the consistency among different measures. In the previous section while examining the underlying mechanisms, we illustrated the consistency between self-reports and biometrics. Next we look into the consistencies among each category of measures separately.

Taking a dimensional view, anxiety can be defined as an emotional state that is high on arousal component and low (i.e. negative) on valence. Considering this definition for anxiety, one might suspect that there is an inconsistency because the measure of arousal is unchanged while STAI-6 which indexes anxiety has decreased; lowered anxiety matches the increased valence, however, it does not match the unchanged arousal.

In fact, it is expected to see lowered arousal with lowered anxiety. Is there a reasonable explanation for this observation? Or does the inconsistency signal a flaw in methodology?

In response to these questions we refer back to Izard's description of emotion patterning for anxiety introduced in section 4.2. In this discrete view of anxiety, it is a complex and dynamic patterning of responses. In other words, it has several components and does not always happen in the same way. In one situation the components with negative valence are more

incentives."

salient; in another situation components with high arousal are more salient. Similarly, the absence of anxiety can be more significant on one dimension (valence or arousal) than another. Therefore, it is not easily possible to conclude that there is an inconsistency.

The above case exemplifies the importance of gathering both the dimensional and discrete measures when working on complex emotional responses such as anxiety. Triangulating the responses from the two perspectives provides a better understanding of the phenomenon.

Another concern with regard to the consistency among self-report measures goes to the relation between valence and arousal. In their article, Bradley, Codispoti, Cuthbert, and Lang [17] show that emotional response on coordinates of valence and arousal has a boomerang shape (figure 8.8), i.e. not all the combinations of valence and arousal usually co-occur in an emotional response. According to the boomerang distribution of emotions in the affect space, we should have seen an increased arousal with the increased valence in our results. However, this did not happen. Now the question is: why? A possible explanation is that the boomerang association between valence and arousal is more salient for very extreme values of valence. For medium values, the correspondence is not as strong. Therefore, having increased valence and unchanged arousal is not necessarily a sign of inconsistency.

The consistency among the measures of autonomic nervous system activity is easier to identify. Reduction in both heart rate and respiration rate indicates increased valence and more relaxed emotional states [55].

Characteristics of the Emotional Response: the Robot's Breathing Makes a Difference

In the following paragraphs, we examine the absolute values of the measures and try to interpret those to gain more insights about the characteristics of the emotional reactions to the interaction.

Within self-reports, we see neutral valence, relatively low arousal, neutral dominance, and relatively low anxiety during baseline and inactive conditions. In active condition, we see relatively high valence, relatively low arousal, relatively high dominance, and relatively low anxiety[34].

These values suggest that participants were feeling quite neutral during baseline, i.e. our baseline sample is close to the real baseline where people are not experiencing a specific emotion. It is also worth noting that measures of

[34]For SAM scales, the reference is the mid-point of the scales (i.e. value 5), while for the STAI-6 measure the reference is the minimum score of 6.

inactive trials are very close to those of baseline for all subjective measures. This indicates that, when perceived as a stuffed toy, stroking the Haptic Creature does not do anything. It neither improves nor bothers. It is almost like *nothing*.

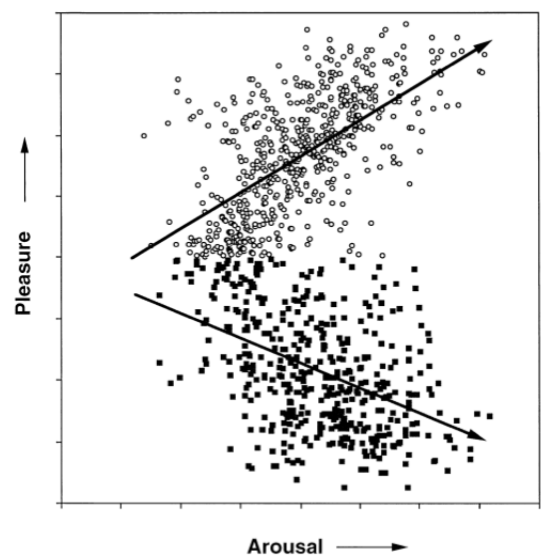


Figure 8.8: Archetypical boomerang distribution of affect (reprinted with permission from [17]. In the picture, valence (pleasure) is depicted on the vertical axis while arousal is depicted on the horizontal axis. Each data point corresponds to the mean ratings of valence and arousal for an emotional stimuli. As can be seen, points fall into a non-monotonic pattern resembling a boomerang shape.

Considering the biometrics, baseline samples of all the measures fall within the normal ranges for adults. Once again this suggests that our baseline sample is close to the true baseline. On the other hand during inactive and active trials, the biometric values are not within the normal ranges any more. In fact, they have all increased. The increased functioning of autonomic nervous systems, indicated by the elevated measures, is either to accommodate the act of stroking, or is a response to robot's presence. The former is more probable according to the self reports.

The above case illustrates the importance of considering the users' expressions in the interpretation of biometrics. In the real application of TAMER, the control of the robot's behaviours should not solely rely on the absolute values of the biometrics. The contextual factors should be considered when interpreting the metrics.

8.7.2 Implications

According to the results and interpretations above, it seems that an emotional transition happens as a result of the interaction with the Haptic Creature when the robot is breathing, symmetrically and constantly on the human's laps, while the human is stroking the robot. The transition is more saliently reflected on measures of valence and anxiety.

The Robot's Stimulation Efficacy and the Human's Mirrored Response

The findings imply the capability of the Haptic Creature to cause the desired emotional transition. Although it may not be generalizable, the transition is toward the state that the robot expresses. Aggregating this finding with the reports in [97] suggests that humans not only expect that the robot mirrors their emotional state, but also themselves mirror the robot's emotional state naturally, with no instruction.

A closer look at the robot's expressions and the resulting emotional response reveals interesting associations. As reported in [96], the robot's breathing rate is designed to communicate arousal (faster breathing: higher arousal), while breathing symmetry is intended for the communication of valence (asymmetric breathing: negative valence). In the study reported here, the breathing was slow and symmetric. Correspondingly, the resulting human's emotional state was low on arousal and positive on valence. This is especially interesting for further interaction design with the Haptic Creature: a targeted emotional transition can be obtained by combining the appropriate rendering parameters.

Learning Explains the Transition

As mentioned above, it seems that there is a direct association between the human's emotional state and that communicated by the robot; the transition is happening toward the state that the robot expresses. Now the question is: what brings about such an association?

According to the values of biometric measures, there is a dearth of evidence that mirroring is happening at the physiological level. In other words, people are not making any direct connection between their physiological functioning and the robot's breathing; the robot's breathing rate is 20 bpm, while at the more relaxed trial, the respiration rate has decreased from 18.5 bpm to about 18 bpm, i.e. it has *diverged* from robot's breathing rate. Therefore, it is more probable that cognitive mechanisms are responsible for such an association and the transition yielding to that.

Assuming that cognition is behind the scene supports the validity of framing TAMER within social cognitive theories for human-animal interaction which is also supported by the consistency of the results with reports of similar interactions with animals. However, further experiments are required to fully verify the idea.

Gathering the above clues, a classical conditioning case explains the observations[35]:

At relaxed emotional states caused by unknown psychological processes (unconditional stimulus) people tend to communicate their state with specific sets of behaviours. In interaction with animals, these human behaviours tend to accompany specific animal behaviours. When this co-occurrence happens repeatedly, the association is learned. Therefore, when animals express the same set of behaviours (conditional stimulus) they produce the effect (i.e. the relaxed emotional state).

Please note that such a mechanism is extremely relevant to TAMER. If the robot can trigger the associations learned with animals, it can activate the same conditioning mechanisms that will eventually help children cope their anxieties.

Approach Behaviours Are Facilitated

In section 8.7.1, we discussed that our results suggest that the interaction with the robot has activated the appetitive response system. This has a very important implication for the application of TAMER for treating anxiety because avoidance and withdrawal behaviours are key to the development and maintenance of anxiety. If the interaction activates a response system that counteracts these behaviours, it has the potential to improve the case of anxiety by changing the mal-adapted behaviours. Further design and experimentation are essential to utilize this potential.

[35] Please note that the presented explanations is more of theorizing for the observed facts. However, it is neither claimed that other explanations are nonexistent, nor that this explanation is the true state of affairs. Further experiments are required to either provide stronger support or deny what is theorized.

Tactile Interaction Is Characterized

Another important outcome of the current study is that it has characterized the effects of tactile interaction in the absence of other factors such as a cognitive task which can particularly impact physiological measures readings.

Guidelines for the Design and Analysis of TAMER User Studies

The discussions in the previous section also have a number of implications in terms of designing user studies and interpreting results.

As shown above, viewing the same phenomenon from different perspectives brings more insights into the phenomenon. In the case of anxiety, it is necessary to thoroughly analyse this complex emotional response because neither does anxiety easily lend itself to dimensional interpretations, nor discrete interpretations draw a full picture of it.

As another guideline, it is important to take the interaction demands into account when interpreting biometrics. The autonomic nervous system activity should support the emotional transition as well as the physical movements involved in the interaction. The changes associated with this process should be taken into account when interpreting the biometric results.

8.7.3 Critiques of Methodology

When generalizing the results of the current study, it is important to consider that these results have been obtained from a single gender population with highly positive attitude towards pets for whom the conditioning case explained above works favourably. Some effects may not be obtained for populations who do not have positive attitude toward pets. Also, the results do not necessarily extend to male population.

Another consideration for interpreting the results of the study is concerned with the emotional transition. Although the study provided strong evidence for the potential of the interaction to cause such a transition, the initial emotional state can also be a factor that impacts the transition. Here, it was only shown that the transition can occur when started off at the baseline condition. Further experimentation is required to be able to claim the same change when starting off a different initial emotional state.

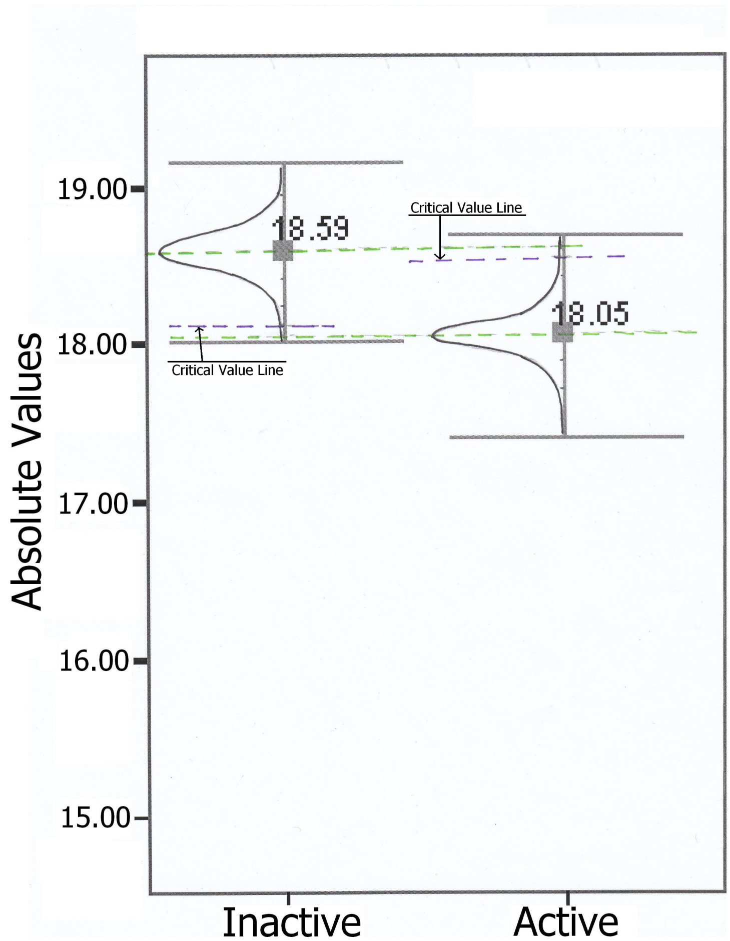


Figure 8.5: Study 2 - sampling distribution shown on top of the sample distribution of non-offset (or absolute) values of respiration rate during inactive and active trials (only during interaction period). Sampling distribution is the semi bell-shaped figure in the picture whereas the sample distribution is shown by error bars. Please note the difference between *sampling* distribution and *sample* distribution: sampling distribution is characterized by sample mean and standard error while sample distribution is characterized by sample mean and standard deviation. The former is the base for statistical analysis on which the violet line represents the critical value. If a sample mean of a trial falls beyond the critical value of the sampling distribution of the other trial, the two means are significantly different. This is the case in the above figure.

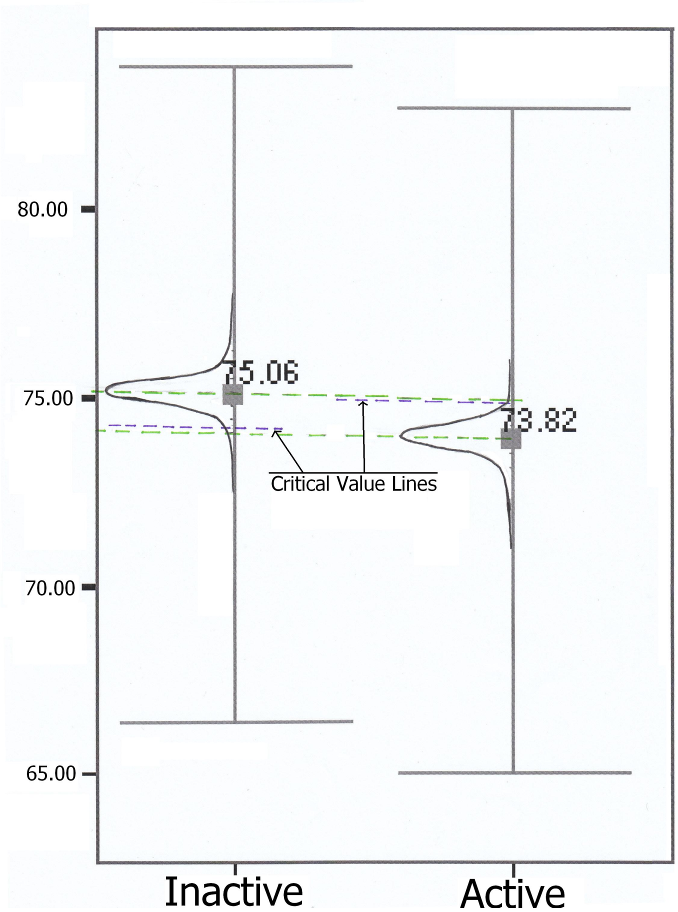


Figure 8.6: Study 2 - sampling distribution shown on top of the sample distribution of non-offset (or absolute) values of heart rate during inactive and active trials (only during interaction period). Sampling distribution is the semi bell-shaped figure in the picture whereas the sample distribution is shown by error bars. Please note the difference between *sampling* distribution and *sample* distribution: sampling distribution is characterized by sample mean and standard error while sample distribution is characterized by sample mean and standard deviation. The former is the base for statistical analysis on which the violet line represents the critical value. If a sample mean of a trial falls beyond the critical value of the sampling distribution of the other trial, the two means are significantly different. This is the case in the above figure.

