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# The Role of Affective Touch in Human-Robot Interaction: Human Intent and Expectations in Touching the Haptic Creature

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**Abstract** Affective touch is a crucial element of early human development, social bonding, and emotional support. Technically and socially difficult to study, it has received little research attention. Our approach employs animal models instantiated by the Haptic Creature, a touch-centric social robot. In this paper, we examine how humans communicate emotional state through touch to the Haptic Creature and their expectations of its reactions. A user study is presented where participants selected and performed gestures they would likely use when conveying nine different emotions to the Haptic Creature. We report a touch dictionary compiled for our research; the gestures participants chose from it; and video analysis of their enactment. Our principal findings regard patterns of gesture use for emotional expression; physical properties of the likely gestures; expectations for the Haptic Creature's response to mirror the emotion communicated; and analysis of the human's higher intent in communication. From the latter finding, we present five tentative categories of "intent" that overlap emotion states: *protective*, *comforting*, *restful*, *affectionate*, and *playful*. These results can help inform the future design of social robots by illuminating details of one direction in affective touch interactions.

**Keywords** Affective touch · Socially interactive robots · Affect display · Human-robot interaction (HRI) · Affect · Haptics · Emotion · Touch · Robot pets

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**Fig. 1** The Haptic Creature. (Photo: Martin Dee)

## 1 Introduction

In the Haptic Creature project, we are investigating the role of affective touch in the social interaction between human and robot—specifically its display, recognition, and emotional influence. Understanding the possibilities and mechanisms by which affective touch can operate, as supported by an expressive, touchable robot, has implications for the design of many human-robot interaction (HRI) applications, ranging from fostering companionship to therapeutic interventions for children, the ill, and the elderly.

Our approach is to leverage research in human-animal interaction through use of a robotic creature that mimics a small animal, such as a cat or dog, sitting on a person's lap. Dubbed the Haptic Creature (Fig. 1), our robot interacts with the human through the modality of touch. An array of touch sensors over its body, coupled with an accelerometer, allow the robot to sense being touched and moved, while it displays it emotional state through adjusting the stiffness of its ears, modulating its breathing, and presenting a vibrotactile purr [50].

While a necessary goal of our research is that the robot be able to recognize human touch gestures, it is by no means sufficient for a compelling interaction. The Haptic Creature must also be able to reason about the higher-level meaning of the touch, which, in our work, is its emotional content. In addition, the robot must present an appropriate response to the human. To that end, we present a study that examines the manner in which humans communicate their emotional state to the Haptic Creature and their expectations of its reaction when their sole interaction modality is touch. Our contributions include:

– A 30-item touch dictionary developed from social psychology and human-animal interaction literature.
– A study design that elucidates parameters of affective touch initiated by the human.
– Identification of touch gestures likely to be used to communicate specific emotions and those which are not.
– Properties of human-robot affective touch for likely gestures.
– Human's expectations for mirrored emotional responses from robot.
– Categorization of the human's higher intents through affective touch: *protective*, *comforting*, *restful*, *affectionate*, and *playful*.

The remainder of this section describes our overall research approach and the specific goals of the work presented herein. This is followed by sections that review related work; briefly describe the Haptic Creature; and discuss the development of the touch dictionary. We continue with details of the user study conducted and subsequent results. This is followed by a discussion that delves deeper into our primary findings. Finally, an appendix summarizes the procedures used for coding the video recordings of participants' touch gesture performances.

### 1.1 Research Approach and Goals

To systematically study the interplay between human and robot in the course of affective touch, we have decomposed the overall interaction into its constituent parts (Fig. 2). It is highly probable that it involves an interactive and synergistic component whereby the emotional state of the human changes in the course of the exchange, and her touching patterns then change as well. Therefore, we wished to examine each part of the system independently, then later synthesize these in order to observe changes as a result of the full interaction loop.

We have previously conducted research that examines the manner and success of the Haptic Creature in communicating its emotional state to the human [52] (Fig. 2, cells 3→4).

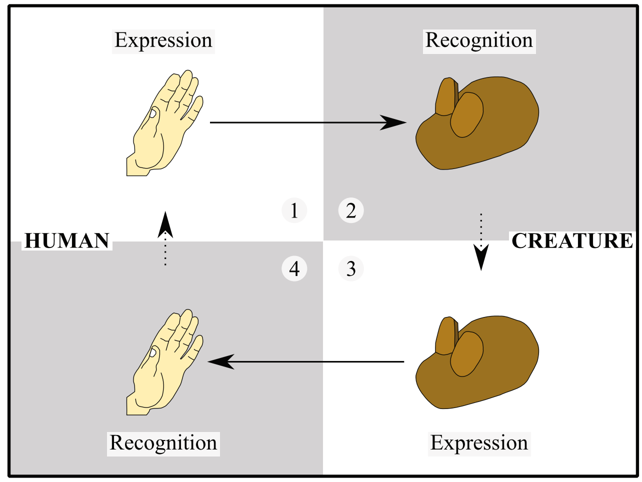


**Fig. 2** Interaction loop between human and Haptic Creature. *Solid* (*horizontal*) *lines* between cells represent a display of affective touch. *Dashed* (*vertical*) *lines* denote an internal update of emotional state as a result of the interaction

The focus of the present work, conversely, is on affective touch originating from the human and displayed to the robot (Fig. 2, cells 1→2). In addition, research is being conducted that combines the knowledge gained from these two studies then circumambulates the full interaction loop. Its focus is on how the communication of emotion through touch influences the emotional state of the human (Fig. 2, cells 4→1).

We are actively developing our robot in concert with our user studies. The Haptic Creature is being designed to study affective touch, but it is also being influenced by the results of studies in which it is employed. We believe that at this stage of our research it is important to conduct tests in more controlled environments. This affords greater control of humans interacting with a new robot and, more importantly, helps guard against a variety of confounding factors inherent in the domain under investigation (see Sect. 2.1). As the Haptic Creature stabilizes and as our research illuminates details of affective touch, we plan to move to more realistic scenarios through ethnographic-based studies (e.g., [28, 45]) to validate our early findings as well as expose new areas of investigation.

Table 1 enumerates the six specific research questions we address in the current research, the goals of which are twofold. Our primary interest, in pursuit of a general understanding the nature of affective touch, is in the general intent and resultant expectations of the human when expressing emotion through touch. Second, the practical outcome of this knowledge is design guidance: for the community, in general, and our ongoing development of the Haptic Creature, in particular. For example, as we update the robot's sensing hardware and advance its gesture recognition software, we can account for likely gestures while discounting those unlikely to occur for this robot. In this paper, we concentrate on the first goal, which the study was designed to

**Table 1** Questions addressed by the research presented in this paper

| | |
|---|---|
| I. | What is the set of plausible touch gestures a human might use to interact with the Haptic Creature? |
| II. | From this set, which particular touch gestures are most likely to be used to communicate emotional state? |
| III. | Of the likely touch gestures, which specific emotions are they used to communicate? |
| IV. | What is the profile of the likely touch gestures? More specifically, what are the common points of contact, durations, and intensities of these gestures? |
| V. | What are the expected emotional responses from the Haptic Creature to the gestures performed for a specific emotion? |
| VI. | How can our results inform the design of social robots which need to communicate emotion haptically? |

address; implications for design, particularly for the Haptic Creature, are discussed where appropriate.

## 2 Related Work

This project draws on research in affective touch, general models of emotion, and prior social robot development. An overview of the most relevant aspects are presented below.

### 2.1 Affective Touch

The communication of one's own emotional state is an important aspect of social interaction, with groups, individuals, and with animals. When individuals share their internal state, they receive approval or disapproval (the latter is important for socialization), and a response that might be supportive (or not) in a variety of ways. Additionally, emotions help to regulate and add significance to an interaction [5].

The study of human *affect display*—the external manifestation of internal emotional state—has mainly focused on the modalities of vision and audition, by social psychologists and HRI designers alike. Visually, humans rely on facial expressions to convey emotion [10], so it is not surprising that affect display in socially interactive robotics has been similarly focused (e.g., [4, 6, 24, 38]). Prosody is the primary parameter of affect display in speech, which has likewise guided auditory systems (e.g., [3, 39, 49]).

On the other hand, *affective touch*—touch that communicates or evokes emotion—has received much less attention in either psychology[18] or social robotics. And yet the sense of touch is unique and important socially. The skin is the largest organ in the human body and the first sense organ to develop; it plays a major role in early development [29]. Touch is proximal, requiring close or direct, physical contact to sense [15].

Recent studies with humans have shown that touch is capable of communicating distinct emotions [16, 17]. General

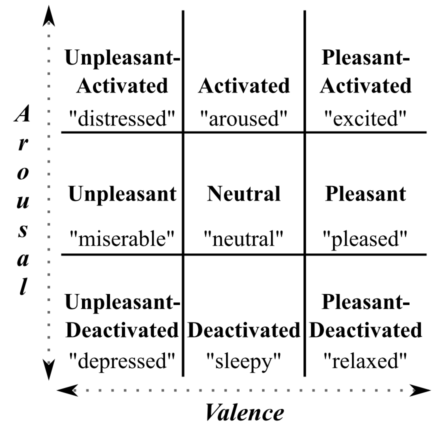


**Fig. 3** A two-dimensional, bipolar model of emotion (adapted from Russell). *Valence* ranges from unpleasant to pleasant. *Arousal* ranges from deactivated to activated. Quoted names are Russell's emotion labels

studies on interpersonal touch, however, have shown various confounding factors such as gender, familiarity, social status, and culture (e.g., [11, 26, 31, 48]). Additionally, these sorts of studies have been found to cause significant levels of participant discomfort (e.g., [46]).

In an attempt to avoid these issues in the Haptic Creature project, we have chosen to draw from models of interaction between human and animal rather than between humans. This approach leverages the rich patterns of nonverbal touch communication that already exist between human and animal [1, 8]. Further, the long history of human-animal bonds [40, 41] is in keeping with our goal of investigating the role of affective touch in fostering companionship.

### 2.2 Dimensional Model of Emotion

Our work closely follows from Russell's theory that emotion is composed of two bipolar, orthogonal dimensions [33, 34, 36]. As depicted in Fig. 3, one dimension, *valence*, is described by the continuum from unpleasant to pleasant, while the other dimension, *arousal*, ranges from deactivated to activated.

