

# Empathic Touch by Relational Agents

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**Abstract**— We describe a series of experiments with an agent designed to model human conversational touch—capable of physically touching users in synchrony with speech and other nonverbal communicative behavior—and its use in expressing empathy to users in distress. The agent is comprised of an animated human face that is displayed on a monitor affixed to the top of a human mannequin, with touch conveyed by an air bladder that squeezes a user’s hand. We demonstrate that when touch is used alone, hand squeeze pressure and number of squeezes are associated with user perceptions of affect arousal conveyed by an agent while number of squeezes and squeeze duration are associated with affect valence. We also show that when affect-relevant cues are present in facial display, speech prosody, and touch used simultaneously by the agent, that facial display dominates user perceptions of affect valence, and facial display and prosody are associated with affect arousal, while touch had little effect. Finally, we show that when touch is used in the context of an empathic, comforting interaction (but without the manipulation of affect cues in other modalities), it can lead to better perceptions of relationship with the agent, but only for users who are comfortable being touched by other people.

**Index Terms**— Animations, Evaluation, Haptic I/O, Natural language, User interfaces

## 1 INTRODUCTION

**E**MPATHIC communication—the process of communicating that one understands the emotional state of another—is a pre-requisite for providing emotional support which, in turn, is a key element for establishing most kinds of meaningful social relationships between people. Within healthcare, for example, clinician empathy for the patient has been widely acknowledged as being an important prerequisite for the establishment of a working alliance relationship, which is associated with improved health outcomes [1]. Empathy alone can also be important: in physician-patient interactions, physician empathy for a patient plays a significant role in prescription compliance, and a physician’s *lack* of empathy for a patient is the single most frequent source of complaints [2].

An essential element of empathic interaction is that the empathizer must clearly communicate their understanding of their partner’s emotional state [3]. An important channel for communicating empathic understanding of distress is through physical touch as an acknowledgment of the distress and a message of comfort and caring.

Empathic communication is also a fundamental requirement for computer agents that autonomously sense and act on user affective state, especially when confirmation of this sensed state by the user is important, as well as in agents that are designed to provide comforting to users, for example in healthcare applications. These abilities are also crucial for agents designed to establish long-term, social-emotional relationships with people; artifacts that have been referred to as “relational agents” [4].

Research on empathic communication by computer

agents has largely been focused on natural language (using text or speech) and facial display as communication channels [5-7]. To date, physical touch has been largely ignored as a channel of empathic communication for computer agents.

In this paper we describe an animated conversational agent that has the ability to touch the user in synchrony with dialogue for the same reasons that people use this modality—to comfort, emphasize, or display or establish social bonds. One embodiment of such a “touchbot” would be a device that hospital patients can hold while lying in their hospital beds, capable of sensing touch (squeezing, stroking, etc.) by the patient and able to use these same communicative signals in conjunction with a speech-based dialogue system for comforting, counseling, and educating the patient.

### 1.1 Human-Human Communicative Touch

There has been a significant amount of research over the last few decades on the forms and functions of touch as a channel of intentional communication between people. Typologies of the forms of touch decompose touch into parameters such as location (hand, shoulder, etc.), intensity, action (stroke, pat, hold, etc.), and duration [8]. Jones and Yarbrough conducted a contextual analysis of 1,500 naturally occurring touches and identified 12 distinct meanings of touch, including support, affection, appreciation, compliance, and attention-getting [9].

Nguyen, et al., studied attitudes towards touch using a survey methodology and found significantly different attitudes towards kinds of touch (e.g., pats as playful vs. strokes as loving, sexual and pleasant) and locations of touch (e.g., touch on hands as loving, friendly and pleasant vs. legs as playful), as well as significant differences in ratings by men and women (e.g., females discriminated between their body parts more than males) [10].

Hertenstein, et al., demonstrated that people can relia-

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bly communicate distinct emotions through touch alone. In this protocol, dyads were separated by a curtain and one person was instructed to communicate a labeled emotion to the other by touching them on their arm or hand. Anger, fear, disgust, love, gratitude and sympathy were decoded at rates significantly above chance levels. The forms of touch (action, duration, and intensity) associated with each emotion were also reported [11].

Several studies have also shown the positive influence touch can have on compliance-gaining. For example, Vaidis, et al. [12] showed that when subjects were presented with a request and touched once, twice or not at all by a confederate, their compliance increased with increasing touch.

Several researchers have also investigated the role of communicative touch in relationship management, although most of this research is on heterosexual romantic partners. Touch can increase closeness and attraction between partners, especially when both partners actively engage in touch [13]. Men tend to initiate touch more in developing relationships, while women tend to initiate touch more in stable relationships [14]. Henley posited that, in general, higher-status individuals have a “touch privilege” leading to more touch initiation compared to those with lower status [15]. However, several subsequent empirical studies have only provided limited support for this position.