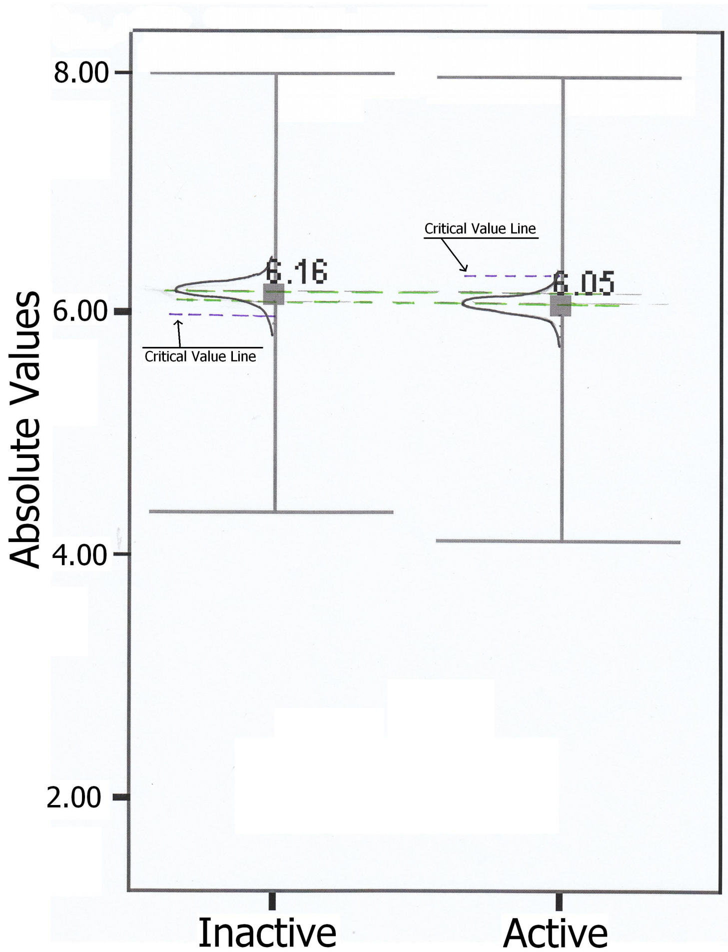


Figure 8.7: Study 2 - sampling distribution shown on top of the sample distribution of non-offset (or absolute) values of galvanic skin response level during inactive and active trials (only during interaction period). Sampling distribution is the semi bell-shaped figure in the picture whereas the sample distribution is shown by error bars. Please note the difference between *sampling* distribution and *sample* distribution: sampling distribution is characterized by sample mean and standard error while sample distribution is characterized by sample mean and standard deviation. The former is the base for statistical analysis on which the violet line represents the critical value. If a sample mean of a trial falls beyond the critical value of the sampling distribution of the other trial, the two means are significantly different. This is *not* the case in the above figure.

Absolute (non-offset) values						
Groups:	Baseline 1		Inactive		Active	
Metrics:	mean	std	mean	std	mean	std
SAM-V (38)	5.53	1.18	5.55	1.31	6.63	1.05
SAM-A (38)	3.08	1.65	3.24	1.36	3.76	1.67
SAM-D (38)	5.26	1.72	5.45	1.55	6.00	1.27
STAI-6 (38)	9.82	2.49	10.37	2.67	9.18	2.52
RR (37)	15.76	2.20	18.59	1.21	18.05	1.39
HR (30)	72.31	15.72	75.96	16.40	73.81	16.71
GSR-L (36)	3.40	2.60	6.16	3.80	6.05	4.00
Offset values						
Groups:			$\Delta_{Inactive}$		Δ_{Active}	
Metrics:			mean	std	mean	std
SAM-V (38)			-0.26	0.94	-1.10	1.01
SAM-A (38)			-0.16	1.48	-0.68	1.90
SAM-D (38)			-0.18	1.01	-0.74	1.08
STAI-6 (38)			-0.55	2.07	0.63	1.53
RR (37)			-2.84	2.30	-2.30	2.46
HR (30)			-2.75	3.76	-1.50	3.13
GSR-L (36)			-2.77	2.32	-2.65	2.43

Table 8.8: Study 2 - means and standard deviations of the collected metrics during different trials. Δ sign represents the offset values with respect to the baseline (i.e. $baseline - value$ of either inactive and active trials). SAM-V: Self-Assessment Manikin scale of Valence, SAM-A: Self-Assessment Manikin scale of Arousal, SAM-D: Self-Assessment Manikin scale of Dominance, STAI-6: 6-item State-Trait Anxiety Inventory, HR: Heart Rate (beats per minute), RR: Respiration Rate (breadths per minute), GSR-L: Galvanic Skin Response Level (micro Siemens). For biometrics, mean values only represent the baseline/interaction period. The number enclosed in parentheses in front of each metric is the number of data points that have been used to derive the mean and standard deviation of that metric.

Self-reports				
	ΔV	ΔA	ΔD	**ΔSTAI-6**
mean difference	1.08	0.53	0.55	-1.18
std	1.36	1.74	1.35	2.12
standard error	0.22	0.28	0.22	0.34
99.3 CI	[0.45, 1.71]	[-0.28, 1.33]	[-0.07, 1.18]	[-2.16, -0.20]
t	4.88	1.87	2.52	-3.45
df	37	37	37	37
p	**<0.001**	0.070	0.016	**0.001**
d	0.79	0.30	0.41	0.56
r^2	**0.39**	0.086	0.15	**0.24**
power	0.97	0.18	0.38	0.72
Biometrics				
	ΔHR	**ΔRR**	ΔGSR-L	
mean difference	-1.24	-0.54	-0.11	
std	2.31	1.09	0.81	
standard error	0.42	0.18	0.13	
99.3 CI	[-2.47, -0.02]	[-1.06, -0.02]	[-0.50, 0.27]	
t	-2.95	-3.00	-0.84	
df	29	36	35	
p	**0.006**	**0.005**	0.401	
d	0.54	0.49	0.14	
r^2	**0.23**	**0.20**	0.02	
power	0.50	0.55	0.03	

Table 8.9: Study 2 - statistical analysis comparing offset inactive and active trials with significance level equal to 0.007 rather than the conventional 0.05 (see 8.5.3 for the rationale). Description of the terms used in the table: Δ: represents the difference between offset values, i.e. $\Delta = \Delta_{Inactive} - \Delta_{Active}$; mean difference: the average of Δ values for all the samples (given the dependent sample design we also have mean difference = active - inactive, i.e. a positive difference means the active value is larger than the inactive value, while a negative different means the opposite); std: standard deviation; CI: confidence interval for 0.007 α-level; t: t statistic; df: degrees of freedom; p: significance level; d: Cohen's measure of effect size (d ≈ 0.2: small effect, d ≈ 0.5: medium effect, d ≈ 0.8: large effect), r^2: r-squared effect size ($r^2 \approx$ 0.01: small effect, $r^2 \approx 0.09$: medium effect, $r^2 \approx 0.25$: large effect).

Chapter 9

Conclusions and Future Work

The main goal of the current thesis work was to provide empirical evidence for the effectiveness of the TAMER idea: interacting with the Haptic Creature, dominantly through the sense of touch, is capable of producing calming effects. The contributions of the work to this goal and to the overall TAMER project are:

- Empirical support for the efficacy of the tactile interaction with the Haptic Creature to produce subjective and physiologically measured calming effects
- A calming tactile interaction based on the literature of human-animal interaction, affective touch, and the previous work on the Haptic Creature, and an iterative design practice described in this thesis
- A strong theoretical foundation for conceptualizing the TAMER approach by phrasing it within the social-cognitive theories of human-animal interaction
- A novel view of interaction design as a systematic search in the interaction space to efficiently guide the development of TAMER
- A roadmap for the TAMER interaction design process

In the next sections the significance of these contributions and the future directions are discussed.

9.1 Significance of Research Contributions

9.1.1 Tactile Interaction Is Calming

Emotional design based on tactile interaction is scarce and little is known about the specific emotional reactions to different forms of interaction through touch. However, this knowledge is critical for developing TAMER and similar applications. The second study was an effort to produce more knowledge in this area.

In this study we asked participants to stroke the robot with one hand and feel its breathing with the other hand while keeping the robot on their laps. We also asked them to minimize their visual contact with the robot during the interaction. In active trials, we had programmed the robot to breathe smoothly at a constant rate communicating its relaxed emotional state.

As the result of the interaction described above, which lasted for 75 seconds, participants' subjective and physiological indicators of emotional experience showed they were happier and calmer when the robot was breathing than when it was not breathing. Our results exemplify the effectiveness of tactile interaction to calm people down which is the core idea that TAMER builds on.

9.1.2 Modelling the Interaction with Animals Is Promising

The design of the calming interaction in the second study was heavily informed by the characteristics of human-animal interaction through touch as well as other research with the Haptic Creature on the tactile communication of emotion. Encouragingly, our results were consistent with the reports from both of these areas suggesting that once interaction with the robot is appropriately modelled based on interaction with real animals it produces similar results. This methodology can be followed for further interaction design of TAMER and similar applications.

9.1.3 Working within the Theoretical Frameworks Directs the Interaction Design

Grounding the conceptualization of the calming interaction in the framework of human-animal interaction helps to clarify the objectives and directions of the interaction design. Since the main inspiration of TAMER has been the healing power of animals, it is reasonable to expect that following similar forms of interaction activates the same healing mechanisms.

9.1.4 Dependency Graph is Applicable to Other Design Problems

The idea of dependency graph for interaction design was first introduced by the author to deal with the inconclusive results of the first study and to break the ambiguities into manageable pieces. However, this strategy is general and can be applied to a variety of other design problems. Examples include and are not limited to: (1) design of human-robot interactions in high risk environments such as factories, (2) design of human interactions with robots or other intelligent systems for educational purposes, and (3) design of novel interaction devices that rely on unconventional communications channels such as gestures, physiological signals, and thoughts. Additionally, unlike the way it was originally derived, the dependency graph can be applied from the early stages of the development.

9.2 Future Work

The research reported in this thesis work can be followed in several directions. The following sections provide more details.

9.2.1 Follow-ups on the Second Study

More in-depth Analysis of Data

The analysis of data gathered in the second study was only preliminary. More in-depth analysis can provide deeper insights with regard to the physiological emotional reaction to the interaction. For example, transient response at the onset of the interaction can be investigated. Or temporal and frequency characteristics of physiological signals can be explored. Analyses of this kind help developing models of emotion in the context of interaction to estimate users' state for a fully autonomous control of robot's behaviours.

Additionally, video records and interviews should be examined to inform the next steps of the interaction design as well as the required modifications to the platform.

Same Protocol With Other Populations

To make sure that the results of the second study are generalizable to a wider adult population, male participants should also be recruited to go through the same data collection procedure.

Having the promising outcome for the interaction with adults, a separate study should be conducted to examine children's reactions. This study can easily follow the protocol of the second study modified for appropriate instructions and measurement instruments.

Other Models of Human-animal Interaction

To be more confident about the possibility of substituting animals with robots, it is important to examine other forms of tactile interaction with the Haptic Ceature. Comparison of results with those of real animals brings more insights about the potential of robot therapy.

Clarifying the Underlying Mechanisms

As discussed in 8.7, further experiments are required to understand the contribution of the human's stroking and the robot's breathing to the outcome of the interaction. It can be concluded that stroking alone is not as effective as stroking while the robot is breathing. However, the question is if stoking is necessary at all. In other words, whether breathing alone can produce the calming effects or the combination of stroking and breathing is the key for calming effects.

Additionally, more experiments are required to gain better understanding of the case of classical conditioning as a potential explanation for the mechanism controlling the interaction effect. These studies are necessary to inform the design of the interaction based on the models of human-animal interaction and to direct the further development of TAMER as an anxiety treatment technique.

Finally, to get better understanding of the characteristics of the effect it is important to examine the role of the initial emotional state in the magnitude and direction of the emotional transition. This knowledge is important to clarify the context where TAMER is most influential.

9.2.2 TAMER Design

Exploring the Design Space Following Stroking

Now that it has been shown that 2-hand stroking while the robot is breathing at a constant rate produces calming effects, the next attribute on the proposed roadmap can be explored[36]. More specifically, the choices of user involvement that are consistent with the current form of tactile interaction can be examined.

[36] Depth-first Search on the dependency graph.

Characterising Emotional Response to Other Forms of Tactile Interaction

To gain more knowledge for emotional design through touch, other forms of tactile interaction can be similarly characterized[37]. For example, the emotional reaction to different user gestures and robot expressions can be explored. In the study that we reported in Chapter 8 we evaluated a combination of tactile interaction and a very high level of user involvement. A possible next step would be to evaluate the combination of tactile interaction and a lower level of user involvement.

Combining Other Modalities: Play and Story

TAMER was conceptualized within human-animal interaction theories for the promise of the benefits that animals brings in the context of childhood emotional disorders. The idea can also integrate other modalities such as play and story-telling in its development to take advantage of other alternative methods in helping disturbed children.

9.2.3 Robotic Platform

Breathing Structure

The breathing structure is so fragile that movements are not felt even if very small forces are applied to the back shell. The problem is that the motor force pulls the moving part *in* rather than pushing it *out*. That is, the motor force aligns the external force instead of counteracting it.

In addition to being fragile, the current structure renders the breathing as unnatural. In the follow-up interviews at the end of the second study some participants pointed out that the breathing feels different from a real animal although they did not express a discomfort with that. Simulating natural breathings is essential to facilitate the transfer of pet effects to the interaction with the Haptic Creature. Therefore, improvements on the mechanical structure of the breathing is strongly recommended.

The breathing mechanism can also be redesigned in a way that people can feel the movements without keeping their hands in contact with the robot. Side-breathing or bottom-breathing are potential hands-free designs.

[37]Breadth-search on the dependency graph.

Shell

The other area that requires enhancement is the robot's shell. The roughness of the shell does not feel natural when the robot is touched. Making the shell feel more natural can significantly improve the emotional experience of the tactile interaction.

9.3 Conclusion

In conclusion, we recall our original goal and summarize what we did. The goal was to provide empirical evidence for the efficacy of a novel idea for anxiety treatment. We grounded our idea in the framework of social cognitive theory as used in human-animal interaction. We modelled the interaction design as a search in a broadly defined interaction space, and then introduced a novel and systematic approach to the interaction design process. We described our iterative design of a human-Creature interaction that was measurably calming, and shared the methodology and results of our two most significant evaluation cycles. Our principal results, from the second study, showed that the interaction with the Haptic Creature, while it is breathing slowly and constantly, produces calming effects as indicated by decreased heart rate and breathing rate as well as the subjective reports.

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Appendix A

Considerations in Designing Experiments Using Biometrics

Considerations on Heart Rate Variability

Guidelines and considerations for obtaining data and extracting measures of heart rate variability have been comprehensively covered in [13]. Here, the main points are summarized:

1. To extract meaningful measures of heart rate variability it is important to have clean data with R-waves accurately timed. The minimum sampling rate of 250-500 Hz for healthy adults has been recommended. However, rates of 500-1000 Hz are required for capturing the low-amplitude components. It is also important to control for the external sources of noise. Signal filtering and methods to detect and correct the potential artifacts should be devised.

2. When indexing parasympathetic control with measures of heart rate variability, it is preferred to use heart period data rather than heart rate data.

3. In generating the data series for spectral analysis, the uneven spacing between data points should be mitigated so the results are relatable to time domain. This can be done by generating an equally spaced time series from the original data points by assuming a sampling interval equal to one-forth of the inter-beat-interval.

4. It is of extreme importance, in particular in the analysis of time series data, to control for the non-stationaries in the signal. As the very first step, the data collection context should be kept consistent and controlled. To deal with the remaining non-stationaries, approaches to remove or characterize these trends should be implemented. Analysis of data in

(multiple) short epoch(s) is also helpful in reducing the effect of non-stationaries.