As described in [52], the Haptic Creature's affect space is modeled using these same valence and arousal dimensions. We use a similar model in the present study when examining affect expressed from the human: the emotions we examine are chosen from various points in this two-dimensional space (Sect. 5.3).

### 2.3 Related Robots

Our research with the Haptic Creature lies at the intersection of the following domains:

– socially interactive robotics;
– affect display;
– zoomorphic robots; and
– touch interaction.

While a comprehensive review of these various domains is beyond the scope of this paper, we draw attention to some other projects that inhabit this space and have provided important contributions to its understanding.

Most notable are the small set of social robots combining touch interaction and animal-like form: Shibata's baby seal, Paro [42]; Stiehl's teddy bear, the Huggable [43]; Saldien and Goris's elephant-like creature, Probo [37]; Ugobe's dinosaur, Pleo [44]; and Sony's dog, Aibo [13]. We cover some of the more significant differentiating factors in relation to these robots. The rationales behind these factors are given in more detail in [50].

The primary differentiation of the Haptic Creature is its strong concentration on the modality of touch for affect display. The Huggable is the only other device possessing full-body sensing; Paro and Aibo both have only limited interaction points for touch input; and it is unclear what touch sensing, if any, Probo currently employs. Most importantly, each of these other projects relies most heavily on visual and auditory expression for affect display originating from robot itself, rather than on touch.

Secondly, the Haptic Creature is unique in its level of zoomorphism. The aforementioned robots all have, to varying degrees, clearly defined features and forms. While a goal of the Haptic Creature is that it be recognizable as animal-like, it is consciously designed to have a more minimalistic appearance. This limits the human's expectations while also shifting focus to the interaction rather than the form.

## 3 The Haptic Creature

The Haptic Creature (Fig. 1) is a robot that mimics a small lap pet. Its affect display system is composed of body, two ears, and breathing and purring mechanisms. For the sensing of human affect, the robot features touch sensors over its entire body and an internal accelerometer for capturing both general movement and high-frequency or localized events such as being poked, shaken, or dropped. A more extensive description of the Haptic Creature's mechatronics and computational architecture can be found in [51], while our preliminary approach to gesture sensing is described in [7].

The robot interacts with the world primarily through the modality of touch. That is, it senses the world exclusively through touch and motion, and the intent is the same for its display. While the nature of some interactions—e.g., breathing—unavoidably produces visual elements as well, effort has been made to reduce non-touch artifacts wherever possible.

The Haptic Creature's emotional state is computed based on interpretation of its sensory inputs. For example, when a human gently strokes the robot sitting on her lap, the Haptic Creature first senses and classifies the gesture and its parameters. Next, depending on the robot's present programmed "personality", it may register this touch as a pleasing interaction. The Haptic Creature then might update its internal emotional state to reflect happiness and, in turn, externally display this through slightly stiffened ears; a gentle purring vibration; and average-paced, rhythmic breaths that cause its rib cage to press and release against the human's hand.

## 4 Touch Dictionary

In the context of our work, we consider a *touch gesture* broadly as the placement of a part or parts of one's body in direct physical contact with another's body, often coupled with movement, in order to convey meaning or intent. In this paper, "gesture" will frequently be substituted as shorthand for "touch gesture".

Our investigation required a set of plausible touch gestures for the human to interact with the Haptic Creature (Research Question I). A review of relevant literature did not yield a comprehensive list in any one source, so we set out to compile our own *touch dictionary*. The result has 30 items and is presented in Table 2.

We began with literature sources from human-animal interaction [1, 22, 23], human-human touch [47], and human-human affective touch [16, 17]. We then generated three separate gesture lists, one from each of these research domains.

Next, we removed impractical or inappropriate gestures. For example, the touch gestures *high five* and *fingers interlock* were removed because the robot possesses no hands or fingers. With the exception of *kiss*, we removed all mouth-related gestures, such as *lick* or *bite*, as these were deemed unsuitable or unlikely.

We then merged these reduced lists. Frequently, gestures from different sources overlapped in kind but not name, so we reduced each to a single, common label across all. For example, our gesture label *contact without movement* was referenced with slightly different wording in all works.

Finally, though not mentioned in our original source materials, the gestures *cradle* and *rock* were added after informal discussions with pilot participants noted their absence.

The original source materials additionally provided definitions on how to perform a small set of the touch gestures. Appropriate existing definitions were used, while all others were adapted from The New Oxford American Dictionary [27]. The gestures *rock* and *rub* used the phrase "to and fro"; while no participants in the present study expressed difficulty, this has since been changed to "back and forth" based on subsequent pilot feedback. In all cases, "Haptic

**Table 2** The touch dictionary

| Gesture label | Gesture definition | Gesture label | Gesture definition |
|---|---|---|---|
| Contact Without Movement | Any undefined form of contact with the Haptic Creature that has no movement. For example: laying one's hand a top the Haptic Creature, or resting one's arm alongside it. | Press | Exert a steady force on the Haptic Creature with your flattened fingers or hand. |
| Cradle | Hold the Haptic Creature gently and protectively. | Pull | Exert force on the Haptic Creature by taking hold of it in order to move it towards yourself. |
| Finger Idly | Gently and randomly pull at the hairs of the Haptic Creature's fur with your fingers. | Push | Exert force on the Haptic Creature with your hand in order to move it away from yourself. |
| Grab | Grasp or seize the Haptic Creature suddenly and roughly. | Rock | Move the Haptic Creature gently to and fro[a] or from side to side. |
| Hit | Deliver a forcible blow to the Haptic Creature with either a closed fist or the side or back of your hand. | Rub | Move your hand repeatedly to and fro[a] on the fur of the Haptic Creature with firm pressure. |
| Hold | Grasp, carry, or support the Haptic Creature with your arms or hands. | Scratch | Rub the Haptic Creature with your fingernails. |
| Hug | Squeeze the Haptic Creature tightly in your arms. Hold the Haptic Creature closely or tightly around or against part of your body. | Shake | Move the Haptic Creature up and down or side to side with rapid, forceful, jerky movements. |
| Kiss | Touch the Haptic Creature with your lips. | Slap | Quickly and sharply strike the Haptic Creature with your open hand. |
| Lift | Raise the Haptic Creature to a higher position or level. | Squeeze | Firmly press the Haptic Creature between your fingers or both hands. |
| Massage | Rub or knead the Haptic Creature with your hands. | Stroke | Move your hand with gentle pressure over the Haptic Creature's fur, often repeatedly. |
| Nuzzle | Gently rub or push against the Haptic Creature with your nose or mouth. | Swing | Move the Haptic Creature back and forth or from side to side while suspended. |
| Pat | Gently and quickly touch the Haptic Creature with the flat of your hand. | Tap | Strike the Haptic Creature with a quick light blow or blows using one or more fingers. |
| Pick | Repeatedly pull at the Haptic Creature with one or more of your fingers. | Tickle | Touch the Haptic Creature with light finger movements. |
| Pinch | Tightly and sharply grip the Haptic Creature's fur between your fingers and thumb. | Toss | Throw the Haptic Creature lightly, easily, or casually. |
| Poke | Jab or prod the Haptic Creature with your finger. | Tremble | Shake against the Haptic Creature with a slight rapid motion. |

Entries listed in alphabetical order of *Gesture Label*; top to bottom, left to right. [a]Though no participants in the present study expressed difficulty with the wording "to and fro", this phrase has been replaced with "back and forth" in subsequent studies based on pilot participant feedback

Creature" was substituted for the receiver of the touch. Others wishing to utilize our touch dictionary need only replace the definition's touch recipient in a similar manner.

## 5 Methods

In a within-subject, single-factor (emotion communicated) comparison, participants answered questions about and performed touch gestures that they would use to convey each of nine emotions (one per factor level). For each emotion communicated, they also predicted the emotional response of the robot to the touch gestures they had just performed and reported any consequent change in their own felt emotional state.

### 5.1 Participants

Data from 30 individuals (50% female) were used. Recruited via fliers, online classifieds, and mailing lists, each was compensated CAD$10 for their participation. Ages ranged from 18 to 41 ($M = 24.33$, $SD = 6.47$), and all self-identified as native English speakers (90% from North America, 10% from elsewhere). None had previously participated in studies with the Haptic Creature. Overall experiences with pets and general attitudes towards them are presented in Sect. 6.4.

### 5.2 Study Setup

The study was conducted in a soundproof observation studio housing a desk and non-adjustable office chair. Atop the

**Fig. 4** Participant interacting with Haptic Creature during study

desk was a 17-inch LCD monitor, a keyboard, and a mouse. Also situated on the desk was a video camera mounted to a tripod that was positioned directly behind and above the computer monitor. All study software, including control of the Haptic Creature, was written in Java and executed on an Intel-based PC running the Gentoo [14] Linux operating system.

Participants sat in the chair and faced the monitor on the desk. The mouse was placed on the side that they self-identified as their mouse hand. The Haptic Creature was situated in the participant's lap with its back end initially facing their non-mouse hand; however, participants were instructed to adjust the robot's position as they saw fit throughout the study. The Haptic Creature was passive throughout: it did not move, communicate with the participants in any way, or respond to their touch gestures. As a result, no extraneous sounds were generated by the robot. Nonetheless, participants wore ear muffs to provide a consistent setup across all our studies (Fig. 4).

### 5.3 Procedure

The entire study took approximately 60 to 75 minutes to complete. Participants were presented with a detailed set of instructions, asked to report their current emotional state, and then taken through the main part of the user study. Once completed, a questionnaire was administered. The facilitator was not present in the room with the participant while the study was being conducted.

The main part of the study was repeated over nine levels of the emotion communicated factor: *distressed*, *aroused*, *excited*, *miserable*, *neutral*, *pleased*, *depressed*, *sleepy*, and *relaxed*. These emotions were taken directly from the two-dimensional model of emotion (Fig. 3) and represent minimum, maximum, and average states for both valence and arousal.

Each participant was presented with all nine levels in randomized order, and a brief (30 second) rest break was given at the end of all but the final condition.