5. In setting the length of data to be analysed, it is important to have enough samples of short-term variations. A duration of at least 10 times the wavelength of the lowest frequency of interest has been recommended. Accordingly, a minimum of 1-min data is required for reliably calculating the high frequency components of heart rate variability (0.15-0.4 Hz) while a minimum of 2-min is needed for the low frequency components (0.05-0.15 Hz)

6. For the analysis of periodic elements of heart rate variability any of the following approaches produce valid and comparable results as long as the data is stationary: fast Fourier transform, auto-regressive modelling, and moving polynomial.

It should be also considered that variations in the measures of heart rate variability in the best case are closely correlated with within-subject variations. Even in such comparisons, it is important to control for the extraneous variations by controlling for the length of the data collection. This implies that within-subject designs with equal-length comparison groups should be considered in obtaining empirical data.

Appendix B

Issues in the Previous Work in TAMER

The past study[38] with the Haptic Creature had resulted in very promising results as to the effectiveness of TAMER idea[40]. However, the study suffered from serious methodological issues which made its results unreliable. To verify the findings, it was necessary to re-run the study before moving on to the next planned step which was a longitudinal investigation.

The issues of the previous study can be discussed within three different categories: interaction design, experimental design, and statistical analysis. These are explained in more details in the following sections.

Issues with Interaction Design:

In the previous work, the design of the interaction was only focused on the behaviours that the Haptic Creature displayed. The robot's breathing rate and pulse rate were modified according to a participant's breathing rate and heart rate (e.g. the robot's breathing rate was set to 20% faster than human's breathing rate). It was hypothesized that these modifications will eventually change the participant's emotional state estimated from the physiological measures.

The *uninformed* nature of the interaction was also emphasized, i.e. participants were not aware of the connectivity of the robot's behaviours to their own physiological state and they were not given any instructions with respect to their behaviours (e.g. they were not told to follow the robot's breathing with their own). It was hypothesized that through the interaction participants' physiological response would consistently change according to the changes in the robot's breathing rate and heart rate, although they are not informed of the devised connection.

More specifically, the robot's breathing rate and pulse rate were changed to be 20% faster and slower than the participant's baseline breathing rate and heart rate. While the robot was sitting on participant's laps, s/he was

[38] This study has been described in Section 4.4 of [40].

interacting with it by keeping one hand on the robot's back to feel the breathing. It was hypothesized that by feeling the breathing and pulse through tactile contact participants would start following the robot's breathing rate and heart rate although not informed of the relation and not instructed to do so.

The above design is neither approved nor disapproved by the literature. However, it is hard to identify the mechanisms that the interaction can build upon. None of the pathways that have been introduced in the literature support the design.

Issues with Experimental Design:

The previous study suffered from several experimental issues. To name a few:

- Partial counter-balancing; the reliability of results was questionable because of the order effect confound.
- Unreliable data collection; the length of the collected data was not enough for reliably extracting some of the physiological features (please refer to the appendix A).
- No cross-check for physiological response; aside from observations, there was no other source of data on the emotional response to the interaction across different experimental conditions.
- No screening on participants' anxiety traits; there was no measure for evaluating the generalizability of results to the target population (children clinically diagnosed with anxiety disorders).
- Inconsistent elicitation of stress response; there were no controls to make sure that the same amount of stress is induced across trials. This is especially a confound given the partial counter-balancing.
- Hawthorne effect especially in case of interview questions.
- No control for the environmental factors; the study room and its setup were not appropriately chosen for the purpose of the study.

Issues with Statistical Analysis:

There were several problems in the statistical analysis of data in the previous study. Being aware of the pitfalls is important to address the problems in future:

- No Bonferroni correction for the multiple t-tests to avoid capitalizing on chance; instead of ANOVA, pair-wise t-tests were used for comparing trials
- No Bonferroni correction for multiple measures to avoid sample specific conclusions.
- Wrong choice of statistical tests; the tests developed for comparing means were used for comparing standard deviations.

If we apply the appropriate adjustments to α-value for the statistical tests carried out in Section 4.4.3 in [40], we will get $\alpha = 0.001$. Therefore, among the results reported in Table 4.9 of [40] only those with p-value smaller than 0.001 represent statistically significant difference.

Appendix C

Study 1: Documents

C.1 Advertisement

- Invitation letter
- Consent form
- Assent form

THE UNIVERSITY OF BRITISH COLUMBIA

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Invitation to Participate in Study

Tamer: Touch-guided Anxiety Management via Engagement with a Robot Pet

Professor Karon MacLean, Ph.D
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Student investigator: Yasaman Sefidgar
Department of Computer Science, University of British Columbia
([redacted])-[redacted]-[redacted] / [redacted]

WHO ARE WE AND WHAT WE DO?
We are a group of computer scientist, mechanical engineers, and psychologists. We are attempting to develop a novel method to help children with anxiety disorders to independently improve their self-regulating abilities. More specifically, in our studies we examine the role of haptic (touch sense) feedback on anxiety levels. We have developed a robotic pet, and our goal is to program it to respond physically to a combination of a child's pattern of touch and biometrically sensed emotional state in a way that rewards patience and progress.

OUR EXPERIMENT AND YOUR PARTICIPATION
In our study we do some experiments. We are inviting you to participate in one of these experiments. Your participation in this experiment is completely voluntary. Before you decide, it is important for you to understand what the research involves. The consent form attached to this invitation will tell you about the study, why the research is being done, what will happen in it and the possible benefits, risks, and discomforts.

If you wish to participate you can sign the consent form and return it back to us or you can send us an email and indicate your interest in the study

WHOM TO CONTACT
If you are interested in this study or you desire any further information, please call Yasaman Sefidgar at [redacted], or email her at [redacted]. You can also contact either of the principal investigators (MacLean or Garland) at the telephone or email addresses listed above, or in person.

Version 1.3, June 25, 2010

THE UNIVERSITY OF BRITISH COLUMBIA

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PARTICIPANT & PARENT INFORMATION AND CONSENT FORM

Tamer: Touch-guided Anxiety Management via Engagement with a Robot Pet

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Sponsor: National Science and Engineering Research Council of Canada (NSERC)

INTRODUCTION

You (or your child) are being invited to take part in this research study because we feel that your participation and feedback will greatly assist us in developing anxiety-reducing robotic devices.

YOUR PARTICIPATION IS VOLUNTARY

Your participation is entirely voluntary, so it is up to you to decide whether or not to take part in this study. Your participating or not participating in this study will neither affect your access to other health care or to your child's treatment in the clinic, nor impact your access to education services or your child's training at school. Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen to you (or your child) during the study and the possible benefits, risks, and discomforts.

If you wish to participate or if you allow your child to participate, you will be asked to sign this form. If you do decide or allow your child to take part in this study, you are still free to withdraw at any time and without giving any reasons for your decision.

If you do not wish to participate, you do not have to provide any reason for your decision not to participate. Please take time to read the following information carefully.

WHO IS CONDUCTING THE STUDY?

The study is being conducted/funded by the National Science and Engineering Research Council of Canada (NSERC). The Principal Investigator has received funds from this agency to compensate subjects for participating in this study. You are entitled to request any details concerning this compensation from the Principal Investigator.

BACKGROUND

This project's goal is to advance a novel tool and technique to help young children attain independent anxiety regulation skills. Engagement will be utilized to give children access to cognitive training by interacting with an expressive animatronic pet. Our research objective is to program this robot to respond physically to a combination of a child's pattern of touch and biometrically sensed emotional state in a way that rewards patience and progress.

WHAT IS THE PURPOSE OF THE STUDY?

The purpose of this study is to examine the role of haptic (touch sense) feedback on anxiety levels. This study investigates your (or your child's) reaction to a small robotic creature that can breath, purr and stiffen its ears, and under some conditions is touch-sensitive.

WHO CAN PARTICIPATE IN THE STUDY?

This study is open to children from ages 7-17, as well as adult subjects between the ages of 17-50. At most 100 participants will take part in this study, most of whom are children who have some kind of anxiety disorder, either mild (30%) or moderate (30%). The rest of the participants are from normal child or adult population. The former (normal child group) constitute the control group and the latter (normal adult group) will participate in pilot experiments.

WHAT DOES THE STUDY INVOLVE?

You and/or your child will be asked to carry out a standardized anxiety test at the beginning of the study and at specific stages throughout the study. It helps to determine the level and type of your (or your child's) anxiety. You (or your child) will be asked to wear external (i.e., non-invasive) sensors that collect some basic physiological information such as heart rate, respiration rate, some muscle activity, and perspiration. We request that you (your child) tell the experimenter if you (or s/he) find the sensor positioning uncomfortable, and adjustments will be made.

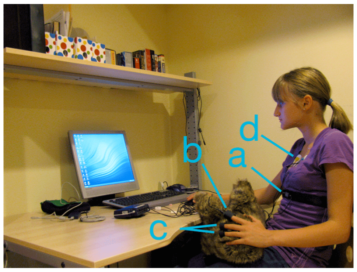


Image 1: User demonstrating possible physiological sensors: respiration rate (a), blood volume pulse (b), skin conductance (c), ECG (d).

During a session, you (your child) will be invited to carry out a primary task (e.g. a computer-based cognitive task) which you (your child) may find mildly challenging; we will collect performance, to relate it to changes in anxiety state. We will invite you (your child) to answer questions in the form of questionnaires, rating scales or interviews. The study will be observed by the experimenters and will be video-recorded. These recordings may be saved and reviewed by the experimenters for later analysis, and possiblely used in research presentations. Any images so used (still and video) will have identifying regions (e.g. face) obscured. The experiment may happen in multiple sessions. The time commitment required for a single session will range from one (more common) to four hours. The time required for all the sessions combined will not exceed 18-20 hours.

If your (your child's) participation is during school hours, it will not interfere with your (your child's) learning objectives. To minimize disruption, participation will occur in a convenient location (e.g. school staff offices if available).

Image 1 shows a photo of a child attached to the physiological sensors that will be used during these experiments. There are four primary sensors that will be used during these experiments:

a. Respiration Rate: A Velcro band is worn around the abdomen outside of the clothing. Expands and contracts with the abdomen to measure respiration rate, waveform, and amplitude.
b. Blood Volume Pulse: also known as a photoplethysmograph (PPG) sensor. A small black box attaches to the distal end of a finger with a Velcro strap or removable medical tape. Measures heart rate.
c. Skin Conductance: Two electrodes attach to Velcro straps, each in turn is attached to the distal end of two fingers on the same hand. Measures galvanic skin response (GSR), the electrical resistance of the skin.
d. ECG: Three electrodes attach to the upper right and left sides of the chest and the lower abdomen or alternatively on left and right forearms. Measures heart electrical activity.

IF YOU DECIDE TO JOIN THIS STUDY: SPECIFIC PROCEDURES

There will be multiple sections in the study. You (your child) may have a break between some sections. After completing an initial very simple anxiety check (a single question) you (your child) will be fitted with the sensors and invited to hold the creature in your (her/his) lap while working on the computer-based task. The creature may move during this experiment. As we finish, you (your child) will be asked about your (her/his) overall experience during the session. At specific times during the experiment you (your child) might be invited to repeat the simple anxiety check. If you (your child) are not sure about any instructions, do not hesitate to ask.

WHAT ARE THE POSSIBLE HARMS AND SIDE EFFECTS OF PARTICIPATING?
There are no expected harms or side effects from participating in this experiment. The biosensors that are worn are non-intrusive, and FDA-approved safe for medical uses.

WHAT ARE THE BENEFITS OF PARTICIPATING IN THIS STUDY?
No one knows whether or not you will benefit from this study. There may or may not be direct benefits to you from taking part in this study. We hope that the information learned from this study can be used in the future to benefit others.

Upon your request, you will be put in contact about the results of the research.

WHAT HAPPENS IF I DECIDE TO WITHDRAW MY CONSENT TO PARTICIPATE?
Your (or child's) participation in this research is entirely voluntary. You (your child) may withdraw from this study at any time. If you (or your child) choose to enter the study and then withdraw at a later time, all data collected about you (or her/him) during the enrolment in the study will be retained for analysis. By law, this data cannot be destroyed.

WHAT WILL THE STUDY COST ME?
You are not expected to incur any personal expenses as a result of your participation in this study. You will be compensated $5 for each 1/2-hour study session.

WILL MY TAKING PART IN THIS STUDY BE KEPT CONFIDENTIAL?
Your confidentiality will be respected. No information that discloses your identity will be released or published without your specific consent to the disclosure. Research records identifying you may be inspected in the presence of the Investigator or his or her designate by representatives of Health Canada and the UBC Research Ethics Board for the purpose of monitoring the research. However, no records which identify you by name or initials will be allowed to leave the Investigators' offices.

WHO DO I CONTACT IF I HAVE QUESTIONS ABOUT THE STUDY DURING MY PARTICIPATION?
If you have any questions or desire further information about this study before or during participation, you can contact Prof. **Karon Maclean** at ([redacted])-[redacted]-[redacted].

WHO DO I CONTACT IF I HAVE ANY QUESTIONS OR CONCERNS ABOUT MY RIGHTS AS A SUBJECT DURING THE STUDY?
If you have any concerns about your rights as a research subject and/or your experiences while participating in this study, contact the Research Subject Information Line in the University of

British Columbia Office of Research Services by e-mail at RSIL@ors.ubc.ca or by phone at 604-822-8598.

SUBJECT CONSENT TO PARTICIPATE

I indicate that I have read, understood, and appreciated the information concerning this study:

- I have read and understood the subject information and consent form.
- I have had sufficient time to consider the information provided and to ask for advice if necessary.
- I have had the opportunity to ask questions and have had satisfactory responses to my questions.
- I understand that all of the information collected will be kept confidential and that the result will only be used for scientific objectives.
- I understand that my participation in this study is voluntary and that I am completely free to refuse to participate or to withdraw from this study at any time.
- I understand that I am not waiving any of my legal rights as a result of signing this consent form.
- I have read this form and I freely consent to participate in this study.
- I have been told that I will receive a dated and signed copy of this form.

SIGNATURES

PRINTED NAME OF SUBJECT	SIGNATURE	DATE
PRINTED NAME OF PRINCIPAL INVESTIGATOR / DESIGNATED REPRESENTATIVE	SIGNATURE	DATE

SUBJECT'S ASSENT TO PARTICIPATE IN RESEARCH

I have had the opportunity to read this consent form, to ask questions about my participation in this research, and to discuss my participation with my parents/guardians. All my questions have been answered. I understand that I may withdraw from this research at any time, and that this will not interfere with the availability to me of other health care or education. I have received a copy of this consent form. I assent to participate in this study.

______________________	______________________	__________
PRINTED NAME OF SUBJECT	SIGNATURE	DATE

SUBJECT CONSENT TO PARTICIPATE

The parent(s) / guardian(s) and the investigator are satisfied that the information contained in this consent form was explained to the child to the extent that he/she is able to understand it, that all questions have been answered, and that the child assents to participate in the research.

SIGNATURES

______________________	______________________	__________
PRINTED NAME OF SUBJECT'S LEGALLY ACCEPTABLE REPRESENTATIVE	SIGNATURE	DATE
______________________	______________________	__________
PRINTED NAME OF PRINCIPAL INVESTIGATOR / DESIGNATED REPRESENTATIVE	SIGNATURE	DATE

THE UNIVERSITY OF BRITISH COLUMBIA

Department of Computer Science
2366 Main Mall
Vancouver, BC Canada V6T 1Z4
Phone: ([redacted]) [redacted]-[redacted]
Fax: ([redacted]) [redacted]-[redacted]

PARTICIPANT ASSENT FORM

Tamer: `Touch-guided Anxiety Management via Engagement with a Robot Pet`

INVITATION
I am being invited to be part of a research study. The research study tries to find better treatments to help children like me. It is up to me if I want to be in this study. No one will make me be part of the study. Even if I agree now to be part of the study, I can change my mind later. No one will be mad at me if I choose not to be part of this study.

WHY ARE WE DOING THIS STUDY?
We are doing this study to investigate how a robot may help reduce my anxiety levels. We want to see my reactions to a robot that may purr, breathe, and move on my lap.

WHAT WILL HAPPEN IN THIS STUDY?

Image 1: User demonstrating possible physiological sensors: respiration rate (a), blood volume pulse (b), skin conductance (c), ECG (d).

During this experiment I will be invited to wear physiological sensors as shown in Image 1 on this subject's hands and chest. These will allow the experimenters to record my heart rate, pulse, breathing rate, and skin conductance (how sweaty I am). If at any time these are uncomfortable they would like me to let them know, so they can adjust them for me.

The experimenters are investigating my reaction to a small robotic creature. Some versions of this robot might be touch-sensitive, or breath, purr and stiffen its ears. I will be asked to hold the creature in my lap while I complete a job on a computer. The creature may move during this experiment. During the computer job, I may sometimes be asked to answer (on the computer screen) a simple question about how I'm feeling right now.

I will be video recorded if I don't feel upset about it. The experimenters may ask me to answer some questions; they are interested in what I think, especially about the robot and how it makes me feel.

WHO IS DOING THIS STUDY?
Prof. Karon Maclean and other investigators from the UBC Computer Science Department will

be doing this study. They will answer any questions I have about this study. I (or my parents or teacher) can also call them at [redacted], if I am having any problems or if there is an emergency and I cannot talk to my parents.

CAN ANYTHING BAD HAPPEN TO ME?
There is nothing in this study that should cause anything bad to happen to me.

WHO WILL KNOW I AM IN THE STUDY?
Only the people who are involved in the study will know that I am in this study. When the study is finished, the investigators will write a report about what was learned. This report will not say my name or that I was in the study. My parents and I do not have to tell anyone I am in the study if we don't want to.

WHEN DO I HAVE TO DECIDE?
I have as much time as I want to decide to be part of the study. I have also been asked to discuss my decision with my parents. If I put my name at the end of this form, I agree to be in the study.

SUBJECT'S ASSENT TO PARTICIPATE IN RESEARCH
I have had the opportunity to read this assent form, to ask questions about my participation in this research, and to discuss my participation with my parents/guardians. All my questions have been answered. I understand that I may withdraw from this research at any time, and participating or not participating in this study will not affect my access to treatment in the clinic or any other health care, as well as education services. I have received a copy of this assent form. I assent to participate in this study.

______________________	______________________	__________
PRINTED NAME OF SUBJECT	SIGNATURE	DATE

C.2 Facilitator's Documents

- Preparation list
- Instruction set

Preparation list
Date: Participant's ID: Comments on special situation:

Instruments and tools

Creature

- Power supply
- USB connector (Standard A-plug - Standard B-plug)
  (Left: standard A-plug, Right: standard B-plug)

- Spare motor and Arduino board in the case you need to test/debug something
- Dust Sweeper as the cooler

Though Technology

(Refer to TT manual: FlexCompInfinit.pdf pages 8-10 (TT-USB, encoder and sensor attachment), 14-17, 19-20 (EKG), 24-25 (GSR), 26-27 (BVP and RESPIRATION))

- Encoder
- Optic cable rolled as instructed in TT Manual
- 2 sets of charged batteries for the encoder (one in the encoder, the other extra)
- TT USB
- TT USB cable (Standard A-plug - Mini B-plug (5 pin))
  (Left: standard A-plug, Right: Mini B-plug (5 pin))

- Sensors cables
- Sensor heads:
  - EKG
  - RESPITATION
  - GSR
  - BVP
- Uni-gel electrodes for EKG sensor (3 for each attachment)
- Velcro or medical tape for BVP
- Sanitizer

Preparation list

Date: Participant's ID: Comments on special situation:

Clocks program

- Modified Clocks program (Have the updated version on the participant's machine which is currently Criollo)
- Participant's station:
    - Machine (notebook or desktop) + charger (or power supply)
    - Mouse
    - External keyboard
    - Headphones
- Background white noise (Currently played from simplynoise.com)
- Neutral video
- A table and a seat with adjustable height comfortable for the participant

TAMER application

- Experimenter's station:
    - Machine (a notebook, preferably mine) + charger with extended cable
- Experimenter's seat where the experimenter can observe participant's interaction with the Creature (1st priority) and participant's work on the Clocks (2nd priority). While the distance between experimenter's place and participants place is currently limited (Creature needs to be connected via USB cable to Experimenter's machine while sitting on Participant's lap) this shouldn't be the case that the participant feels being monitored by the experimenter. The observation shouldn't be intrusive at all. It's also important that the participant is not able to see experimenter's screen.

Other

- Experimenter's instruction sheet
- Stop watch to hold the time
- Preparation list (this list)
- Interview questions
- Pencil and paper self-assessment question sheets
- A signed copy of Assent and Consent ---> I'll give them all at once to the school reception
- 2 extension cords (one with several outlets, the other with a long cable)
- Camera (to record the room arrangement, only for the 1st setup)
- Two charged sound recorder with enough capacity
- Extra Screen so the experimenter is able to follow participant's performance on the task (at this moment, Criollo (SPIN laptop) is used as participants machine. Mouse, a normal keyboard and a monitor are provided by EAS. This monitor is where participants work with, while the experimenter can follow them in the Criollo's screen. This is really great, without any interference I can see exactly what they see. My position is such that I can also observe their interaction with the Creature. That's awesome!)

Preparation list

Date: Participant's ID: Comments on special situation:

Tasks

Creature

- Prepare the Creature after you have set up other things. The wires and cables connected to it, should be over others so it can be easily given back and forth.
- Check the Creature's back shell placement
- Connect the Creature to the experimenter's machine with the USB cable
- Connect the Creature to the power supply and leave it turned on.
- Have the power cable so that it will reach the Creature from the sides of the participant's seat. This way it is not on the way.
- Hide the cable with the tail
- Have the fur fixed and fitted on the Creature before participant arrives
- Check if the Creature receives commands appropriately
- Have a place to put the Creature off the sight
- Check the motor temperature frequently to make sure it doesn't get hot (have it on the instruction set document too)
- After finishing the experiment turn the Creature off (unplug it) and then cool the motor down (have it on the instruction set document too)

Thought Technology

- Connect the encoder and the TT USB with optic cable (open the cable as needed)
- Connect the TT USB to the experimenter's machine with the USB cable
- Connect the sensor cables to the encoder
- Connect the sensors, be sure to plug EKG sensor on channel A or B. The higher sampling rates on these channels help collecting better EKG signals. Preferably don't plug other sensors on A or B. 256Hz sampling rate on other channels is more than enough for RESPIRATION and GSR and good enough for BVP. (Currently TAMER application assumes sampling rate of 256 Hz for respiration so DO NOT connect respiration to channel A or B).
- Check and record the battery level of the encoder with the provided application before starting the experiment. The level shouldn't be below 50%.
- Check if sensors are read well
- Disconnect the sensors and have them ready for demonstration
- Sanitize the sensors
- Attach the EKG electrodes
- EKG placement (also on instruction set)
  - Negative electrode (yellow pin): right forearm; top right side of the chest
  - Positive electrode (blue pin): left forearm; center of the chest above stomach
  - Ground electrode (black pin): left forearm; top left side of the chest
- Keep all the wires and cables not on the way where participant or experimenter sits or walks

Preparation list

Date: Participant's ID: Comments on special situation:

- Turn the encoder off
- Turn the encoder on upon participant's arrival (also in instruction set)
- Turn the encoder off and change and recharge batteries at the end of each experiment (also in instruction set)

Clocks program

- Connect the charger/power supply
- Connect the second screen to participant's machine
- Have the screen participant's are going to work on at the appropriate distance so they can easily read the screen
- Place the mouse and keyboard according to participant's being left-handed or right-handed (provide enough space for both cases)
- Connect mouse and external keyboard USB to the participant's machine
- Copy the Neutral Video
- Install the modified version of the Clocks on the participants' machine
- Copy the white noise on the computer, adjust it to always repeat; adjust the volume too (currently I run it off the website)
- Play the white noise (it's actually a pink noise)
- Run the Clocks program and test if it works fine
- Do the configuration: ID, level, Creature's state
- Check the volume of the Clocks audio-feedback
- Adjust the program for the participant's level and the condition of the experiment

TAMER application

- Check the COM ports, make changes to the code accordingly
- Run the application (currently run the C++ code in the debug mode)
- Check the application to see if it works well
- Check the files

Other

- Arrange the room such that:
  - The participant doesn't feel being monitored (experimenter doesn't directly have view to the participant's screen)
  - The participant shouldn't be able to see experimenter's screen
  - The participants shouldn't be distracted by external distractors so shouldn't face the door or the window to a public place

    My description to the EAS coordinator: *'A place where students can work without distraction and has enough room for setting up the equipment; basically there would be a computer on which students work on the Clocks program, and a notebook from which the experimenter will control the robot. To be sure that experimenter's presence won't affect students' performance, there should be enough space between where the students work and where the experimenter sits.'*
- Take a photo of the final arrangement for records (for the 1st setup only)

Preparation list

Date: Participant's ID: Comments on special situation:

- Have both recorders ready (charged, enough space)
- Test the recorders.
- Turn the recorder on when participant arrives; don't pause recording as it's a measure of the length of the experiment (also on the instruction set)
- Turn your cellphone off
- Review the participants information (left-handed, right-handed, skill level, age, name)
- Have wires arranged in a clean way
- If needed:
    - Close TOSHIBA (on Criollo) pop-up menu on the bottom left corner of the screen.
    - Close the opened EXCEL processes at the end of each experiment.
- Assign the appropriate ordering to the participant
- Label all the documents with date, time, participants ID, and assigned ordering as assigned in participants' demographic sheet. (Also in the instruction set)
- Try to fill in the general values in the instruction sheet by the known information of your participant (e.g. Clocks level, time limit, assigned order of conditions, etc.).
- Open a word document to enter your notes during the experiment.

Instruction Set
Date: Participant's ID: Comments on special situation:

Overview of the steps

1. Greetings
2. Introduction, experiments instructions, and hooking up with the sensors
    a. Goal (be careful not give them any idea of what they should do with the Creature; add nothing more than Consent/Assent form information)
    b. Task (what is different)
        i. Wearing headphone
        ii. Audio feedback
            1. Beeps
            2. White noise
        iii. Elapsed time
        iv. Self-assessment (mention at the time of demonstration)
    c. Sensors,
    d. Creature (look and feel)
    e. Emphasis on the importance of the accuracy and speed
    f. What to avoid:
        i. Speaking
        ii. Moving:
            1. Fingers
            2. Hand
            3. Body
    g. Task practice under all the conditions
3. Demonstration
    a. Training + let them feel comfortable
        i. Sensors
        ii. Self-assessment
            1. What it means
            2. How to response it
            3. Walking them through the levels
        iii. White noise
        iv. How to cooperatively work with Clocks
            1. Start with my permission
            2. Wait after finishing a set
        v. How tight the time is (here you can see if the limit actually works with them)
        vi. How hard the task is (check to see if the task is stressful enough)
    b. Possible States
        i. Baseline
        ii. NO
        iii. INACTIVE
        iv. ACTIVE
    c. Adjustments in task, sensors if needed

Instruction Set
Date: Participant's ID: Comments on special situation:

4. Some interview questions (any thing general and not related to their experience through the experiment) (goal: allowing enough time for them to settle down and get comfortable with the experimenter, environment, sensors)
    a. General mood,
    b. How comfortable they are in working with the keypad, having the sensors on them, and wearing headphone.
    c. Final check on the stressfulness of the task
5. Data Collection
    a. Baseline
    b. Step 1:
    c. Step 2:
    d. Step 3:
    e. Baseline
    f. Step 4:
    g. Step 5:
    h. Step 6:
    i. Baseline
6. Take the sensors off
7. Ask the rest of the interview questions
8. Thanks!

[Currently it's possible to do two experiments a day; One in the morning (before lunch), and the other in the afternoon (after lunch). I should be careful to have the same number of participants in the mornings and in the afternoons mainly because physiological state will change after having lunch.]

[
- **While using these scripts, keep your eye contact with the participants; smile from time to time; read with appropriate pace and try to pronounce the words clearly. Also explain them why you are reading off the sheet.**
- **If things did not go exactly as the procedure, try to adopt yourself; don't instruct the participant as much as you can.**

- **Prepare the setup according to the preparation list prior to the participant's arrival.**
- **Have the participants' information sheet available.**
- **Check the previous recordings during or review the steps during the times you need for the program to start.**

]

Hi <name>, I'm Yasaman. Nice to meet you. How are you doing today?

[Try to read from their actions if they are not fine. Tell them they can do it at another time if they don't feel well.]

Instruction Set
Date: Participant's ID: Comments on special situation:

Thank you for your participation. That's a great help to our research.

For today's experiment, we first talk about what's going to happen and how you can help us. Then we practice the steps, and then we start the experiment.

[Start the recorder.]

You are going to sit here and I'll sit there.

Now, I'm going to read you the instructions; it's to make sure that I'm not forgetting any important point. I hope you are fine with it.

Before we start let me check if you are comfortable. Is the seat or the table appropriate? Don't you want it to be higher or lower? Please let me know if you don't feel comfortable and then we can adjust.

In case you are interested to know more about what we are doing, we are trying to find ways that help children and youth feel comfortable at school, learn better, and succeed. So you are a part of the study that will benefit a lot of people. Are you happy about it?

We have a little robot that I'm sure you already know about. We also have some sensors to help us understand what's going on. I'll show you all of them shortly.

Basically, you wear the sensors and then start reading Clocks. Sometimes you will keep the robot on your laps, sometimes not.

[Pay attention to the way they are sitting on the seat. Make sure their posture won't increase the possibility of movement.]

Alright… Let's see how the sensors are like.

I start with the EKG sensor. EKG is the short form of electrocardiogram. Don't worry about the name, it just listens to your heart. We have some electrodes which stick to your skin so the sensor doesn't fall off. They can be easily taken off. They are also disposable and are used only for you. Would you like to look at them closely?

The electrodes are placed on your chest. The yellow electrode is placed close to your right shoulder; the black one is placed close to your left shoulder; and the blue one is placed on the center of your chest right above the stomach **[demonstrate]**.

Ok, let's put them on your chest. I peel them off so you can stick them to your chest. Please pass them underneath your clothes. **[Ask them to press against the electrodes]**

Instruction Set
Date: Participant's ID: Comments on special situation:

Are you comfortable with it?

[Let the EKG wires come down from the side where is closer to the encoder. This way the cables are not on the way.]

Next one is called respiration sensor. It's this elastic strip that is worn around the chest. You can look at it if you like.

When you inhale, it expands; when you exhale, it contracts **[demonstrate while you are talking]**. *This way it can tell us how you are breathing.*

Is it ok if I fasten it around your chest? Just rise your arms up. **[Fasten it tight enough so that it doesn't gradually slip down.]**

Are you comfortable with it? Is it too tight or too loose?

Before moving on with the rest of the sensors, I want to show you the Creature- our little robot

[

- **Try to hand in the Creature over the wires; have all the wires pass under the Creature wires.**
- **Have the Creature positioned according to their being left-handed or right-handed in a way that they can feel its movements.**

]

Do you do the Clocks with your left hand or your right hand?