The main part of the study was composed of the following steps:

- likelihood rating of touch gestures;
- performance of likely touch gestures;
- prediction of the robot's emotional response; and
- participant affect report.

Each step of the procedure is detailed below.

#### *5.3.1 Instructions*

Instructions provided participants with a general overview of the research being conducted; an explanation of the Haptic Creature and information on interacting with it; and the study procedure, including a detailed explanation of the response formats employed.

#### *5.3.2 Touch Gestures Likelihood Rating*

Participants were presented with an emotion to communicate to the Haptic Creature and asked to rate the likelihood of using gestures from the touch dictionary (Table 2).

Each gesture label and its corresponding definition was presented one at a time in randomized order. Responses were recorded on a five-point rating scale: *Very Unlikely* (1), *Unlikely* (2), *Neither Unlikely nor Likely* (3), *Likely* (4), *Very Likely* (5).

When determining a response, participants were asked to imagine the Haptic Creature to be their pet, one with which they have a close and comfortable relationship. They were directed to think about and imagine that they were feeling the given emotion then consider the given touch gesture. Participants were further instructed that they were not feeling the given emotion *because of* the Haptic Creature. Rather, they were to consider conveying the emotion as if the robot was an impartial observer or companion.

#### *5.3.3 Likely Touch Gestures Performance*

Participants physically performed a subset of the gestures on the Haptic Creature. Criterion for inclusion in this subset was any gesture the participant ranked as likely to be used for the given emotion (i.e., $\geq$4) in the previous step.

Touch gestures from the subset and their corresponding definitions were presented one at a time in randomized order.

**Table 3** Emotion label list for predicting the Haptic Creature's emotional response

| | | | |
|---|---|---|---|
| Afraid[a] | Angry[a] | Aroused | Depressed |
| Disgusted[a] | Distressed | Excited | Happy[a] |
| Miserable | Neutral | Pleased | Relaxed |
| Sad[a] | Sleepy | Surprised[a] | None Of These[b] |

Unmarked labels are from Russell; [a]from Ekman; [b]avoids artificial agreement

As in the previous step, participants were directed to imagine feeling the given emotion then consider the presented touch gesture.

Each gesture performance was captured on video and by the robot's touch sensors and accelerometer. An analysis of the video recordings will be presented in Sect. 6.2. The sensor data recordings are intended for future use in refinement of the Haptic Creature's gesture recognition engine [7] and will not be discussed in this paper.

#### 5.3.4 Haptic Creature Emotional Response Prediction

Participants predicted the emotional response of the Haptic Creature as a result of the gestures they had just performed. They chose one of sixteen emotion labels from a provided list (Table 3). Six options were Ekman's basic emotions [9]: *afraid*, *angry*, *disgusted*, *happy*, *sad*, and *surprised*. Nine were from Russell's dimensional model of affect (as discussed in Sect. 2.2): *aroused*, *depressed*, *distressed*, *excited*, *miserable*, *neutral*, *pleased*, *relaxed*, and *sleepy*. The emotion words were presented in alphabetized order with a final option, *none of these*, to address shortcomings of forced-choice emotion responses [12, 35].

Consistent with the list used in our previous study [52], the decision to include both Ekman and Russell emotion labels was to increase the overall richness of available choices by combining words from research on distinct emotions (Ekman) with those from research on the dimensional nature of emotions (Russell).

#### 5.3.5 Participant Affect Report

At the beginning of the study and each time after predicting the robot's emotional response, participants reported their current emotional state. This was recorded via seven-level versions of Lang's Self-Assessment Manikin (SAM) rating scales for valence and arousal [25]. Instructions for using the SAM scales were adapted from Bradley and Lang (2007) [2]; however, the order of each scale was reversed such that the valence scale was labeled "Unhappy versus Happy" and the arousal scale was labeled "Calm versus Excited". The SAM images were from PXLab [19] and measured 69 × 74 pixels. To increase visibility of the facial expressions, we used portrait versions of the valence images rather than more traditional full figure.

This data was collected to inform a forthcoming study on the full interaction loop with the Haptic Creature and was not analyzed for this paper.

#### 5.3.6 Post-study Questionnaire

At the conclusion of the study, participants completed an extensive questionnaire. This survey collected demographic information; pet experience and attitudes; general impressions of the Haptic Creature; and details related to the emotions communicated and touch gestures performed.

## 6 Results

Our results begin with participants' ratings for the likelihood that they would use various touch gestures when displaying specific emotions. Next, we detail the properties of touch interactions observed between participants and the robot. This is followed by participants' reported expectations of the Haptic Creature's emotional response to the gestures they performed. We conclude with a summary of relevant responses to the post-study questionnaire.

### 6.1 Touch Gesture Likelihood

For each of the emotions communicated, participants ranked their likelihood of using gestures from our touch dictionary. Responses were recorded on a five-point scale that ranged from *Very Unlikely* (1) to *Very Likely* (5). We consider a gesture likely to be used to communicate a specific emotion if its mean likelihood rating exceeds the likelihood scale's midpoint value (3). We present the results in two tables.

#### 6.1.1 Precedence of Gesture Use

Table 4 provides the mean likelihood rating for each gesture under each emotion condition. In addition, a total score was computed for each gesture by summing all respective mean likelihood ratings. The table is sorted in descending order of this total score: gestures at the top of the table can be considered overall more likely to be used to communicate emotion compared with those at the bottom. Furthermore, individual cells are shaded to draw attention to likely emotions for each gesture. Those gestures that are likely to communicate one or more emotions are highlighted in boldface, while the remaining gestures are not considered likely to be used. Table 4 therefore presents a complete view of

**Table 4** Mean likelihood touch gestures would be used to communicate given emotions

| Gesture | Emotion | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Distressed | Aroused | Excited | Miserable | Neutral | Pleased | Depressed | Sleepy | Relaxed | |
| **Stroke** | 2.97 | 3.50 | 3.40 | 3.07 | 3.93 | 4.13 | 3.47 | 3.73 | 4.33 | 32.53 |
| **Contact** | 2.90 | 2.37 | 2.00 | 3.70 | 4.57 | 3.10 | 4.40 | 4.60 | 4.63 | 32.27 |
| **Hug** | 2.77 | 3.60 | 3.87 | 3.37 | 3.00 | 4.30 | 3.63 | 3.57 | 3.47 | 31.58 |
| **Hold** | 3.13 | 3.00 | 3.37 | 3.37 | 3.83 | 3.80 | 3.53 | 3.60 | 3.80 | 31.43 |
| **Rub** | 2.67 | 3.70 | 3.80 | 3.07 | 3.47 | 3.97 | 3.03 | 3.03 | 3.70 | 30.44 |
| **Pat** | 2.80 | 3.50 | 3.37 | 2.63 | 3.73 | 3.87 | 3.07 | 3.10 | 3.83 | 29.90 |
| **Cradle** | 2.77 | 2.80 | 2.60 | 3.10 | 3.23 | 3.70 | 3.53 | 3.80 | 3.93 | 29.46 |
| **Massage** | 2.43 | 3.53 | 3.27 | 2.47 | 3.27 | 3.43 | 2.73 | 3.17 | 4.03 | 28.33 |
| **Scratch** | 2.80 | 3.33 | 3.50 | 2.80 | 3.27 | 3.40 | 2.63 | 2.63 | 3.67 | 28.03 |
| **Finger Idly** | 2.67 | 2.70 | 2.33 | 2.73 | 3.80 | 2.90 | 3.30 | 3.07 | 3.73 | 27.23 |
| **Rock** | 2.47 | 2.97 | 2.80 | 2.70 | 2.83 | 3.10 | 2.90 | 3.00 | 2.90 | 25.67 |
| **Nuzzle** | 2.00 | 2.93 | 3.37 | 2.50 | 2.67 | 3.50 | 2.67 | 2.93 | 2.87 | 25.44 |
| **Tickle** | 1.57 | 3.20 | 3.80 | 1.80 | 2.77 | 3.87 | 2.03 | 2.63 | 3.33 | 25.00 |
| **Squeeze** | 2.77 | 3.00 | 3.60 | 2.57 | 2.33 | 2.67 | 2.43 | 2.27 | 2.33 | 23.97 |
| **Lift** | 2.00 | 3.13 | 4.00 | 1.67 | 2.53 | 3.37 | 1.60 | 1.53 | 2.43 | 22.26 |
| Pull | 2.67 | 2.83 | 2.77 | 2.53 | 2.07 | 2.37 | 2.23 | 2.27 | 2.07 | 21.81 |
| Press | 2.87 | 2.53 | 2.57 | 2.43 | 2.57 | 2.33 | 2.23 | 2.13 | 2.13 | 21.79 |
| **Kiss** | 1.47 | 2.93 | 2.87 | 1.80 | 2.10 | 3.37 | 2.10 | 2.40 | 2.73 | 21.77 |
| **Swing** | 1.90 | 2.83 | 3.73 | 1.80 | 2.07 | 3.00 | 1.73 | 1.73 | 2.10 | 20.89 |
| Tap | 2.70 | 2.47 | 2.90 | 1.90 | 2.63 | 2.20 | 2.00 | 1.93 | 2.00 | 20.73 |
| Pick | 2.70 | 2.37 | 2.47 | 2.23 | 2.33 | 2.20 | 2.33 | 1.73 | 2.10 | 20.46 |
| Push | 2.83 | 1.63 | 1.63 | 2.93 | 1.83 | 1.80 | 2.30 | 2.07 | 1.53 | 18.55 |
| Poke | 2.07 | 2.50 | 2.67 | 2.10 | 1.97 | 1.80 | 1.90 | 1.60 | 1.43 | 18.04 |
| **Toss** | 1.67 | 2.60 | 3.30 | 1.73 | 1.97 | 2.27 | 1.37 | 1.23 | 1.80 | 17.94 |
| Tremble | 2.67 | 2.27 | 2.30 | 2.50 | 1.53 | 1.50 | 2.30 | 1.37 | 1.37 | 17.81 |
| Grab | 2.47 | 2.50 | 2.97 | 2.00 | 1.70 | 1.83 | 1.70 | 1.30 | 1.30 | 17.77 |
| Pinch | 2.43 | 2.07 | 2.10 | 2.17 | 1.83 | 1.80 | 1.83 | 1.53 | 1.53 | 17.29 |
| Shake | 2.47 | 2.07 | 2.80 | 1.80 | 1.23 | 1.40 | 1.50 | 1.17 | 1.40 | 15.84 |
| Slap | 1.90 | 1.40 | 1.47 | 1.87 | 1.37 | 1.30 | 1.50 | 1.17 | 1.17 | 13.15 |
| Hit | 1.77 | 1.27 | 1.40 | 1.70 | 1.23 | 1.10 | 1.33 | 1.03 | 1.03 | 11.86 |

Gestures are listed in descending order of *Total* score, which was computed for each gesture by summing its mean likelihood ratings. Likelihood scale ranged from *Very Unlikely* (1) to *Very Likely* (5). Gestures that are highlighted *in boldface* have at least one mean likelihood rating greater than 3.00. *Emotion* cell shading key: (3.00, 3.50) [3.50, 4.00) [4.00, 5.00]

the responses, while giving an overall sense of precedence for touch gesture use for affect display (Research Question II).