Here is the robot. So what do you think? **[Allow some time for them to answer before asking the next question.]** *What is it like?*

You can pet it if you like. **[Let some time]** *How do you like petting it? Let's give it a name. What would you call it?*

<Creature's name> can actually move. You will see in few minutes.

Let's first finish the sensors. There are two sensors left. One is called GSR. GSR stands for galvanic skin response. This sensor measures how sweaty you are. It has two electrodes. Each of these electrodes is placed at the end of one finger of one of your hands. To have it fixed on your fingers, there is a Velcro around it. The Velcro is fastened around the finger. Would you like to see the electrodes?

Let's put them on your fingers.

Instruction Set
Date: Participant's ID: Comments on special situation:

Is it tight? Loose? Is it comfortable?

The last sensor is called BVP, short form of blood volume pulse. It does something similar to the one on your chest but in a different way, i.e. it listens to your heart. It can do it when it is placed on your thumb. To have this sensor fixed we need to use a tape around it. You can look at it if you want.

Let me have it on your thumb now.

Are you comfortable?

If at any time you felt a sensor is bothering or it is loose, please let me know.

[Instruct them what not to do to be able to control the movement artifacts especially while not having the Creature]

There are things that cause the sensors to go wrong and I would appreciate if you can avoid these things when I'm collecting data, although you are free to do them during the breaks. I'll let you know when is a break.

Movements are the main source of problems so please try not to move your fingers, your hand, or your body.

Examples of the actions that you had better avoid are: stretching your body like this **[demonstrate]**, *opening and closing your fingers, tapping on a surface, yawning, or changing your posture.* **[Demonstrate the actions while you are talking about them and remind them for each data collection step]**

The other source of problems is speaking. So please try not to speak unless something is bothering you, or there is something wrong with the sensors.

So far so good? Do you have any questions? If you have any questions, feel free to ask.

Next I'm going to show you the Clocks program. I know you are already familiar with it but there are a few differences that I would like to explain.

The first difference is that when working on Clocks, you will wear a headphone that plays a sea wave like sound in the background. The headphone will help you concentrate better.

You are now reading <Num> hands right? So we would ask you to answer to <Num-1 =< 3>-hand questions. It should be pretty easy for you, right?

Instruction Set
Date: Participant's ID: Comments on special situation:

We have made it a little bit harder; although, I'm sure it won't be that hard for you. The hard part is that you're timed, i.e. it is really important to read the clocks as fast as you can. So the second difference is that you have limited time to finish a set.

Keep in mind that, still it's really important to be accurate when reading the clocks. You shouldn't have more than 2 mistakes.

Try to be fast but still accurate. At the end of our experiments here, we will give the one with the best score a very good prize. Each set of clocks you do within time and with high accuracy, gets you one step closer to that grand prize, so do your best. OK?

The third difference is that, you hear an audio feedback on how much time you still have. When you first start reading, you will hear beeps with a large gap in between the two. When half of your time has passed the beeps get closer to warn you that there is not a lot of time left. When the time has finished, you will hear the very fast beeps that tell you that you have run out of your time and should finish. For example when you start it's like beep [pause] *beep* [pause] *beep, then it gets like beep* [shorter pause] *beep* [shorter pause] *beep, and at the end it's like beep, beep, beep. So it gives you a kind of idea of how much time you have.*

Please pay attention that, you need to finish a set in <time limit> seconds.

[3-hand: 74 s □ 2-hand: 64 s □ minute-hand: 32 s □]

To help you better estimate your time, another feedback about the time is given to you. It is the number shown at the top left corner of the clocks screen. **[Show them where it is tentatively]** *This is the forth difference. This number tells you how many seconds you have spent so far. I'll show you this number once we started practicing* **[Demonstrate it on the Clocks screen]**.

There is one other difference. At the end of each set you will be asked this question on how you feel based on your recent experience when answering to questions under time pressure. **[Demonstrate on the screen]**.

The lower the bar, the more relaxed you feel. The higher the bar, the more worried you feel. At the lowest level, you are completely relaxed, like when you are enjoying your favorite TV program. At the highest level you are completely stressed out, like when you have to talk in front of a lot of people, or you have to talk with a strange person, or when you really want to run away. Could you give me some other examples of the times that you feel really good or very bad? Can you remember the time when you felt like that? **[Help them to locate each feeling on the thermometer]** *(What else? How about a little more/less than that?)* **[Engage them in a conversation about it to ensure that they are getting it]**

Instruction Set
Date: Participant's ID: Comments on special situation:

You can change the level of the bar as many times as you want. After you are sure about your selection, click on the 'show score' button. The button won't appear unless you move the slider or do a selection.

Next you can see your score and the time it took you to do the set. The ones on the screen are just examples. When you get here, wait for me to do some configuration and prepare the next step so we can proceed.

[
- **Connect the sensors cables.**
- **Be careful about the cables; pass them beneath the Creature's wires.**
- **Be sure to plug EKG sensor on channel A or B, the rest on a channel from C-J.**
- **Turn the encoder on.**

- **Arrange wires in a clean way.**
- **Have the Creature in a way that they can feel the movements.**
- **Press the key to start.**

]

First, I need to make sure that everything works well. This may take a few minutes. During this time, I would like to ask you to watch a video. In the video there is a square that randomly moves and also changes its color. We would like to ask you to follow the square when it moves or changes color. It's important to always look at the center of the square and not the edges of it.

I would appreciate if you avoid moving or speaking. Ready to start?

[
- **Take the first baseline here.**
- **Name files with this convention: yymmdd_hh_mm_condition_rep.**
- **Analyze the respiration rate.**
- **Write down the breath period, and uses the value for demonstration.**

breath length	**age specific range**	**35% of range**	**Creature's breath length**

]

Great everything seems to work fine.

Well let's see what's going to happen in the experiment. The main purpose of this section is for you to get an idea of what you are going to do, how long it's going to take, how challenging it is, anything that you would like to know before hand. So feel free to ask if you have any questions.

Instruction Set

Date: Participant's ID: Comments on special situation:

Some general points about the experiment. In this experiment, you will work in 3 different conditions. When you have <Creature's name> and it moves like now. When you don't have it, and when you just work on the Clocks without <Creature's name> being present.

From time to time I might need to check my application. When I do that, you do not need to work on the Clocks or keep <Creature's name> on your lap, you will simply watch that square video.

As I mentioned before you need to do a set within <time limit> seconds. It is important to be fast and accurate at the same time. Finishing a set in more than <time limit> seconds or having more than two mistakes will cause you to lose the set.

After you have seen your score you can take a break until I again ask you to start doing the Clocks. During this time I'll prepare my program and it initializes its value.

When you have <Creature's name> keep your hand on the side of it's back. When you don't have <Creature's name>, keep your hand on your lap.

Again, I would like to ask you not move your fingers or your hand. Please try not to move your body or change your posture too frequently. Also please do not speak unless you feel uncomfortable or there is something wrong. Ok?

Now, I'm going to show you how <Creature's name> moves. And we will practice the experiment a little bit. OK?
It will take a little for my program to initialize its values, so please wait.

[Name files with this convention: yymmdd_hh_mm_condition_rep.]

Well it's now moving. How do you like it?

You will start working on the Clocks by pressing the 'begin' button when I prompt you to.

Are you ready? Let's move on; Please press on the begin button **[Tell them to start after seeing the first few message notices on the screen; press 'm' when they actually start].**

Before you start answering the question please look at this increasing number; this is the time you have spent since the beginning of the set. Don't worry that your time is passing just for now. But for the rest of the experiment, make sure that you finish on time.

Now wear on your headphones and start answering the questions.

Instruction Set
Date: Participant's ID: Comments on special situation:

[Let them finish a set. Look at the question number to press 'q' on time: right after they answer to the last clock question.]

Please take off your headphone.

[
- **Ask: how hard it was for them to do the set, if they had any problem with the beeps or the white noise; ask now so you can adjust if needed and can get feedback on the change before proceeding to the actual experiment.**
- **Ask: if they are comfortable working with the task, especially while BVP and GSR are on them.**
- **Ask how significant they found the movements.**

]

Were you fine with the headphone when working on the Clocks? Were you able to hear the outside noise? Were you comfortable with the beeps?

How were the beeps? How did you feel when hearing the beeps?

What do you think about the task? Do you think that in general it is manageable within the time?

Were you comfortable with the sensors when keeping <Creature's name>?

How did you find <Creature's name>'s movements? Were they easy to perceive? Were they distracting?

Just to demonstrate what the other possibilities are like, I will have <Creature's name> sleep so it doesn't move any more, and you do a set again. Then I'll ask you to give it back to me, and again work on the Clock. OK?

Please wear on the headphones.

[
- **Fully hide the Creature in NO condition and baseline.**
- **Observe their score and time to make the appropriate adjustments on the time limit.**
- **Observe if they keep their hand on the Creature. If not ask the reason. Take off the GSR if needed.**
- **Observe their interaction with the Creature all over the experiment.**
- **After each transition, let 45s for them to settle down. Pretend you are working on the program or this is the time required by the program.**

]

Please take off the headphone.

Instruction Set
Date: Participant's ID: Comments on special situation:

Great, we are done with the practice section. How are you feeling? Are you ready for the actual experiment?

Perfect, we will do the same thing as you just did although the order might differ. So some times you will sit without doing Clocks while you are watching the moving square video. Sometimes you have <Creature's name> on your lap while answering the Clocks questions. It can either be sleeping or alive. Some other times it's not on your lap when you are working on the Clocks.

[Repeat the considerations to help them follow better]

Just to review the important points: please do your best to go as fast as you can. It's important to finish the set in time. After the time is passed you have lost the set, although you need to finish before continuing to the next set. Don't forget that you should give correct answers. More than 2 wrong answers will cause you to lose the set. Do your best to get the grand prize.

The other point: Please try to have as few movements as possible. Please try not to move your fingers, your hand, or your body.

While you have <Creature's name> on your lap, keep your hand on the side of its back without moving your hand. While you don't have it on your lap, keep your hand on your own lap. Again it is important not to move your hand.

And the last point: please do not speak when you are reading Clocks or when watching the video unless there is something wrong.

If you are not comfortable with the sensors or the headphone, please let me know right now, and I will adjust it.

[Adjust the pink-noise volume; write down the final level if you have made any changes. (Default level: 18% volume over the website when PC's volume was also fixed on 18%]

After you finish a set till you start another set, you can take a break and doing any of the things I just mentioned is fine.

Well, before moving on, I would like to make sure if everything is fine.

Are you comfortable with the sensors? Can you easily keep your hand on <Creature's name>? **[Make sure the Respiration sensor is tight; the EKG sensor is well in contact; the GSR and BVP sensors are fixed]**
Are you comfortable with the headphone? Is the volume appropriate? Can you hear outsid

Instruction Set
Date: Participant's ID: Comments on special situation:

Does the background sound or beeps bother you?
Are you comfortable with the Clocks? Do you think that it is doable?

[
- **Follow the same procedure as the demonstration although you don't need to give them the instructions.**
- **Constantly monitor their performance on the task to make sure they are still on the task.**
- **At the beginning of each step of the experiments, sensor placements should be checked; also appropriate configuration on the Clocks should also be applied.**
- **Check each collection after to make sure data is fine. What if it wasn't?**
- **Check the respiration sensor after each set.**
- **Check Creature's temperature frequently throughout the experiment.**
- **After you have done the entire configuration on the Clocks and TAMER application, as well as Creature state, allow some time (45s) for them to settle down.**
- **After they finished each set tell them they are free to move or speak; tell them it's the break.**
- **If you are restarting the Clocks be careful about the level, and the rest of the configuration.**

]

[Start video camera.]

[
- **Restart the video**
- **Press the key on TAMER application and the video at the same time.**
- **Baseline script:**

]

I need to check my application (again) before we can move on. Please put on the headphones.

[Don't forget the pencil and paper self-assessment]

[Getting the Creature back Script][When getting the Creature back have it off the sight]

At this point, I should ask you to give <Creature's name> back to me (again). Once I prompt, you can start by clicking on the 'begin' button. Again please avoid moving or speaking.

[Giving the Creature script]

Instruction Set
Date: Participant's ID: Comments on special situation:

In the next step you are going to have <Creature's name> on your lap, so I'm going to hand it to you. Start with my prompt. Please be careful not to move or speak **[Always make sure that wires don't trouble the movement; they shouldn't be on the way]**

Great, we are done. Let's take the sensors off.

[Make sure that the recorder is on]

There are few questions that I would like you to answer.

Well, thank you very much for your help. I hope you are the winner of the grand prize.

[
- **Turn the encoder off and recharge batteries**
- **Turn the Creature off and cool the motor down.**
- **Recharge encoder batteries.**

]

C.3 Participant's Documents

- SCARED
- Paper and Pencil thermometer
- Interview questions

Screen for Child Anxiety Related Disorders (SCARED)

Child Version (To be filled out by the CHILD)

ID

Date: Age: Gender: M F

Directions:

Below is a list of statements that describe how people feel. Read each statement carefully and decide if it is "*Not True or Hardly Ever True*" or "*Somewhat True or Sometimes True*" or "*Very True or Often True*" for you. Then, mark the response that seems to describe you **for the last 3 months**.

Please respond to all statements as well as you can, even if some do not seem to concern you.

	0 Not True or Hardly Ever True	1 Somewhat True or Sometimes True	2 Very True or Often True
1. When I feel frightened, it is hard to breathe.			
2. I get headaches when I am at school.			
3. I don't like to be with people I don't know well.			
4. I get scared if I sleep away from home.			
5. I worry about other people liking me.			
6. When I get frightened, I feel like passing out.			
7. I am nervous.			
8. I follow my mother or father wherever they go.			
9. People tell me that I look nervous.			
10. I feel nervous with people I don't know well.			
11. I get stomachaches at school.			
12. When I get frightened, I feel like I am going crazy.			
13. I worry about sleeping alone.			
14. I worry about being as good as other kids.			
15. When I get frightened, I feel like things are not real.			
16. I have nightmares about something bad happening to my parents.			
17. I worry about going to school.			
18. When I get frightened, my heart beats fast.			
19. I get shaky.			
20. I have nightmares about something bad happening to me.			

Screen for Child Anxiety Related Disorders (SCARED)

Child Version (To be filled out by the CHILD)

ID:

Date:

	0 Not True or Hardly Ever True	1 Somewhat True or Sometimes True	2 Very True or Often True
21. I worry about things working out for me.			
22. When I get frightened, I sweat a lot.			
23. I am a worrier.			
24. I get really frightened for no reason at all.			
25. I am afraid to be alone in the house.			
26. It is hard for me to talk with people I don't know well.			
27. When I get frightened, I feel like I am choking.			
28. People tell me that I worry too much.			
29. I don't like to be away from my family.			
30. I am afraid of having anxiety (or panic) attacks.			
31. I worry that something bad might happen to my parents.			
32. I feel shy with people I don't know well.			
33. I worry about what is going to happen in the future.			
34. When I get frightened, I feel like throwing up.			
35. I worry about how well I do things.			
36. I am scared to go to school.			
37. I worry about things that have already happened.			
38. When I get frightened, I feel dizzy.			
39. I feel nervous when I am with other children or adults and I have to do something while they watch me (for example: read aloud, speak, play a game, play a sport.)			
40. I feel nervous when I am going to parties, dances or any place where there will be people that I don't know well.			
41. I am shy.			

Screen for Child Anxiety Related Disorders (SCARED)

Parent Version (To be filled out by the PARENT concerning child)

ID
Date: Child's Age: Child's Gender: M F Parent Gender: M F

Directions:
Below is a list of statements that describe how people feel. Read each statement carefully and decide if it is "*Not True or Hardly Ever True*" or "*Somewhat True or Sometimes True*" or "*Very True or Often True*" for your child. Then, mark the response that seems to describe your child **for the last 3 months**.
Please respond to all statements as well as you can, even if some do not seem to concern your child.

	0 Not True or Hardly Ever True	1 Somewhat True or Sometimes True	2 Very True or Often True
1. When my child feel frightened, it is hard for him/her to breathe.			
2. My child gets headaches when he/she is at school.			
3. My child doesn't like to be with people he/she doesn't know well.			
4. My child gets scared if he/she sleeps away from home.			
5. My child worries about other people liking him/her.			
6. When my child gets frightened, he/she feels like passing out.			
7. My child is nervous.			
8. My child follows me wherever I go.			
9. People tell me that my child looks nervous.			
10. My child feels nervous with people he/she doesn't know well.			
11. My child gets stomachaches at school.			
12. When my child gets frightened, he/she feels like he/she is going crazy.			
13. My child worries about sleeping alone.			
14. My child worries about being as good as other kids.			
15. When he/she gets frightened, he/she feels like things are not real.			
16. My child has nightmares about something bad happening to his/her parents.			
17. My child worries about going to school.			
18. When my child gets frightened, his/her heart beats fast.			
19. He/she gets shaky.			
20. My child has nightmares about something bad happening to him/her.			

Screen for Child Anxiety Related Disorders (SCARED)

Parent Version (To be filled out by the PARENT concerning child)

ID:

Date:

	0 Not True or Hardly Ever True	1 Somewhat True or Sometimes True	2 Very True or Often True
21. My child worries about things working out for him/her.			
22. When my child gets frightened, he/she sweats a lot.			
23. My child is a worrier.			
24. My child gets really frightened for no reason at all.			
25. My child is afraid to be alone in the house.			
26. It is hard for my child to talk with people he/she doesn't know well.			
27. When my child gets frightened, he/she feels like he/she is choking.			
28. People tell me that my child worries too much.			
29. My child doesn't like to be away from his/her family.			
30. My child is afraid of having anxiety (or panic) attacks.			
31. My child worries that something bad might happen to his/her parents.			
32. My child feels shy with people he/she doesn't know well.			
33. My child worries about what is going to happen in the future.			
34. When my child gets frightened, he/she feels like throwing up.			
35. My child worries about how well he/she does things.			
36. My child is scared to go to school.			
37. My child worries about things that have already happened.			
38. When my child gets frightened, he/she feels dizzy.			
39. My child feels nervous when he/she is with other children or adults and he/she has to do something while they watch him/her (for example: read aloud, speak, play a game, play a sport.)			
40. My child feels nervous when he/she is going to parties, dances or any place where there will be people that he/she doesn't know well.			
41. My child is shy.			

Screen for Child Anxiety Related Disorders (SCARED)

Child Version—Pg. 1 of 2 (To be filled out by the CHILD)

Name: ____________________________________

Date: ____________________________________

Directions:
Below is a list of sentences that describe how people feel. Read each phrase and decide if it is "Not True or Hardly Ever True" or "Somewhat True or Sometimes True" or "Very True or Often True" for you. Then for each sentence, fill in one circle that corresponds to the response that seems to describe you for the last 3 months.

	0 **Not True or Hardly Ever True**	**1** **Somewhat True or Sometimes True**	**2** **Very True or Often True**
1. When I feel frightened, it is hard to breathe.	○	○	○
2. I get headaches when I am at school.	○	○	○
3. I don't like to be with people I don't know well.	○	○	○
4. I get scared if I sleep away from home.	○	○	○
5. I worry about other people liking me.	○	○	○
6. When I get frightened, I feel like passing out.	○	○	○
7. I am nervous.	○	○	○
8. I follow my mother or father wherever they go.	○	○	○
9. People tell me that I look nervous.	○	○	○
10. I feel nervous with people I don't know well.	○	○	○
11. I get stomachaches at school.	○	○	○
12. When I get frightened, I feel like I am going crazy.	○	○	○
13. I worry about sleeping alone.	○	○	○
14. I worry about being as good as other kids.	○	○	○
15. When I get frightened, I feel like things are not real.	○	○	○
16. I have nightmares about something bad happening to my parents.	○	○	○
17. I worry about going to school.	○	○	○
18. When I get frightened, my heart beats fast.	○	○	○
19. I get shaky.	○	○	○
20. I have nightmares about something bad happening to me.	○	○	○

Screen for Child Anxiety Related Disorders (SCARED)

Child Version—Pg. 2 of 2 (To be filled out by the CHILD)

	0 **Not True or Hardly Ever True**	**1** **Somewhat True or Sometimes True**	**2** **Very True or Often True**
21. I worry about things working out for me.	○	○	○
22. When I get frightened, I sweat a lot.	○	○	○
23. I am a worrier.	○	○	○
24. I get really frightened for no reason at all.	○	○	○
25. I am afraid to be alone in the house.	○	○	○
26. It is hard for me to talk with people I don't know well.	○	○	○
27. When I get frightened, I feel like I am choking.	○	○	○
28. People tell me that I worry too much.	○	○	○
29. I don't like to be away from my family.	○	○	○
30. I am afraid of having anxiety (or panic) attacks.	○	○	○
31. I worry that something bad might happen to my parents.	○	○	○
32. I feel shy with people I don't know well.	○	○	○
33. I worry about what is going to happen in the future.	○	○	○
34. When I get frightened, I feel like throwing up.	○	○	○
35. I worry about how well I do things.	○	○	○
36. I am scared to go to school.	○	○	○
37. I worry about things that have already happened.	○	○	○
38. When I get frightened, I feel dizzy.	○	○	○
39. I feel nervous when I am with other children or adults and I have to do something while they watch me (for example: read aloud, speak, play a game, play a sport.)	○	○	○
40. I feel nervous when I am going to parties, dances, or any place where there will be people that I don't know well.	○	○	○
41. I am shy.	○	○	○

SCORING:

A total score of $\geq$ **25** may indicate the presence of an **Anxiety Disorder**. Scores higher that 30 are more specific.

A score of **7** for items 1, 6, 9, 12, 15, 18, 19, 22, 24, 27, 30, 34, 38 may indicate **Panic Disorder** or **Significant Somatic Symptoms**.

A score of **9** for items 5, 7, 14, 21, 23, 28, 33, 35, 37 may indicate **Generalized Anxiety Disorder**.

A score of **5** for items 4, 8, 13, 16, 20, 25, 29, 31 may indicate **Separation Anxiety Disorder**.

A score of **8** for items 3, 10, 26, 32, 39, 40, 41 may indicate **Social Anxiety Disorder**.

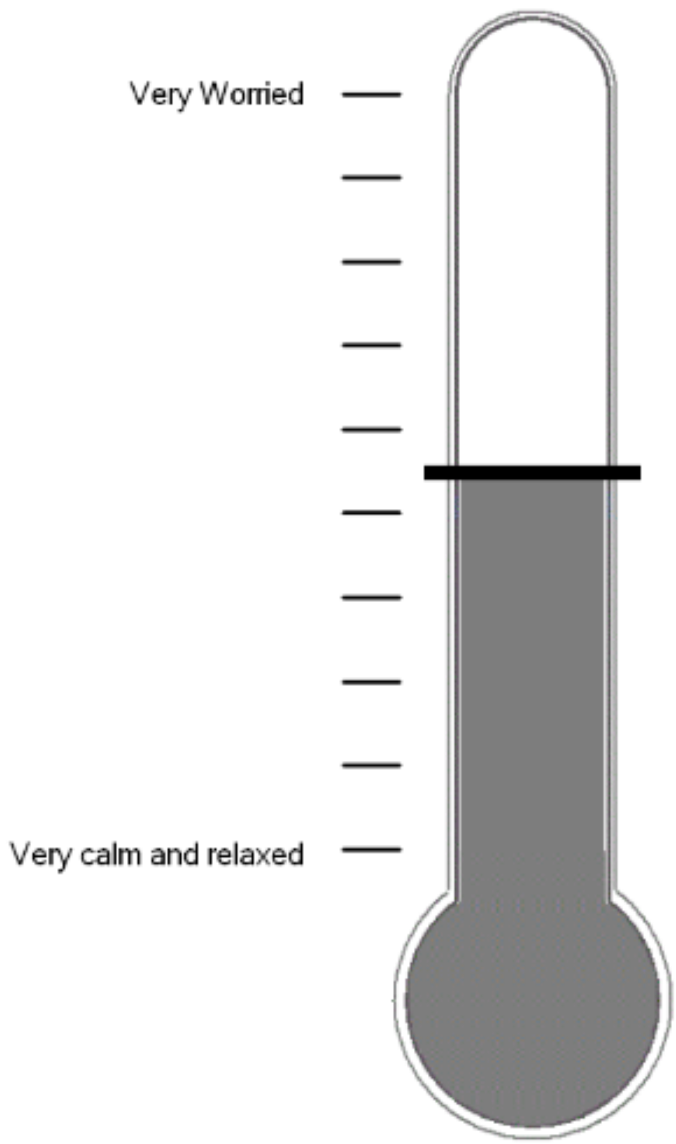
A score of **3** for items 2, 11, 17, 36 may indicate **Significant School Avoidance**.

**For children ages 8 to 11, it is recommended that the clinician explain all questions, or have the child answer the questionnaire sitting with an adult in case they have any questions.*

Developed by Boris Birmaher, M.D., Suneeta Khetarpal, M.D., Marlane Cully, M.Ed., David Brent M.D., and Sandra McKenzie, Ph.D., Western Psychiatric Institute and Clinic, University of Pgh. (10/95). E-mail: birmaherb@msx.upmc.edu

Please tell us how you feel now

Move the slider by moving the bar or by clicking on its scale so it best shows your feelings



Date:
Participant’s ID:
Comments on special situation:
[Try to think about what you want to know beyond what you can see in the data collected. Try to think about things that can direct next levels of the study]

Question	Answer
How was it during the clocks? Is it a generally hard task? Could other students do this?	
Some things are hard about the task, some things are easy about it. What are the things that are hard about it? What are the things that are easy about it?	
Do you think having the creature there makes it harder or easier or no difference? ? Would it be harder or easier for someone?	
Do you like <Creature’s name>? Do you think that it would help kids?	
What are the things about having the creature there that bothered you? Do you think that it bothers somebody else?	
Would you like to have the creature?	

Appendix D

Study 2: Documents

D.1 Advertisement

- Advertisement flyer
- Sign-up instructions
- Email correspondence: initial correspondence and reminder

THE UNIVERSITY OF BRITISH COLUMBIA

Department of Computer Science
2366 Main Mall, Room [redacted]
Vancouver, B.C. Canada V6T 1Z4

tel: ([redacted]) [redacted]-[redacted]
fax: ([redacted]) [redacted]-[redacted]
email: [redacted]

Participants Needed For UBC Studies With Furry Robot

We are researchers in the Department of Computer Science at the University of British Columbia and are currently recruiting participants for one of several upcoming user studies.

Our research is investigating the manner in which humans and robots communicate emotion through touch. For this purpose, we are developing a small, furry robot capable of expressing and recognizing emotion through the sense of touch.

Depending on the particular study, you may be asked to:
- Interact with the robot through touch;
- Attempt to judge the robot's emotional state;
- Answer questions about your current emotional state.

General Information:
- The studies take approximately 1 hour.
- Typical compensation for participation is $10.
- The studies normally will be conducted at the Vancouver campus of UBC.

General Restrictions on Participation:
- You must be between the ages of 19 and 50 years old.
- You must be a native English speaker, preferably from North America.
- You may not participate in more than one study related to this robot.

Specific details regarding the individual studies, including how to register for participation, can be found via the following link.

This study has been approved by The University of British Columbia; Office of Research Services; Behavioural Research Ethics Board.

https://sites.google.com/site/tamerrecruitment/
https://sites.google.com/site/tamerrecruitment/
https://sites.google.com/site/tamerrecruitment/
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https://sites.google.com/site/tamerrecruitment/

Physiological Affect Study

Thank you for your interest in participating in our study! For instructions on how to sign up, please go to the bottom of the page.

Research Overview

I am a member of the SPIN research group in the Department of Computer Science at the University of British Columbia. I am recruiting participants in user studies as part of my M.Sc. research under the supervision of Dr. Karon MacLean.

Our research is investigating the manner in which humans interact through the sense of touch. For this purpose, we are developing the Haptic Creature: a small, furry robot capable of expressing and recognizing emotions through the sense of touch.

Study Details

The purpose of this study is to examine how people interact through the sense of touch. In particular, this study examines the influence of this form of interaction on physiological signals.

You will interact with the Haptic Creature while you wear external (i.e. non-invasive) sensors that monitor heart rate, respiration rate, and perspiration. At points throughout the study you will be asked to report your current emotional state via a questionnaire.

General Information

- The study will take approximately **1 hour** to complete.
- You will be compensated **$10** for your participation.
- The study will be conducted at the **Vancouver campus of the University of British Columbia**.

Restrictions on Participation

- You must be between **19 and 50 years old**.
- You must be a **native English speaker**, preferably from North America.
- You must **not** have participated in any previous studies with the Haptic Creature.

This study has been approved by The University of British Columbia; Office of Research Services; Behavioural Research Ethics Board (#H01-80470).

If you have any questions, do not hesitate to e-mail me: Yasaman Sefidgar <[redacted]>

Signup Instructions

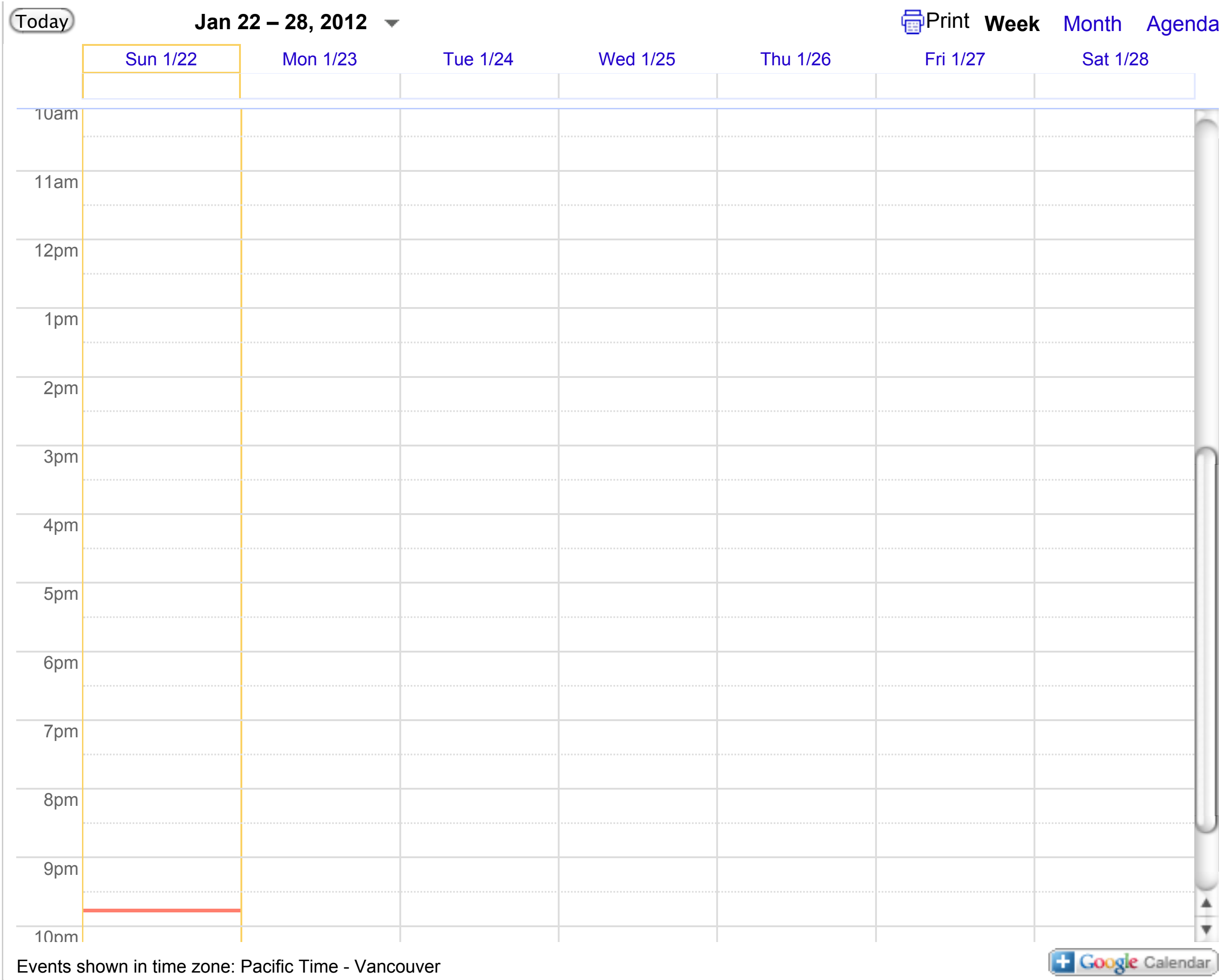
We greatly appreciate your willingness to participate in our studies; however, **we ask that you take seriously your role by signing up only if you intend to provide honest and thoughtful responses to the best of your ability**.