From this, it can be observed that gestures which are likely to communicate one or more emotions are predominantly affectionate in nature: *stroke*, *hug*, *hold*, *rub*, *pat*, *cradle*, *massage*, *scratch*, *rock*, *nuzzle*, *tickle*, *squeeze*, *lift*, *kiss*, *swing*, and *toss*. In addition, the two low activity gestures are included: *contact without movement* and *finger idly*. On the other hand, the remaining (unlikely) touch gestures are principally aggressive: *pull*, *press*, *tap*, *pick*, *push*, *poke*, *tremble*, *grab*, *pinch*, *shake*, *slap*, and *hit*.

### *6.1.2 Likely Gestures Within Affect Space*

Table 5, on the other hand, organizes the emotion conditions in correspondence with the layout of the affect space depicted in Fig. 3. For the given emotion, only likely gestures are included and presented in descending order of their respective mean likelihood rating for that emotion (Research Question III). This table allows easier comparison of likely gestures both within a specific emotion condition as well as across the affect space's two dimensions—valence (horizontal) and arousal (vertical). In turn, this layout exposes several patterns of interaction.

**Table 5** Touch gestures likely to communicate given emotions

| Emotion | | Emotion | | Emotion | |
|---|---|---|---|---|---|
| Gesture | *L* | Gesture | *L* | Gesture | *L* |
| Distressed | | Aroused | | Excited | |
| Hold | 3.13 | Rub | 3.70 | Lift | 4.00 |
| | | Hug | 3.60 | Hug | 3.87 |
| | | Massage | 3.53 | Tickle | 3.80 |
| | | Stroke | 3.50 | Rub | 3.80 |
| | | Pat | 3.50 | Swing | 3.73 |
| | | Scratch | 3.33 | Squeeze | 3.60 |
| | | Tickle | 3.20 | Scratch | 3.50 |
| | | Lift | 3.13 | Stroke | 3.40 |
| | | | | Pat | 3.37 |
| | | | | Nuzzle | 3.37 |
| | | | | Hold | 3.37 |
| | | | | Toss | 3.30 |
| | | | | Massage | 3.27 |
| Miserable | | Neutral | | Pleased | |
| Contact | 3.70 | Contact | 4.57 | Hug | 4.30 |
| Hug | 3.37 | Stroke | 3.93 | Stroke | 4.13 |
| Hold | 3.37 | Hold | 3.83 | Rub | 3.97 |
| Cradle | 3.10 | Finger Idly | 3.80 | Tickle | 3.87 |
| Stroke | 3.07 | Pat | 3.73 | Pat | 3.87 |
| Rub | 3.07 | Rub | 3.47 | Hold | 3.80 |
| | | Scratch | 3.27 | Cradle | 3.70 |
| | | Massage | 3.27 | Nuzzle | 3.50 |
| | | Cradle | 3.23 | Massage | 3.43 |
| | | | | Scratch | 3.40 |
| | | | | Lift | 3.37 |
| | | | | Kiss | 3.37 |
| | | | | Rock | 3.10 |
| | | | | Contact | 3.10 |
| Depressed | | Sleepy | | Relaxed | |
| Contact | 4.40 | Contact | 4.60 | Contact | 4.63 |
| Hug | 3.63 | Cradle | 3.80 | Stroke | 4.33 |
| Hold | 3.53 | Stroke | 3.73 | Massage | 4.03 |
| Cradle | 3.53 | Hold | 3.60 | Cradle | 3.93 |
| Stroke | 3.47 | Hug | 3.57 | Pat | 3.83 |
| Finger Idly | 3.30 | Massage | 3.17 | Hold | 3.80 |
| Pat | 3.07 | Pat | 3.10 | Finger Idly | 3.73 |
| Rub | 3.03 | Finger Idly | 3.07 | Rub | 3.70 |
| | | Rub | 3.03 | Scratch | 3.67 |
| | | | | Hug | 3.47 |
| | | | | Tickle | 3.33 |

Emotions are ordered in correspondence with Fig. 3. *L* is gesture's mean likelihood rating for given emotion (Table 4). Gestures for each emotion are listed in descending order of *L*—gestures where $L \leq 3.00$ have been omitted

When moving from negative valence emotions to positive, the number of likely gestures increases for the emotion communicated. Taking the high arousal factor levels as the most extreme example, *distressed* has only one likely gesture, while *aroused* has eight, and *excited* has 13.

When focused on the arousal dimension, the *finger idly* touch gesture is likely only for low arousal emotions, while *cradle* and *contact without movement* are likely for low-to-neutral (non-high) arousal emotions.

When considering the valence dimension, the *massage* and *scratch* touch gestures are likely for neutral-to-positive (non-negative) valence emotions. Particular to positive valence emotions, the *tickle* gesture is likely for all three; *nuzzle* is likely for neutral-to-high (non-low) arousal emotions; while *kiss* and *rock* are likely only for *pleased*; and *swing* and *toss* are likely only for *excited*.

Finally, emotions that are high-to-neutral in arousal and negative in valence—*distressed* and *miserable*—are dominated by sustained gestures. While the other emotion levels also contain sustained touch gestures, these two have a preponderance of them.

## 6.2 Touch Gesture Profile

All touch gestures performed on the Haptic Creature were recorded on video and subsequently coded via the procedure described in the Appendix. The resultant data is presented in two separate tables.

### *6.2.1 Gesture Points of Contact*

Table 6 lists the frequencies for contact locations computed for each likely touch gesture (Research Question IV). We calculated the number of times a particular body element—e.g., fingers, palm, chest—touched the robot. Similarly, for the Haptic Creature we counted the number of times a distinct part of its body was touched by participants. Although video coding distinguished between left and right side of the body, our listed frequencies combine the two. For example, touches by the left forearm and right forearm of participants were considered together simply as "forearms" without regard for side. The frequencies of contact points were then computed as a percentage of the total number of times a touch occurred for the particular gesture.

From the perspective of the human (touch initiator), it is not surprising that the palm-side of the fingers and hands were employed for every likely touch gesture. Of note, however, would be that the back-side of the fingers were also employed for *finger idly*, *scratch*, and *tickle*, making these the most finger-centric gestures. Also of interest is that four sustained gestures—*hug*, *hold*, *cradle*, and *contact without movement*—along with the repetitive gesture,

**Table 6** Human (initiator) and Haptic Creature (receiver) points of contact frequency for given touch gestures

| Gesture | Human | | Haptic Creature | | Gesture | Human | | Haptic Creature | |
|---|---|---|---|---|---|---|---|---|---|
| | Contact Point | % | Contact Point | % | | Contact Point | % | Contact Point | % |
| Stroke | Fingers: Palm-Side | 53 | Back | 72 | Rock | Fingers: Palm-Side | 39 | Side: Aft | 31 |
| | Hands: Palm-Side | 40 | | | | Hands: Palm-Side | 24 | Back | 19 |
| | | | | | | Arms: Fore: Rear | 15 | Underbelly: Aft | 17 |
| Contact | Fingers: Palm-Side | 38 | Back | 57 | | | | | |
| | Hands: Palm-Side | 28 | Side: Aft | 12 | Nuzzle | Fingers: Palm-Side | 34 | Back | 23 |
| | Arms: Fore: Rear | 18 | | | | Hands: Palm-Side | 19 | Side: Aft | 21 |
| | | | | | | | | Underbelly: Aft | 14 |
| Hug | Fingers: Palm-Side | 23 | Back | 25 | | | | | |
| | Arms: Fore: Rear | 18 | Side: Aft | 25 | Tickle | Fingers: Palm-Side | 49 | Back | 65 |
| | Hands: Palm-Side | 17 | Underbelly: Aft | 14 | | Fingers: Back-Side | 24 | | |
| | Chest | 13 | Underbelly: Fore | 12 | | Hands: Palm-Side | 21 | | |
| Hold | Fingers: Palm-Side | 30 | Side: Aft | 28 | Squeeze | Fingers: Palm-Side | 53 | Back | 39 |
| | Hands: Palm-Side | 20 | Back | 21 | | Hands: Palm-Side | 31 | Side: Aft | 33 |
| | Arms: Fore: Rear | 17 | Underbelly: Aft | 17 | | | | | |
| | Chest | 13 | Underbelly: Fore | 11 | Lift | Fingers: Palm-Side | 62 | Side: Aft | 33 |
| | | | | | | Hands: Palm-Side | 32 | Underbelly: Aft | 25 |
| Rub | Fingers: Palm-Side | 50 | Back | 75 | | | | Back | 19 |
| | Hands: Palm-Side | 42 | | | | | | | |
| | | | | | Kiss | Fingers: Palm-Side | 45 | Side: Aft | 24 |
| Pat | Fingers: Palm-Side | 50 | Back | 73 | | Hands: Palm-Side | 25 | Back | 18 |
| | Hands: Palm-Side | 42 | | | | | | Underbelly: Aft | 12 |
| | | | | | | | | Underbelly: Fore | 11 |
| Cradle | Fingers: Palm-Side | 27 | Side: Aft | 28 | | | | | |
| | Hands: Palm-Side | 19 | Back | 22 | Swing | Fingers: Palm-Side | 56 | Side: Aft | 29 |
| | Arms: Fore: Rear | 19 | Underbelly: Aft | 14 | | Hands: Palm-Side | 29 | Underbelly: Aft | 17 |
| | Chest | 14 | | | | | | Back | 16 |
| | | | | | | | | Underbelly: Fore | 13 |
| Massage | Fingers: Palm-Side | 52 | Back | 67 | | | | | |
| | Hands: Palm-Side | 37 | Side: Aft | 14 | Toss | Fingers: Palm-Side | 56 | Side: Aft | 22 |
| | | | | | | Hands: Palm-Side | 33 | Underbelly: Aft | 19 |
| Scratch | Fingers: Palm-Side | 41 | Back | 75 | | | | Rump | 14 |
| | Fingers: Back-Side | 26 | | | | | | Back | 13 |
| | Hands: Palm-Side | 25 | | | | | | | |
| Finger Idly | Fingers: Palm-Side | 51 | Back | 83 | | | | | |
| | Hands: Palm-Side | 26 | | | | | | | |
| | Fingers: Back-Side | 14 | | | | | | | |

Gestures are listed in descending order of *Total* score; top to bottom, left to right. Only gestures with at least one mean likelihood rating greater than 3.00 are listed. (Total scores and likelihood ratings are presented in Table 4.) Only frequencies greater than 10% are listed

*rock*, all utilized the forearm. Moreover, the first three of these sustained gestures also came into contact with the chest.

From the perspective of the Haptic Creature (touch receiver), its back was touched for every likely gesture. With the exception of *massage*, the robot's back was the sole point of contact for repetitive touch gestures where it was not picked up: *finger idly*, *pat*, *rub*, *scratch*, *stroke*, and *tickle*. While for all nine gestures where the Haptic Creature was picked up—*cradle*, *hold*, *hug*, *kiss*, *lift*, *nuzzle*, *rock*, *swing*, and *toss*—its underbelly was touched. Finally, the robot's rump was only touched for the *toss* gesture.

**Table 7** Mean duration and mean pressure intensity of likely touch gestures when communicating given emotions

| Gesture | Emotion | *D* | *I* | Gesture | Emotion | *D* | *I* | Gesture | Emotion | *D* | *I* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Stroke | Aroused | 1.02 | 2.30 | Rub | Aroused | 1.11 | 2.64 | Scratch | Aroused | 0.65 | 2.38 |
| | Excited | 0.82 | 2.36 | | Excited | 0.53 | 2.63 | | Excited | 0.36 | 2.43 |
| | Miserable | 1.21 | 2.24 | | Miserable | 1.14 | 2.68 | | Neutral | 0.68 | 2.20 |
| | Neutral | 1.31 | 2.05 | | Neutral | 1.60 | 2.48 | | Pleased | 0.45 | 2.22 |
| | Pleased | 1.07 | 2.17 | | Pleased | 0.77 | 2.65 | | Relaxed | 0.74 | 2.19 |
| | Depressed | 1.60 | 2.10 | | Depressed | 1.17 | 2.67 | | | | |
| | Sleepy | 1.57 | 1.94 | | Sleepy | 1.35 | 2.60 | Finger Idly | Neutral | 1.13 | 1.94 |
| | Relaxed | 1.57 | 1.94 | | Relaxed | 1.18 | 2.71 | | Depressed | 1.21 | 2.05 |
| | | | | | | | | | Sleepy | 1.33 | 1.85 |
| Contact | Miserable | 5.29 | 1.69 | Pat | Aroused | 0.47 | 1.85 | | Relaxed | 1.14 | 1.86 |
| | Neutral | 5.24 | 1.59 | | Excited | 0.36 | 1.76 | | | | |
| | Pleased | 3.72 | 1.86 | | Neutral | 0.50 | 1.65 | Rock | Pleased | 2.39 | 2.29 |
| | Depressed | 5.59 | 1.77 | | Pleased | 0.51 | 1.76 | | | | |
| | Sleepy | 5.24 | 1.65 | | Depressed | 0.68 | 2.00 | Nuzzle | Excited | 3.12 | 2.38 |
| | Relaxed | 5.83 | 1.69 | | Sleepy | 0.79 | 1.60 | | Pleased | 2.78 | 2.25 |
| | | | | | Relaxed | 0.71 | 1.66 | | | | |
| Hug | Aroused | 6.40 | 2.28 | | | | | Tickle | Aroused | 0.42 | 2.13 |
| | Excited | 5.85 | 2.36 | Cradle | Miserable | 9.29 | 2.05 | | Excited | 0.64 | 2.08 |
| | Miserable | 7.82 | 2.15 | | Neutral | 9.25 | 2.08 | | Pleased | 0.45 | 2.11 |
| | Pleased | 7.15 | 2.39 | | Pleased | 7.61 | 2.22 | | Relaxed | 0.52 | 1.89 |
| | Depressed | 7.79 | 2.21 | | Depressed | 8.39 | 2.08 | | | | |
| | Sleepy | 7.28 | 2.13 | | Sleepy | 8.22 | 2.01 | Squeeze | Excited | 2.31 | 2.47 |
| | Relaxed | 6.67 | 2.31 | | Relaxed | 8.96 | 2.14 | | | | |
| | | | | | | | | Lift | Aroused | 4.92 | 2.65 |
| Hold | Distressed | 7.11 | 2.27 | Massage | Aroused | 1.13 | 2.60 | | Excited | 4.49 | 2.56 |
| | Excited | 5.63 | 2.27 | | Excited | 0.71 | 2.54 | | Pleased | 4.60 | 2.65 |
| | Miserable | 7.28 | 2.17 | | Neutral | 0.97 | 2.51 | | | | |
| | Neutral | 7.21 | 2.27 | | Pleased | 0.87 | 2.54 | Kiss | Pleased | 3.50 | 2.19 |
| | Pleased | 6.34 | 2.10 | | Sleepy | 1.17 | 2.42 | | | | |
| | Depressed | 6.40 | 2.17 | | Relaxed | 0.96 | 2.48 | Swing | Excited | 2.12 | 2.56 |
| | Sleepy | 7.90 | 2.07 | | | | | | | | |
| | Relaxed | 7.36 | 2.13 | | | | | Toss | Excited | 1.94 | 2.56 |

Gestures are listed in descending order of *Total* score (presented in Table 4); top to bottom, left to right. *D* is gesture's mean duration (seconds) for given emotion; durations for sustained gestures are for the entirety of the touch, whereas durations for repetitious gestures represent a single repetition. *I* is gesture's mean pressure intensity for given emotion. Intensity rating ranged from *light* (1) to *strong* (3)

### *6.2.2 Gesture Duration and Intensity*

Table 7 presents the mean duration and mean pressure intensity of likely touch gestures when communicating specific emotions (Research Question IV). Durations were calculated in seconds from the beginning to end of the touch interaction; sustained gestures, such as *hug*, were considered for the entirety of the interaction, whereas repetitious gestures, like *stroke*, compute the average for a single repetition. Pressure intensities were computed by converting the intensity coding scale (see Appendix) to numeric vales—*light* (1) to *strong* (3)—then generating a mean. Inter-rater reliability was determined via Cronbach's $\alpha$, which yielded 0.97 for duration and 0.83 for intensity.

We begin by examining the general differences across the various touch gestures. The repetitious gestures *tickle*, *pat*, and *scratch*, generally had the shortest durations, while *finger idly*, *rub*, and *stroke*, overall had the longest. Repetitive touch gestures *pat*, *finger idly*, and *tickle*, generally had the lowest pressure intensities, whereas *rub* and *massage* had the highest. The sustained gestures *lift* and *contact without movement* overall had the shortest durations, while *cradle* generally had the highest. The sustained touch gesture *con-*

*tact without movement* generally had the lightest pressure intensity, whereas *lift* overall had the strongest.

Next, we examine the differences within the touch gestures when considering the emotions communicated. Many patterns appear in relation to changes in either arousal or valence independently. On the other hand, some cluster in the upper-right (around *excited*) or bottom-left (around *depressed*) of the affect space (Fig. 3).

The *stroke* gesture generally increased in duration and decreased in intensity as arousal decreased. *Rub* was shorter in duration clustered around *pleased*, *excited*, and *aroused*. *Pat* increased in duration in relation to a decrease in arousal. *Massage*, on the other hand, decreased in duration in relation to a positive shift in valence, while also clustered higher intensity around *pleased*, *excited*, and *aroused*. *Scratch* decreased intensity in relation to a decrease in arousal. The *tickle* gesture had longer duration in positive valence emotions, while higher intensity clustered around *pleased*, *excited*, and *aroused*. The *hug* gesture clustered longer duration and lower intensity around *miserable*, *depressed*, and *sleepy*, while shorter duration and higher intensity clustered around *pleased*, *excited*, and *aroused*. The *hold* touch gesture had notably shorter duration for *pleased* and *excited*, while lower intensity clustered around *sleepy*, *relaxed*, and *pleased*. *Cradle* decreased in duration as arousal decreased, except for positive valence emotions.

### 6.3 Haptic Creature Emotional Response

For each of the emotions communicated, participants predicted the Haptic Creature's emotional response to the touch gestures they had just performed. Predictions were recorded via a forced choice from among sixteen emotion labels (Table 3).

From this list, Russell's nine emotion labels are dimensional in nature so have direct mappings to the emotions communicated (Fig. 3). Ekman's six labels, on the other hand, do not have a direct mappings but may overlap with Russell's labels. As a result, we applied an equivalency mapping determined from one of our previous studies [52]:

- Ekman's *sad* was considered to be equivalent with Russell's *depressed*;
- Ekman's *afraid*, *angry*, and *disgusted* were considered to be equivalent with Russell's *distressed*;
- Ekman's *happy* was considered to be equivalent with Russell's *pleased*; and
- Ekman's *surprised* was not equivalent with any other emotion labels.

We computed the frequency with which each emotion label was chosen for each emotion communicated. Any Ekman label that corresponded to a Russell label was counted as if the Russell label was chosen. The results are summarized in Table 8. For reference, we include here the frequency breakdown for any composite emotion labels presented in the table.