- The Recruitment Schedule below lists the available dates and times for participating in the study.
- Each cell represents an hour long slot
- Choose the slots for which you are able to participate
- Order these choices based on your preference, with the first being the most preferred and so on.
- Send me an e-mail with the information using the following template:

```
To: einsian@cs.ubc.ca
Subject: Physiological Affect Study Participation

    YOUR NAME
    YOUR AGE
    YOUR GENDER
    YOUR PHONE NUMBER
    YOUR E-MAIL ADDRESS

    "I affirm that I am between 19 and 50 years old."

    "I affirm that I am a native English speaker."

    "I affirm that I have not participated in any previous studies with the Haptic Creature."

    1ST PREFERRED TIME SLOT
    2ND PREFERRED TIME SLOT
    3RD PREFERRED TIME SLOT
    ...
```

- I will reply back to you as quickly as possible with confirmation of a specific time slot for your participation. More specific information, including the location of the study, will be provided after your e-mail for a time slot.
- Priority will be given to those who sign-up for earlier time slots as interest for our studies usually exceeds the required number of participants.

Recruitment Schedule, August 02 - September 23


Today
Jan 22 – 28, 2012
Print
Week
Month
Agenda
Sun 1/22
Mon 1/23
Tue 1/24
Wed 1/25
Thu 1/26
Fri 1/27
Sat 1/28
10am
11am
12pm
1pm
2pm
3pm
4pm
5pm
6pm
7pm
8pm
9pm
10pm
Events shown in time zone: Pacific Time - Vancouver
Google Calendar

```
Hello, XXX.

Thank you for your interest in participating in my study!

You have been scheduled...

    Date & Time:  DAYNAME, August ?? at ?:00?m
    Location   :  ICICS/CS x727

Information on locating the building and the room can be found on the
following web page...

    http://www.icics.ubc.ca/facilities/shared/directions.php

If you need to get in touch with me for any reason, do not hesitate to
contact me via email.

Thanks again!
```

Hello, XXX.

This is a reminder of your scheduled participation tomorrow in my user study. If you are no longer able to meet at the scheduled time, please reply to me via email as soon as possible.

If you are running late tomorrow, please e-mail me or try to reach me on the Usability Lab phone: ([redacted]) [redacted]-[redacted]. [This is a land-line telephone, which only accepts calls (not text messages).]

Also, as a courtesy to those who are sensitive to fragrances, please refrain from wearing any perfume or cologne, if possible.

Thank you again for your interest in participation.

D.2 Facilitator's Documents

- One-time preparation list
- Regular preparation list
- Study scripts
- Payment confirmation sign-up page

One-time preparation

The following items has been set up in X727C

- experimenter’s table and chair
- temporary wall
- experimenter's sit for giving instructions
- participant’s table and chair
- covering sheet
- participant’s machine
    - Monitor + VGA cable + power cable (for monitor)
    - Criollo laptop + charger
    - mouse
    - ear muffs
    - Set Criollo to never sleep
- experimenter’s machine
    - my laptop + charger
- timer
- sensor suit
    - sensor heads: ECG, Respiration, GSR, BVP
    - sensor cables
    - TT encoder
    - optical cable
    - TT USB
    - TT USB cable (standard A - mini B)
    - Uni-gel electrodes
    - 2 sets of charged batteries
    - adhesive tape
- sanitizer
- 2 power extensions
- camera
    - tri-pod
    - tape
    - power
    - controller
    - camera
    - view range on the ground
- 2 sound recorders
- Creature
    - fur
    - back-shell
    - power
    - bed
    - cooler
- door warning sheets
- documents
    - consent forms
    - participant’s instruction

one-time preparation list

        - SAM
        - STAI-6
        - sensor
        - interview questions
    - Experimenter's instructions
        - script-action instruction set
        - regular preparation list
        - overview of steps
- participant's pen

regular preparation list

										- participant’s monitor --> off
										- moving square:
										- file name --> yymmdd_ID
										- set on the questions screen
										- mouse in the middle of the table
										- ear muffs --> sanitized
										- mouse --> sanitized
										- sensors
										- sanitized
										- ECG electrodes --> attached
										- batteries --> checked, changed if necessary, recharged if necessary
										- collector
										- Creature moves
										- delay --> set at minimum
										- smooth start --> checked
										- video tape --> changed
										- recorder
										- battery
										- capacity
										- Creature
										- back shell --> fixed to cover fiberglass
										- firm-ware --> uploaded (if necessary)
										- cooled
										- set at off
										- on its bed

regular preparation list

										- consent form
										- 10$ stipend
										- pen
										- participant's instructions and questions
										- SAM
										- STAI-6
										- sensors
										- PAS
										- interview questions
										- experimenter's instructions
										- script-action
										- regular preparation
										- overview of steps
										- ordering --> assigned: ID%4
										- xx = 00, both practice and study sessions start with inactive
										- xx = 01, practice session starts with inactive, study session starts with active
										- xx = 10, practice session starts with active, study session starts with inactive
										- xx = 11, both practice and study sessions start with active
										- activate silent profile on the cell phone
										- replace the sit so there is enough room to reach it when the participant arrives

greet
Thanks for coming today. We really appreciate your participation in this study. Let's go to the study room so I can talk more about your involvement. Please come this way.

direct them to the room

direct them to the chair
You will be sitting here. Before we start I would like to ask you to turn your cellphone off. Thank you.

sit on the chair to their right and keep the robot on your laps

read
We are interested in how people interact through the sense of touch. For this purpose, we have developed this furry robot that mimics a small animal sitting on your laps. For about the next half an hour or so, you will be interacting with our furry robot in a number of trials. In some of the trials, it breathes by moving its back rib cage up and down. In some others, it doesn't breathe. You will be informed whether it is going to breathe or not at the beginning of each trial. It won't switch from breathing to not breathing or vice versa during a trial.

After each trial, you will rate your interaction in terms of how it made you feel. There are no right or wrong answers so simply respond as honestly as you can. When asking about your feelings we use two rating scales that are generally used for asking about people's feelings. Please read the instructions on how to use each of these scales and let me know when you are finished. You can find the instructions on the table in front of you.

go behind the wall
wait for them to finish (you can prepare TT program or update Creature's firmware although not suggested)
come back to them
get the robot back on your laps

read
Any questions?

answer questions (if any)

turn on the screen

read
Before we move on, I would like you to rate your feelings at this moment. This is just to help you get a feel of how ratings are done. So please look at the screen and by mouse clicks select the figures and numbers that best describe your feelings at this moment.

wait
pay attention to their answers

read and demonstrate
Thank you.

For interacting with the furry robot, you will keep it on your laps as I do right now. You will then have one of your hands in close contact with its back in a way that you can feel the breathing. It is best to lean your hand on your lap so that your hand doesn't get tired. You will use the other hand to stroke the furry robot. Move its head a little bit outward so you have enough room to move your hand.

For stroking, gently move your hand in one direction. Not too fast, not too slow. This is fast, this is slow, this is right in between which we want. This is pushing too hard, this is the opposite, and this is right in between which we want.

One point is that if you press too hard, it won't be able to breathe. So to feel the breathing only exert small forces.

We will now try to see in which direction you are more comfortable to keep the robot. You may want to turn so we can work together.

hand them in the robot

read
Please keep it on your laps. The direction doesn't matter now, we will try it in both ways. You can move its head outward. Move your hand fast, now slow, now in between. That's good. Let's focus on pressure. Press in firm, now lift off your hand, now in between. That's good.

wait a little bit for both speed and pressure

read
Now let's change the direction.

Let's try the same thing in this direction. Try stroking. You can move its head outward. Move your hand fast, now slow, now in between. Let's focus on pressure. Press in firm, now lift off your hand, now in between.

Which direction are you more comfortable with? Is it the direction in which you stroke with your dominant hand?

wait for the answer and record it

read
To better understand how the interaction affects you, we also monitor your cardiovascular and electrodermal activity. Please read the instructions about the sensors we use in the study for this purpose. I will help you then to wear on the sensors.

I am now going to get the robot back so you can easily put on the sensors

hook them up with the sensors
change the location of the encoder (if needed)

read
During the interaction with the robot you will wear these ear muffs. Also, we ask you not to look at the robot while interacting with it. This sheet that partially covers the robot and your hands will help you minimize your visual contact with the robot.

In each trial, you begin by watching a square moving on the screen for about a minute. During this time please keep your hand on your sides and not in contact with the furry robot. When prompted on the screen, place your hands on the robot's body with one hand fixed on its back and the other hand ready for stroking. When you are ready, let me know. E.g. say "ready". You will be then prompted on the screen to start stroking. The prompt disappears and a black screen comes up. Continue stroking on that black screen until you are asked to rate your feelings.

There is a practice session to help you get a feel of how the trials are like. Also, you can let me know if there is a need for any adjustments. The practice session is very similar to the study session but it is shorter.

After you submit your ratings please do not click on the screen any more. The application is sensitive to clicks and stops working properly when unwanted clicks occur.

From time to time I need to check the sensors. When I do that, please watch the square on the screen for about a minute again. The square then disappears and a blank screen comes up. Wait on that screen until you are asked to rate your feelings. Do not look at the robot during this time. Also, it is important not to move and talk during this time because sensors get noisy.

Now I'm going to my desk in order to check the sensors. Please put on the ear muffs.

connect the sensors to the encoder
turn on the encoder
turn on the camera
start recording

go behind the wall

prepare TT application
enter robot's mode as not moving
enter file name (yymmdd_hh_mm_ID_Bp)

start data collection by pressing space +
click on the top right corner of the screen to show squares

wait on squares for 20 sec

mark TT application twice when the blank screen comes up

wait on the screen for 20 sec

stop TT when questions come up

check the files while they are answering questions
if everything is fine, let the participant know that trials will start. Adjust otherwise.

read
Sensors are fine. Trials will start now. You can pick up the robot.

prepare TT application
enter robot's mode (either moving or not moving based on the ordering)
inform the participant of the robot's mode

Facilitator's instruction set

enter file name (yymmdd_hh_mm_ID_I/Ap)

click on the screen (except for top right and left corners)

when prompted, start data collection by pressing space +
click on the screen to show squares

wait on squares for 20 sec

mark TT application on "hands on" screen +
turn the robot on (if necessary) +
inform the participant

when prompted, mark TT application +
click on the screen for blank screen

wait on the screen for 20 sec

stop TT application when questions come up
turn the robot off (if turned on)
check the files while they are answering questions

repeat for two trials

come to them to hand in the PAS and demographic questionnaire

read
Thank you very much. We are done with practice trials. Please put the robot aside. Is there any thing that I need to adjust for you?

do the adjustments (if any)

wait for answer +
change the short loop to long loop

read
Before moving on to the study session, I would like you to take your time and fill out this questionnaire. You may need to take the sensors off of your hand.

wait until they are done
re-install the sensors (if necessary)

read
I again need to examine the sensors. Please put on the ear muff.

go behind the wall

prepare TT application
enter robot's mode as not moving
enter file name (yymmdd_hh_mm_ID_B1)

start data collection by pressing space +
click on the top right corner of the screen to show squares

wait on squares for 60 sec

mark TT application twice when the blank screen comes up wait on the screen for 75 sec

stop TT when questions come up

check the files while they are answering questions
if everything is fine, let the participant know that trials will start. Adjust otherwise.

read
Sensors are fine. Trials will start now. You can pick up the robot.

prepare TT application
enter robot’s mode (either moving or not moving based on the ordering)
inform the participant of the robot’s mode
enter file name (yymmdd_hh_mm_ID_I/A)

click on the screen (except for top right and left corners)

when prompted, start data collection by pressing space +
click on the screen to show squares

wait on squares for 60 sec

mark TT application on “hands on” screen +
turn the robot on (if necessary) +
inform the participant

when prompted, mark TT application +
click on the screen for blank screen

wait on the screen for 75 sec

stop TT application when questions come up
turn the robot off (if turned on)
check the files while they are answering questions

repeat for two trials

read
Thank you very much. I need to check the sensors one more time. So please put the robot aside and let me know when you are set. Please wear the ear muffs as well if you don’t.

go behind the wall

prepare TT application
enter robot’s mode as not moving
enter file name (yymmdd_hh_mm_ID_B2)

start data collection by pressing space +
click on the top right corner of the screen to show squares

wait on squares for 60 sec

mark TT application twice when the blank screen comes up

wait on the screen for 75 sec

stop TT when questions come up

check the files while they are answering questions

read
Thank you very much. we are done. You can take off the sensors now. For ECG sensor , I suggest to snap out the electrodes and remove the disposable part when taking shower.

help removing the sensors

read
There are few questions that I would like you to answer

turn the video off
turn the recorder on

THE UNIVERSITY OF BRITISH COLUMBIA

The Haptic Creature Project – Physiological Affect
(BREB Ethics Approval #H01-80470)
Compensation Record

Date	Participant Name	ID	Paid	Participant Signature	Participant E-mail
			$10.00		
			$10.00		
			$10.00		
			$10.00		
			$10.00		
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			$10.00		
			$10.00		
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			$10.00		
			$10.00		
			$10.00		
			$10.00		
Date	**Participant Name**	**ID**	**Paid**	**Participant Signature**	**Participant E-mail**

Revised 1/22/2012
Page 1 of 1

D.3 Participant's Documents

- Consent form
- SAM instructions
- STAI-6 instructions
- Sensor placement instructions
- Pet attitude scale questionnaire
- Interview questions

Department of Computer Science
2366 Main Mall
Vancouver, B.C. Canada V6T 1Z4
tel: ([redacted]) [redacted]-[redacted]
fax: ([redacted]) [redacted]-[redacted]

PARTICIPANT'S COPY CONSENT FORM

Project Title: The Haptic Creature Project – Physiological Affect
(UBC Ethics #H01-80470)

Principal Investigators: Dr. Karon MacLean; Associate Professor; Dept of Computer Science; [redacted]
Student Investigator: Yasaman S. Sefidgar; M.Sc. Candidate; Dept of Computer Science; [redacted]

The purpose of this study is to examine how people's interaction through the sense of touch impacts their emotions as measured by physiological metrics.