**Table 8** Predicted emotional response of Haptic Creature based on emotion communicated

| Emotion | | Emotion | | Emotion | |
|---|---|---|---|---|---|
| Label | % | Label | % | Label | % |
| Distressed | | Aroused | | Excited | |
| *Distressed*[b] | 35 | Pleased[c] | 30 | *Excited* | 47 |
| Surprised | 14 | *Aroused* | 23 | Aroused | 20 |
| | | Excited | 23 | Pleased[c] | 20 |
| Miserable | | Neutral | | Pleased | |
| Depressed[a] | 31 | Relaxed | 53 | *Pleased*[c] | 57 |
| Distressed[b] | 31 | *Neutral* | 13 | Excited | 20 |
| Pleased[c] | 17 | Pleased[c] | 13 | | |
| Depressed | | Sleepy | | Relaxed | |
| *Depressed*[a] | 37 | *Sleepy* | 43 | *Relaxed* | 50 |
| Relaxed | 20 | Relaxed | 33 | Pleased[c] | 23 |
| Neutral | 17 | Neutral | 17 | Sleepy | 13 |

Labels for corresponding emotions communicated are highlighted in boldface. Only frequencies greater than 10% are listed. [a]*Depressed* includes *Sad*. [b]*Distressed* includes *Afraid*, *Angry*, and *Disgusted*. [c]*Pleased* includes *Happy*

- *Distressed* communicated
  *distressed* (35%) = *distressed* (21%) + *afraid* (7%) + *angry* (7%) + *disgusted* (0%)
- *Aroused* communicated
  *pleased* (30%) = *pleased* (20%) + *happy* (10%)
- *Excited* communicated
  *pleased* (20%) = *happy* (13%) + *pleased* (7%)
- *Miserable* communicated
  *depressed* (31%) = *sad* (17%) + *depressed* (14%)
  *distressed* (31%) = *distressed* (14%) + *afraid* (7%) + *angry* (7%) + *disgusted* (3%)
- *Neutral* communicated
  *pleased* (13%) = *pleased* (10%) + *happy* (3%)
- *Pleased* communicated
  *pleased* (57%) = *happy* (37%) + *pleased* (20%)
- *Depressed* communicated
  *depressed* (37%) = *sad* (23%) + *depressed* (14%)
- *Relaxed* communicated
  *pleased* (23%) = *pleased* (16%) + *happy* (7%)

### 6.4 Questionnaire Responses

Here we summarize the results of participants' responses to pertinent parts of the post-study questionnaire: experience with pets and attitudes towards them; difficulty understanding emotion words and touch gestures; intensity level when touching the robot; and expectations of the robot's response. Unless otherwise noted, all participants ($N = 30$) responded to each question.

General experience with pets was determined through the Companion Animal Bonding Scale (CABS) [32], which has a range of 8–40. Overall, 9 participants (30%) had no pets; 8 (27%) completed only the *retrospective* scale, which measures childhood experience; 1 (3%) completed only the *contemporary* scale; and 12 (40%) completed both. Participants completing the retrospective CABS ranged from 15 to 40 ($N = 20$, $M = 25.20$, $SD = 6.78$), while those completing the contemporary CABS ranged from 17 to 39 ($N = 13$, $M = 27.08$, $SD = 6.54$).

General attitudes towards pets was determined through the Pet Attitude Scale–Modified (PAS–M) [30], which has an overall range of 18–126. Participants' scores ranged from 44 to 126 ($M = 96.83$, $SD = 19.83$).

Participants were presented with the word list of emotions they were asked to communicate during the study and asked if they had any difficulty understanding them. The results were 21 participants (70%) reported *No* and 9 (30%) *Yes*. Of those expressing difficulty, *aroused* was overwhelmingly reported as being ambiguous, often in relation to *excited*.

Similarly, participants were presented with the list of gestures they were asked to perform during the study and asked if they had any difficulty understanding the words or their definitions. The results were 26 participants (87%) reported *No* and 4 (13%) *Yes*.

Participants were asked to reflect on their general intensity when interacting with the Haptic Creature. When compared with a living creature, participants' responses regarding the overall intensity of their touch with the robot were 12 (42%) *Held Back*; 13 (42%) *Same*; and 5 (16%) *More Intense*. These responses did not directly influence any other analysis of touch intensity (e.g., Sect. 6.2). Rather, the data allows a high-level view as to how participants approached touching the robot.

Participants were asked about their overall expectations for the robot's change in emotional state based on the emotions they were communicating. The results were 12 participants (40%) reported *Response Similar To What I Was Communicating*; 13 (43%) *Response Sympathetic To What I Was Communicating*; and 5 (17%) *Not Sure*.

## 7 Discussion

The overall goal of the present study was to gain a deeper understanding of affective touch when it originates from the human. In this section we discuss the result of our user study. We begin by reflecting on the overall design of the study. This is followed by comments on how the Haptic Creature itself influenced participant responses. We then continue with a combined analysis of the various results that we use to generalize into categories of human intent. We proceed with discussion about participants' overall expected emotional response of the Haptic Creature. Finally, we conclude with comments related to how we might apply knowledge gained from the study towards improving the robot's hardware and software.

### 7.1 Reflections on Study Design

Overall, this first effort to quantitatively and qualitative assess human emotion-based touch produced a dataset of gesture frequencies and physical characteristics which will be highly useful for our own further research as well as others. Our triangulating approach combined self-reported choices from a well-validated collection of touch terms, with unbiased and systematic observation of actual gesture performance, giving us additional confidence in data reliability. The study design, however, could be further improved in terms of efficiency, participant effort, and granularity of results.

First, this study could have been conducted as two studies: the gesture likelihood rating alone, then, separately, performance of likely gestures and specifying the robot's expected emotional response. Separate participant pools would be acceptable, and the result would reduce the time of participation. Also, from the standpoint of statistical strength, the set of gestures performed in the second study would have been the same for all participants, having emerged as a net result of the first study.

The second issue regards the compromise between resource expense of video analysis and useful granularity. We found video coding extremely useful for determining contact points, especially for the human; however, measurement of contact intensity scaling was too coarse-grained (3 levels) and often difficult to accurately determine visually. Similarly, the time granularity (1 second) was also too coarse. For sustained touches—e.g., *contact without movement* or *hug*—this often was not an issue. On the other hand, information for repetitive gestures—e.g., *stroke* or *rub*—has the potential of incomplete capture. A time window much less than 1 second would obviate this latter issue but would require a much greater time investment for video coding. A potential alternate approach to simplify pressure intensity ratings would be to view a touch gesture performance as a whole, then make an overall interpretation.

### 7.2 Influence of Robot Context and Morphology

Two key properties of the Haptic Creature likely influenced participant responses.

First, the context of the robot in the study was that of a close pet. Participants, not surprisingly, gravitated toward friendlier gestures and away from aggressive ones as a result of this imagined relationship.

Second, the size and form factor of the robot allowed for some gestures—e.g., *lift* or *swing* or *toss*—that would be difficult to imagine if the Haptic Creature was much larger (unless the touch was localized to smaller appendages). As a consequence, this rendered unlikely other gestures that might be natural for much smaller or larger robots. Similarly, the manner of interaction might have varied accordingly. For example, a *pat* or *massage* might vary in intensity and location for robots of notably different sizes and morphology.

## 7.3 Human Intent through Affective Touch

Jones and Yarbrough [20] conducted a study that examined human-human touch in daily interactions and, from the results, developed 12 "characteristics of meaning". While the scope and focus of our research differs somewhat, we nonetheless have been guided in spirit by their work as we also seek to infer greater meaning from the touch gestures.

Our results provide two different perspectives on human-initiated affective touch. Tables 4 and 5 give insight into the *likelihood* of touch gesture use, while Tables 6 and 7 provide details on the *manner* of this interaction. Through comparing these views, it is possible to move towards a higher-level understanding of the human's expressive intent.

To that end, we performed a meta-analysis driven primarily by patterns of gestures shared between emotions and, secondly, by observed commonalities in the physical expression of those gestures. This produced five tentative categories of "intent" which overlap emotion states: *protective*, *comforting*, *restful*, *affectionate*, and *playful*. These are individually designated in Fig. 5 and each described here in turn.

*Protective* This intent corresponds to emotions that are high-to-neutral in arousal and negative in valence: *distressed* and *miserable* (Fig. 5, wavy). Unlike the other intents, it is dominated by sustained gestures, many of which require the human to hold the Haptic Creature enclosed in the forearms and in close proximity to the chest: *hold*, *hug*, *cradle*.

*Comforting* This intent corresponds to emotions that are both neutral-to-low in arousal while negative in valence: *miserable* and *depressed* (Fig. 5, shaded). It has sustained gestures similar to *protective*; however, *comforting* also includes several repetitious ones: *stroke*, *rub*, *finger idly*, and *pat*. With the exception of *stroke*, these repetitious gestures display higher pressure intensities here than other intents in which they also exist. On the other hand, the sustained gesture *hug* has lower intensity, along with longer durations, compared with other intents.

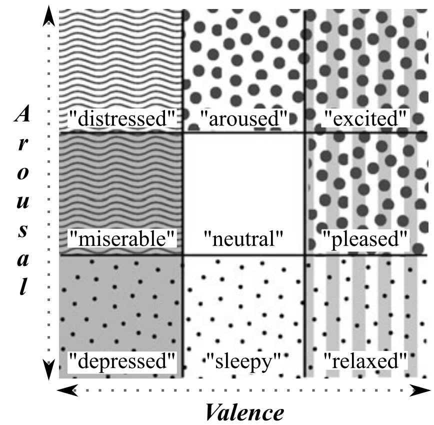


**Fig. 5** Human intent through affective touch. The regions are (counterclockwise from upper-left): *protective* (*wavy*); *comforting* (*shaded*); *restful* (*small dots*); *affectionate* (*stripes*); *playful* (*large dots*)

*Restful* This intent corresponds to low arousal emotions: *depressed*, *sleepy*, and *relaxed* (Fig. 5, small dots). It has sustained gestures similar to both the *protective* and *comforting* intents but differs in two ways. First, when moving from negative valence to positive, *restful* includes the repetitive *massage* gesture followed by *scratch* and *tickle*. Second, when compared with higher arousal states, common gestures generally have lower intensities—*stroke*, *massage*, *scratch*, *tickle*—or longer durations—*stroke*, *rub*, *pat*, *scratch*.

*Affectionate* This intent corresponds to the emotions of positive valence: *relaxed*, *pleased*, and *excited* (Fig. 5, stripes). Distinguished by their strong reliance on the use of fingers, *tickle*, *scratch*, and *massage*, exist predominantly in this intent. Also included are the more intimate *nuzzle*, *kiss*, and *rock* gestures. When compared with other intents, the durations for *hug*, *hold*, and *massage*, were generally shorter, while the intensity for *hug* was higher.

*Playful* This intent coincides with emotions *pleased*, *excited*, and *aroused* (Fig. 5, large dots). Overlapping the *affectionate* intent, this one differs in that it places greater emphasis on the gestures *lift*, *swing*, and *toss*, which correspond to the Haptic Creature being extensively moved in space. Additionally, *squeeze*, a gesture of relatively high intensity, exists solely in the *excited* emotional state. Gestures common to other intents often have shorter durations—*stroke*, *rub*, *pat*, *scratch*—or higher pressure intensities—*stroke*, *massage*, *scratch*, *tickle*—in this intent.

While our proposed intents need validation through further study, it is encouraging that some bear resemblance to categories from Jones and Yarbrough. For example, their "support" category is similar to our *protective* and *comforting* intents, while their "affectionate" and "playful" categories have direct counterparts in our intents—though they divide "playful" between "playful affection" and "playful aggression".

Regardless, the advantages of finding a higher-level interpretation of touch data are considerable.

First, the process of higher-level categorization helps to illuminate the human's general nature when choosing these gestures for these emotions: it not only implies the *how* but also the *what*. For example, the human might choose to communicate either *miserable* or *depressed* through *comforting*, using a set of gestures that are suitable for both of those emotions—as well as other gestures that are more specific.

Second, this knowledge can inform the ability to make sense of the human's low-level actions. For the robot to display an appropriate reaction, it needs to be able to reason beyond "the human squeezed me" and even past the implications that "the human is excited". Therefore, the Haptic Creature's emotion controller must find patterns in the touch that imply intent. For example, properties of the *protective* or *comforting* intents differ from those of the *playful* one; not only by the set of gestures employed but, more abstractly, by the observed physical properties of the human's touches. An intriguing practical extension of this is that, given an adequate model, it may not be necessary to fully recognize a gesture. Rather, by noting certain shared properties of the touch, the robot may directly infer the intent.

### 7.4 Mirrored Emotional Response Expected from Haptic Creature

As reflected in Fig. 2, we are ultimately interested in the complete interaction cycle between human and robot. While the previous section discusses the human's emotional intent when communicating with the robot through touch, here we anticipate the full interaction loop by examining the human's expectation of the robot's emotional response (Research Question V).

The results in Table 8 show participants' overall expectation was for the Haptic Creature to respond in-kind. That is, they expected the robot would mirror the emotion they were communicating. Notable deviations are *aroused* and *neutral*, which have a pattern of shifting positive valence and lower arousal. Also, *miserable* has no mirrored relation: the expected emotional response is split equally between higher and lower arousal while remaining negative in valence.

These general results, however, are contradicted somewhat by two additional data points. First, though the post-study questionnaire results (Sect. 6.4) somewhat confirms the in-kind response, it also shows nearly the same percentage of participants expecting a sympathetic response. This may explain the notable deviations mentioned in the previous paragraph. Second, another interesting contradiction is based on participants' specification for likely gestures, in particular for negatively valenced emotions. By always employing non-cruel, non-aggressive gestures in negative emotions, participants may not truly expect the Haptic Creature to take on the same emotional state as themselves. Rather, this actually may imply their expectation (possibly unconscious) for a sympathetic, rather than a mirrored, response.

### 7.5 Implication for Haptic Creature Design

Overall knowledge of which gestures are used helps advance the development of a robot wishing to interact with humans through touch. For example, touch sensing hardware can be specified and tuned for specific touch gestures, and recognition software similarly can concentrate on primary gestures while having little concern for those never to be used. For this section, we focus on the study results as it impacts our Haptic Creature; nonetheless, the results can be generalized to other social robots which have the possibility of utilizing touch (Research Question VI).

The Haptic Creature's back and (aft) sides appear to be the predominate point of interaction with the human. As a result, the touch sensors need to be more densely populated in these areas in order to pick up the variety of gestures. In addition, several likely gestures exist whose motion has a shearing component—e.g., *stroke*, *rub*, *massage*—so the type of sensors employed must be sensitive to this manner of movement. Similarly, though it is not explicitly demonstrated in the data, the robot's curved surface, especially its back, poses added challenges for some touch sensor technologies.

When examining the gestures likely to be used, one surprising finding was that some of the lighter touches—e.g., *finger idly*, *nuzzle*, *tickle*—have a lower likelihood of communicating emotional state when compared to some of the more pronounced touches such as *stroke* or *rub*. While we still feel that these lighter touches are important to recognize, it is beneficial to know where trade-offs may be made.

Finally, as noted, the more violent gestures such as *hit*, *slap*, and *shake* have a very low likelihood of being used. Nonetheless, gestures with equal movement of the robot exist in likely touch gestures such as *lift*, *swing*, *toss*, and *rock*. Therefore, it is critical that the robot have the ability to sense movement in addition to pressure from touch, thereby confirming our decision to employ a three-axis accelerometer.

## 8 Conclusion

In this paper, we detailed a user study that investigated the human's intent and expectations when displaying emotional touch. This touch was directed to our Haptic Creature robot, which was imagined by participants as their close pet.

We began by compiling a dictionary of plausible touch gestures for use in the study. Results allowed us to document which gestures the human was more likely to use and for which specific emotions. Given the stated relationship with the Haptic Creature, participants gravitated to less aggressive, more affectionate gestures.

We also presented the physical properties of the touch interaction, which included common points of contact as well as duration and intensity of gestures. Results show the human's fingers and hands to dominate repetitious gestures, while forearms and chest were included in sustained gestures. For the Haptic Creature, the back was the major point of contact from the human, while its aft sides were included in many sustained gestures.

Through synthesis of these various results, we were then able to begin an inference of the human's intent when communicating emotion through touch to the robot. We have categorized these as *protective*, *comforting*, *restful*, *affectionate*, and *playful*. In addition, participants demonstrated an expectation that the Haptic Creature provide an emotional response similar to the ones they were communicating.

Future work includes taking knowledge gained from this study to advance the development of the Haptic Creature. We plan to focus its gesture recognition engine on likely gestures, while placing less emphasis on unlikely ones. Similarly, we plan to enhance the touch sensing capabilities of the robot's back since it is the predominate point of contact. Moreover, knowledge of the human's intent and expectations will also aid the Haptic Creature in providing a more compelling interaction, though additional studies will be needed to further validate the intent categorization we have presented.

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## Appendix: Video Coding of Touch Gestures

This appendix summarizes the procedures we used for the coding of video recordings of participants' touch gesture performances on the Haptic Creature. In general, the procedures closely followed those used by Hertenstein [16, 17].

Coders were naïve to the research study goals as well as the emotions being communicated by participants; however, the coders were informed of the gestures being performed. The video was analyzed on a second-by-second basis with the following data recorded: contact point of the human, contact point of the Haptic Creature, and pressure intensity of the contact.

The contact points were selected appropriately from the diagrams shown in Figs. 6, 7, and 8. These diagrams were adapted and greatly expanded from those developed by

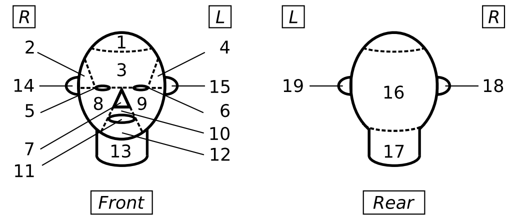


**Fig. 6** Demarcation of human head for touch gesture contact points. *R* (*Right*) and *L* (*Left*) are from the human's perspective

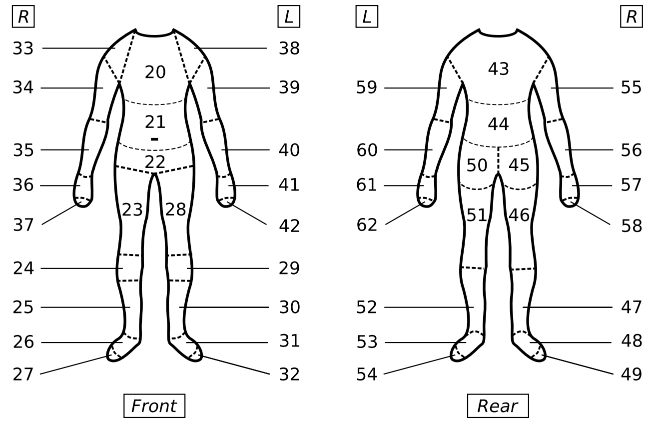


**Fig. 7** Demarcation of human body for touch gesture contact points. *R* (*Right*), *L* (*Left*), *Front*, and *Rear* are from the human's perspective. Hands are positioned with the palm-sides facing to the rear

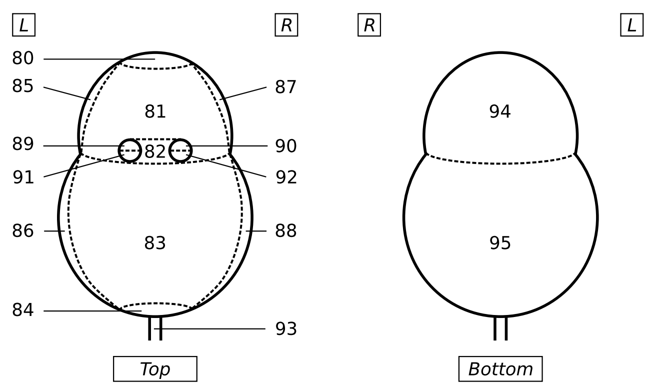


**Fig. 8** Demarcation of Haptic Creature for touch gesture contact points. *L* (*Left*), *R* (*Right*), *Top*, and *Bottom* are from the Haptic Creature's perspective

Jourard [21]. The diagram for the Haptic Creature did not previously exist, while the body and face diagrams did not contain enough detail for our purposes. This was particularly evident in the need for more fine-grained demarcation for hands and fingers. Our resultant diagrams, however, are likely even more detailed than what was needed for our current study.