In this study you will be asked to interact with a small robot covered in a soft fur. This robotic creature, loosely resembling a small animal such as a cat, dog, or rabbit, can simulate breathing. At points throughout the study you will be asked to report your current emotional state via a questionnaire. You will also be asked to provide general demographic information as well as feedback on your experiences during the study.

During the interaction, you will be asked to wear external (i.e., non-invasive) sensors that collect some basic physiological information such as the heart rate, respiration rate, some muscle activity, and perspiration.

You will be asked to wear headphones to mask external noises. During the study you may be videotaped. Videotapes may be used for analysis and may also be used in research presentations in the Department of Computer Science at the University of British Columbia. We will contact you for explicit permission before using any video or still images taken here which could identify you, in presentations outside of UBC. If you are not sure about any instructions, do not hesitate to ask.

REIMBURSEMENT:	$10
TIME COMMITMENT:	1 × 60 minute session
CONFIDENTIALITY:	*You will not be identified by name in any study reports. Data gathered from this experiment will be stored in a secure Computer Science account accessible only to the experimenters.*

You understand that the experimenter will ANSWER ANY QUESTIONS you have about the instructions or the procedures of this study. After participating, the experimenter will answer any other questions you have about this study.

Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time without jeopardy. Your signature below indicates that you have received a copy of this consent form for your own records, and consent to participate in this study.

If you have any concerns about your treatment or rights as a research subject, you may contact the Research Subject Info Line in the UBC Office of Research Services at 604-822-8598.

Department of Computer Science
2366 Main Mall
Vancouver, B.C. Canada V6T 1Z4
tel: ([redacted]) [redacted]-[redacted]
fax: ([redacted]) [redacted]-[redacted]

RESEARCHER'S COPY CONSENT FORM

Project Title: The Haptic Creature Project – Affective Touch Influence
(UBC Ethics #H01-80470)

Principal Investigators: Dr. Karon MacLean; Associate Professor; Dept of Computer Science; [redacted]
Student Investigator: Yasaman S. Sefidgar; M.Sc. Candidate; Dept of Computer Science; [redacted]

The purpose of this study is to examine how people's interaction through the sense of touch impacts their emotions as measured by physiological metrics.

In this study you will be asked to interact with a small robot covered in a soft fur. This robotic creature, loosely resembling a small animal such as a cat, dog, or rabbit, can simulate breathing. At points throughout the study you will be asked to report your current emotional state via a questionnaire. You will also be asked to provide general demographic information as well as feedback on your experiences during the study.

During the interaction, you will be asked to wear external (i.e., non-invasive) sensors that collect some basic physiological information such as the heart rate, respiration rate, some muscle activity, and perspiration.

You will be asked to wear headphones to mask external noises. During the study you may be videotaped. Videotapes may be used for analysis and may also be used in research presentations in the Department of Computer Science at the University of British Columbia. We will contact you for explicit permission before using any video or still images taken here which could identify you, in presentations outside of UBC. If you are not sure about any instructions, do not hesitate to ask.

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Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time without jeopardy. Your signature below indicates that you have received a copy of this consent form for your own records, and consent to participate in this study.

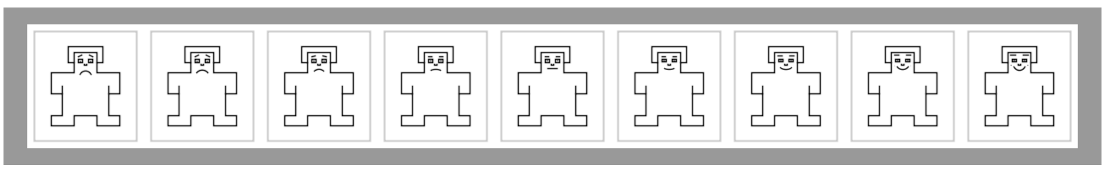
If you have any concerns about your treatment or rights as a research subject, you may contact the Research Subject Info Line in the UBC Office of Research Services at 604-822-8598.

You hereby CONSENT to participate and acknowledge RECEIPT of a copy of the consent form:

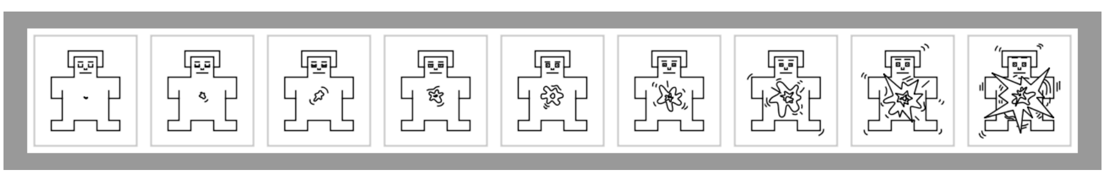
Printed Name__________________________ Date____________ Signature________________________

Below, you will see 3 sets of 9 figures, each arranged along a continuum. We call this set of figures SAM, and you will be using these figures to rate how you felt while interacting with the furry robot. You will make all 3 ratings after *each* trial. SAM shows three different kinds of feelings: Unhappy vs. Happy, Calm vs. Excited, and Controlled vs. In-control.

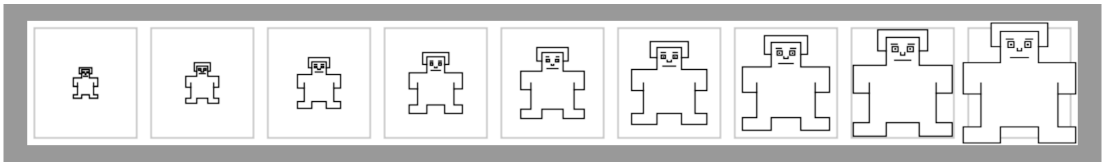
You can see that each SAM figure varies along each scale. In this illustration, the first SAM scale is the unhappy-happy scale, which ranges from a frown to a smile. At one extreme of the unhappy vs. happy scale, you felt happy, pleased, satisfied, contented, hopeful. If you felt completely *happy* while interacting with the furry robot, you can indicate this by selecting the figure at the right. The other end of the scale is when you felt completely unhappy, annoyed, unsatisfied, melancholic, despaired, bored. You can indicate feeling completely *unhappy* by selecting the figure at the left. The figures also allow you to describe intermediate feelings of pleasure, by selecting any of the other pictures. If you felt completely neutral, neither happy nor unhappy, select the figure in the middle.



The calm vs. excited dimension is the second type of feeling displayed here. At one extreme of the scale you felt stimulated, excited, frenzied, jittery, wide-awake, aroused. If you felt completely *aroused* while interacting with the robot, select the figure at the right. On the other hand, at the other end of the scale, you felt completely relaxed, calm, sluggish, dull, sleepy, unaroused. You can indicate you felt completely *calm* by selecting the figure at the left. As with the unhappy-happy scale, you can represent intermediate levels by selecting any of the other figures. If you are not at all excited nor at all calm, select the figure in the middle of the row.



The last scale of feeling that you will rate is the dimension of controlled vs. in-control. At one end of the scale you have feelings characterized as completely controlling, influential, in control, important, dominant, autonomous. You can indicate that you felt *dominant* by selecting the figure at the right. At the opposite extreme of this scale, you felt completely controlled, influenced, cared-for, awed, submissive, guided. Please indicate feeling *controlled* by selecting the figure at the left. Note that when the figure is large, you feel important and influential, and that it will be very small when you feel controlled and guided. If you feel neither in control nor controlled select the middle picture. Please also note that although you are asked to rate your feelings while interacting with the robot, feeling in-control or controlled is about your internal feelings, and not about your relation with the robot.



An important point to notice is that your rating of each trial should reflect your immediate personal experience, and no more. Please rate each one *AS YOU ACTUALLY FELT WHILE YOU INTERACTED WITH THE ROBOT*.

After a trial, make your ratings on all 3 dimensions as quickly as possible and get ready for the next trial. There are no right or wrong answers, so please rate your feelings as honestly as possible.

Should you have any questions regarding the rating, feel free to ask the facilitator.

STAI-6 - Self-assessment questionnaire (Y-6 item)

A number of statements which people have used to describe themselves are given below. After each trial, read each statement and then select the most appropriate number to the right of the statement to indicate how you feel right at the moment based on your experience while interacting with the furry robot. There are no right or wrong answers. Do not spend too much time on any statement but give the answer which seems to best describe your present feelings best.

	Not at all	Somewhat	Moderately	Very much
1. I feel calm	1	2	3	4
2. I am tense	1	2	3	4
3. I feel upset	1	2	3	4
4. I am relaxed	1	2	3	4
5. I feel content	1	2	3	4
6. I am worried	1	2	3	4

Physiological Sensors Instructions

There are 4 sensors used in this study:

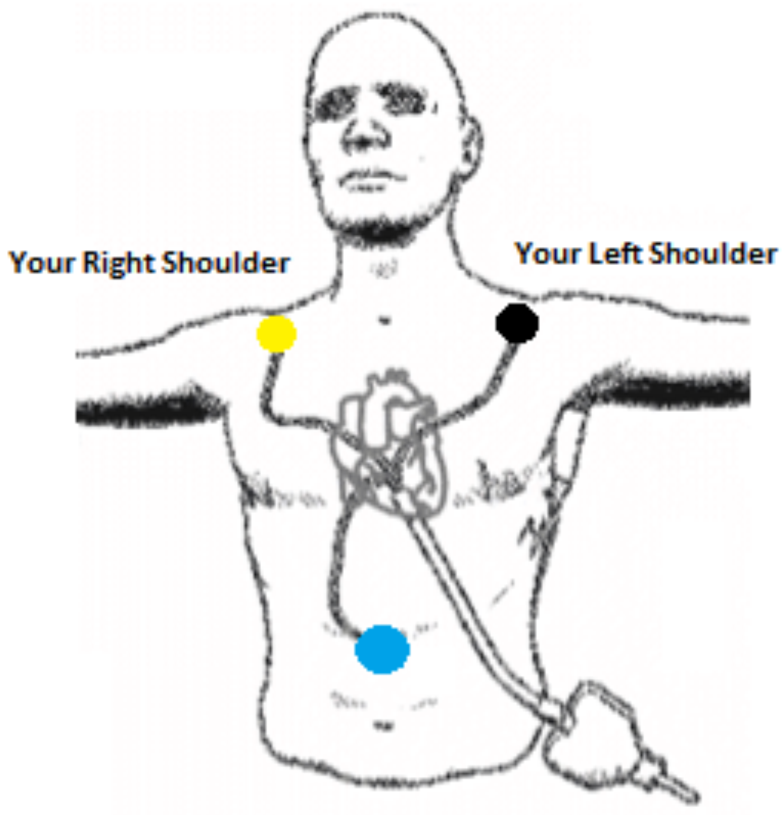
- Electrocardiogram (ECG) sensor to record heart electrical activity
- Respiration sensor to record lungs activity
- Galvanic Skin Response (GSR) sensor to record electrodermal activity
- Blood Volume Pulse (BVP) sensor to record heart beats

Please read on for the instructions on how sensors are used.

ECG sensor

ECG sensor consists of three electrodes placed on the chest. Sticky disposable electrodes are used to keep the sensors fixed. Please peel off the electrodes and stick them to your chest as follow:

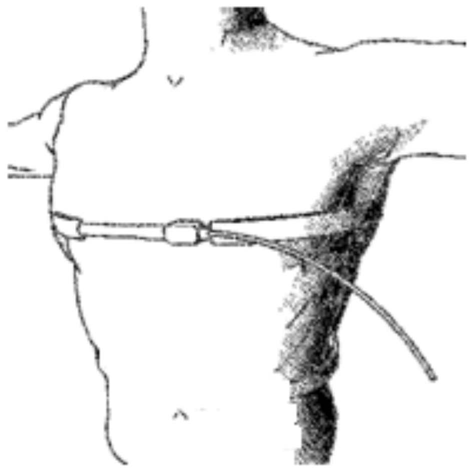
- Yellow electrode: on the right shoulder
- Black electrode: on the left shoulder
- Blue electrode: lower center or left side of the chest



After sticking electrodes, press a little bit against each to make sure they have stuck to your skin.

Physiological Sensors Instructions

Respiration sensor
Respiration sensor consists of a long velcro strap stretched around the chest as follows. To wear the sensor, rise your arms up, take a deep breath and ask the facilitator to fasten the strap around your chest.



GSR sensor
GSR sensor has two electrode snaps sewn inside velcro straps that are fastened around the index finger and the ring finger tight enough so the electrode surface is in contact with the finger pad. However, it shouldn't be too tight to limit blood circulation. Ask the facilitator to help you fasten the straps around your fingers.

BVP sensor
BVP sensor is held pressed against the palmer surface of the thumb with a velcro strap. It shouldn't be too tight to limit blood circulation as well. Ask the facilitator to help you with placing the sensor on the tip of your thumb.

There are considerations for using the sensors. Please avoid speaking, moving your body, or moving your fingers during the trials when data is collected. Otherwise data becomes noisy. At all the other times you are free to move and speak.

If at any time you found that a sensor is loose or it is bothering you, ask the facilitator for adjustments.

ID: Date: Pet Attitude Scale*

Age ____

Sex ____

Please answer each of the following questions as honestly as you can, in terms of how you feel right now. This questionnaire is anonymous and no one will ever know which answers are yours. So, don't worry about how you think others might answer these questions. There aren't any right or wrong answers. All that matters is that you express your true thoughts on the subject.

Please answer by circling one of the following seven numbers for each questions.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

For example, if you slightly disagree with the first item, you would circle the number three.

Thank you for your assistance.

1. I really like seeing pets enjoy their food.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

2. My pet means more to me than any of my friends (or would if I had one).

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

3. I would like to have a pet in my home.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

4. Having pets is a waste of money.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

Please note that this label only exists in the thesis copy not in the original scale

5. House pets add happiness to my life (or would if I had one).

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

6. I feel that pets should always be kept outside.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

7. I spend time every day playing with my pet (or would if I had one).

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

8. I have occasionally communicated with my pet and understood what it was trying to express (or would if I had one).

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

9. The world would be a better place if people stop spending so much time caring for their pets and started caring more for other human beings instead.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

10. I like to feed animals out of my hand.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

11. I love pets.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

Please note that this label only exists in the thesis copy not in the original scale

12. Animals belong in the wild or in zoos, but not in the home.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

13. If you keep pets in the house, you can expect a lot of damage to furniture.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

14. I like house pets.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

15. Pets are fun, but it’s not worth the trouble of owning one.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

16. I frequently talk to my pets (or would if I had one).

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

17. I hate animals.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

18. You should treat your house pets with as much respect as you would a human member of your family.

1	2	3	4	5	6	7
Strongly Disagree	Moderately Disagree	Slightly Disagree	Unsure	Slightly Agree	Moderately Agree	Strongly agree

Please note that this label only exists in the thesis copy not in the original scale

interview questions ID: Date:

Clarify with ‘why’ and ‘how’ whenever possible

<table>
<tr><td>Were you comfortable during the interaction? (elaborate on sensors, the direction of interaction, and the gesture)</td><td>How the interaction can change so you feel better? How do you prefer it be?</td></tr>
<tr><td rowspan="2">Did you like breathing? How did it felt like?</td><td>How did you feel the first time the robot started breathing?</td></tr>
<tr><td>How was the time? Was it any different during the trials in study session?</td></tr>
<tr><td>Can you describe what you felt and perceived during the interaction?</td><td>else?</td></tr>
</table>