The intensity of touch estimated the level of human-applied pressure and was recorded by means of a four-item scale (adapted directly from [16, 17]): *N* (no touch) = no physical contact with the Haptic Creature; *L* (light touch) = indentation on the Haptic Creature's fur or movement of its body is not apparent or barely perceptible; *M* (moderate touch) = some fur indentation or movement of the Haptic Creature's body but not extensive; and *S* (strong touch) = indentation on the Haptic Creature's fur is fairly deep or movement of the its body is substantial as a result of the pressure or force of the touch.

It is useful to note that the numbers utilized in the demarcation diagrams, as well as the values of pressure intensity scale, were designed to be unique so as to allow for easy validation of coded data.

## References


1. Beck A, Katcher AH (1996) Between pets and people: the importance of animal companionship. Purdue University Press, West Lafayette
2. Bradley MM, Lang PJ (2007) The international affective picture system (IAPS) in the study of emotion and attention. In: Coan JA, Allen JJ (eds) Handbook of emotion elicitation and assessment. Series in affective science. Oxford University Press, London, pp 29–46. Chap 2
3. Breazeal C (2003) Emotive qualities in lip-synchronized robot speech. Adv Robot 17(2):97–113
4. Breazeal CL (2002) Designing sociable robots. MIT Press, Cambridge
5. Campos JJ, Mumme DL, Kermoian R, Campos RG (1994) A functionalist perspective on the nature of emotion. Monogr Soc Res Child Dev 59(2/3):284–303
6. Canamero LD, Fredslund J (2000) How does it feel? Emotional interaction with a humanoid LEGO robot. In: Socially intelligent agents: the human in the loop. Papers from the AAAI fall symposium, pp 23–28
7. Chang J, MacLean K, Yohanan S (2010) Gesture recognition in the haptic creature. In: Kappers A, van Erp J, Tiest WB, van der Helm F (eds) Haptics: generating and perceiving tangible sensations—EuroHaptics 2010. Lecture notes in computer science, vol 6191. Springer, Berlin, pp 385–391
8. Darwin C (1872) The expression of the emotions in man and animals. Murray, London
9. Ekman P (1992) Are there basic emotions? Psychol Rev 99(3):550–553
10. Ekman P, Friesen WV (1971) Constants across cultures in the face and emotion. J Pers Soc Psychol 17(2):124–129
11. Fisher JD, Rytting M, Heslin R (1976) Hands touching hands: affective and evaluative effects of an interpersonal touch. Sociometry 39(4):416–421
12. Frank MG, Stennett J (2001) The forced-choice paradigm and the perception of facial expressions of emotion. J Pers Soc Psychol 80(1):75–85
13. Fujita M, Kitano H (1998) Development of an autonomous quadruped robot for robot entertainment. Auton Robots 5(1):7–18
14. Gentoo (2009) Gentoo Linux. http://www.gentoo.org/. Aug 2009
15. Heller MA, Schiff W (eds) (1991) The psychology of touch. Erlbaum, Hillsdale
16. Hertenstein MJ, Holmes R, McCullough M, Keltner D (2009) The communication of emotion via touch. Emotion 9(4):566–573
17. Hertenstein MJ, Keltner D, App B, Bulleit BA, Jaskolka AR (2006) Touch communicates distinct emotions. Emotion 6(3):528–533
18. Hertenstein MJ, Verkamp JM, Kerestes AM, Holmes RM (2006) The communicative functions of touch in humans, nonhuman primates, and rats: a review and synthesis of the empirical research. Genet Soc Gen Psychol Monogr 132(1):5–94
19. Irtel H (2007) PXLab: The psychological experiments laboratory. Mannheim (Germany): University of Mannheim. http://www.pxlab.de/
20. Jones SE, Yarbrough AE (1985) A naturalistic study of the meanings of touch. Commun Monogr 52(1):19–56
21. Jourard SM (1966) An exploratory study of body-accessibility. Br J Soc Clin Psychol 5:221–231
22. Katcher AH (1981) Interrelations between people and pets. In: Interactions between people and their pets: form and function. Thomas, Springfield, pp 41–67
23. Katcher AH, Friedmann E, Goodman M, Goodman L (1983) Men, women, and dogs. Calif Vet 37(2):14–17
24. Kobayashi H, Hara F (1995) A basic study on dynamic control of facial expressions for face robot. In: RO-MAN '95: Proceedings of the 4th IEEE international workshop on robot and human communication, July 1995, pp 275–280
25. Lang PJ (1980) Behavioral treatment and bio-behavioral assessment: computer applications. In: Sidowski JB, Johnson JH, Williams TW (eds) Technology in mental health care delivery systems. Ablex, Norwood, pp 129–139
26. Major B, Heslin R (1982) Perceptions of cross-sex and same-sex nonreciprocal touch: it is better to give than to receive. J Nonverbal Behav 6(3):148–162
27. McKean E (ed) (2005) The new Oxford American dictionary, 2nd edn. Oxford University Press, London
28. Melson GF, Kahn PH Jr, Beck AM, Friedman B, Roberts T, Garrett E (2005) Robots as dogs?: Children's interactions with the robotic dog AIBO and a live Australian shepherd. In: CHI '05 Extended abstracts on human factors in computing systems, CHI EA '05, New York, New York, USA, 2005. ACM, New York, pp 1649–1652
29. Montagu A (1986) Touching: the human significance of the skin. Perennial Library, New York
30. Munsell KL, Canfield M, Templer DI, Tangan K, Arikawa H (2004) Modification of the pet attitude scale. Soc Anim 12(2):137–142
31. Nguyen T, Heslin R, Nguyen ML (1975) The meanings of touch: sex differences. J Commun 25(3):92–103
32. Poresky RH, Hendrix C, Hosier JE, Samuelson ML (1987) The companion animal bonding scale: internal reliability and construct validity. Psychol Rep 60:743–746
33. Russell JA (1979) Affective space is bipolar. J Pers Soc Psychol 37(3):345–356
34. Russell JA (1980) A circumplex model of affect. J Pers Soc Psychol 39(6):1161–1178
35. Russell JA (1994) Is there universal recognition of emotion from facial expression? A review of the cross-cultural studies. Psychol Bull 115(1):102–141
36. Russell JA, Weiss A, Mendelsohn GA (1989) Affect grid: a single-item scale of pleasure and arousal. J Pers Soc Psychol 57(3):493–502
37. Saldien J, Goris K, Yilmazyildiz S, Verhelst W, Lefeber D (2008) On the design of the huggable robot Probo. J Phys Agents 2(2):3–11
38. Scheeff M, Pinto J, Rahardja K, Snibbe S, Tow R (2000) Experiences with Sparky, a social robot. In: Workshop on interactive robotics and entertainment, Pittsburgh, Pennsylvania, USA, April 2000. AAAI Press, Menlo Park
39. Scheutz M, Schermerhorn P, Kramer J, Anderson D (2007) First steps toward natural human-like HRI. Auton Robots 22(4):411–423
40. Serpell JA (1996) In the company of animals: a study of human-animal relationships. Cambridge University Press, Cambridge

41. Serpell JA (2000) Handbook on animal-assisted therapy: theoretical foundations and guidelines for practice. In: Animal companions and human well-being: an historical exploration of the value of human-animal relationships. Academic Press, New York, pp 3–19. Chap 1
42. Shibata T, Mitsui T, Wada K, Touda A, Kumasaka T, Tagami K, Tanie K (2001) Mental commit robot and its application to therapy of children. In: Proceedings of IEEE/ASME international conference on advanced intelligent mechatronics, IEEE/ASME, July 2001, vol 2, pp 1053–1058
43. Stiehl WD, Lieberman J, Breazeal C, Basel L, Lalla L, Wolf M (2005) Design of a therapeutic robotic companion for relational, affective touch. In: ROMAN 2005. IEEE international workshop on robot and human interactive communication, August 2005, pp 408–415
44. Ugobe (2007) PleoWorld—the home of Pleo, the robotic baby dinosaur from Ugobe Life Forms. http://www.pleoworld.com/
45. Wada K, Shibata T, Saito T, Sakamoto K, Tanie K (2005) Psychological and social effects of one year robot assisted activity on elderly people at a health service facility for the aged. In: Proceedings of the 2005 IEEE international conference on robotics and automation, 2005. ICRA 2005, pp 2785–2790
46. Walker DN (1975) A dyadic interaction model for nonverbal touching behavior in encounter groups. Small Group Res 6(3):308–324
47. Weiss SJ (1992) Measurement of the sensory qualities in tactile interaction. Nurs Res 41(2):82–86
48. Willis FN Jr, Hamm HK (1980) The use of interpersonal touch in securing compliance. J Nonverbal Behav 5(1):49–55
49. Yilmazyildiz S, Mattheyses W, Patsis Y, Verhelst W (2006) Expressive speech recognition and synthesis as enabling technologies for affective robot-child communication. In: Zhuang Y, Yang S, Rui Y, He Q (eds) Advances in multimedia information processing—PCM 2006. Lecture notes in computer science, vol 4261. Springer, Berlin, pp 1–8
50. Yohanan S, MacLean K (2008) The Haptic Creature project: social human-robot interaction through affective touch. In: Proceedings of the AISB 2008 symposium on the reign of catz & dogz: the second AISB symposium on the role of virtual creatures in a computerised society, April 2008, vol 1, pp 7–11
51. Yohanan S, MacLean KE (2009) A tool to study affective touch: goals & design of the haptic creature. In: CHI '09: Proceedings of the 27th international conference extended abstracts on human factors in computing systems, New York, New York, USA, 2009. ACM, New York, pp 4153–4158
52. Yohanan S, MacLean KE (2011) Design and assessment of the Haptic Creature's affect display. In: HRI '11: Proceedings of the 6th ACM/IEEE international conference on human-robot interaction, New York, New York, USA, March 2011. ACM, New York, pp 473–480



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