## 1.2 Touch in Health Communication

In healthcare, the functions of touch have been classified into such categories as comforting, connecting, and orienting [16], and comforting touch has been further decomposed into categories such as promoting physical comfort vs. emotional comfort [17].

The importance of physical touch between a health provider and client in face-to-face interaction has been widely documented. For example, hospital patients who are touched by providers have been found to be more satisfied with their experience overall compared to non-touched patients [18]. Touch has also been found to be effective for providing comfort for terminally ill older adults [19] and effective in improving pain and mood in patients with advanced cancer [20]. Health providers—nurses in particular—have been found to frequently use comforting touch with patients. One study of 30 critical care nurse-patient dyads in a hospital setting found that caring touch was used by the nurses twice per hour on average (with a range of 0-17) [21]. This latter study also demonstrated that most comforting touch was given on patients’ hands and accompanied by verbal messages. People also generally rate nurses who touch their patients as more competent compared to nurses who do not [22].

Additional therapeutic forms of touch, such as massage, have also been widely used within healthcare to effectively reduce pain, anxiety, depression and fatigue across many conditions ranging from labor pain during childbirth to pre-debridement anxiety for burn patients [23]. Although many such kinds of touch within the healthcare context have been identified (e.g., [16]), we have been primarily concerned with “affective” and

“simple” touch that is used by a provider to intentionally deliver a message of comforting to a patient in pain or distress.

## 1.3 Article Overview

In the remainder of this paper we first review related work on the construction of computational artifacts that use communicative touch with users before describing the design of our own “touchbot” agent. We then present the results of an initial study to investigate the ability of the agent to communicate affect using only the touch actuator, and then describe a study using touch together with an animated face and synthetic speech to determine the relative contributions of these modalities on user perceptions of affect. We finally describe an experiment to determine the ability of empathic touch to establish a sense of closeness with a relational agent, before concluding.

## 2 RELATED WORK ON COMMUNICATIVE TOUCH BY COMPUTERS

A few researchers have developed systems that use touch as a mediated form of communication, relaying hugs [24], strokes [25], massages [26], or touch dynamics [27, 28] between users. Smith and MacLean conducted a series of experiments to characterize the accuracy with which dyads could communicate discrete emotions (anger, delight, relaxed, and unhappy) using a haptic device, finding they performed significantly above chance [29]. Haans & IJsselstein replicated a study demonstrating that touching increases compliance using a technology-mediated form of touch [30]. Although they failed to find significant results, the trends were in the expected direction.

Bailenson and Yee investigated the communication of personality cues via mediated handshakes. They found that metrics describing the dynamics of an individual’s handshake were stable over time, and that certain metrics showed different patterns between men and women. They also demonstrated that men liked mediated partners who mimicked their handshake more than women [31].

Baumann, et al, experimented with wearable haptic devices for communicating attention-getting to users, simulating both squeezes (around the wrist, via a strap that could tighten) and finger taps (on the back of the wrist). They evaluated gestures by having study participants experience each gesture and then select multiple descriptors from a list of 16 adjectives (e.g., insistent, hesitant, reassuring, anxious, etc). The authors only reported significant results for two high level comparisons: symmetric vs. asymmetric waveform stimuli, and squeeze vs. tap. Their methodology also involved the playback of continuous, repeating waveform stimuli rather than discrete, communicative gestures, and they used the haptic devices in isolation without any other information being conveyed via other modalities [32].

A few researchers have explored autonomous systems that touch users for affective or therapeutic purposes, such as therapeutic massage [33], or to communicate the

affective state of artificial creatures [34]. However, we are aware of no prior work that attempts to simulate conversational touch, that is, touch actuated by an embodied conversational agent or robot that is employed as an integrated, synchronized component of a conversational message.

Cramer, et al., studied attitudes towards a robot that touched users in various ways by having subjects watch videos of a (simulated) robot tapping a user's shoulder, hugging a user, or giving a "high five". They found no effect of this manipulation on subject ratings of the user-robot relationship, although there were effects of touch on perceptions of machine-likeness and dependability [35].

Finally, Salminen, et al., investigated the ability of a "fingertip stimulator" (small friction-based rotating cylinder) to convey affective messages to a user by manipulating its motion parameters. Their experiments demonstrated that certain patterns of motion affected user ratings of pleasantness (valence) and arousal in systematic ways [36].

### 3 THE TOUCHBOT AGENT

Based on observational studies of the body locations where nurses touch patients [21], as well as studies of where people are comfortable being touched by strangers [10], we constructed an agent that would touch users on their hands. We also wanted to ensure that the touch felt comfortable and organic, so our design for the haptic output device uses a glove with an air bladder sewn into the palm (Figure 1). The bladder is placed inside the glove so that inflation within the confined space of the glove exerts pressure across a wearer's palm. The bladder is inflated or deflated via two valves, one connected to a 25

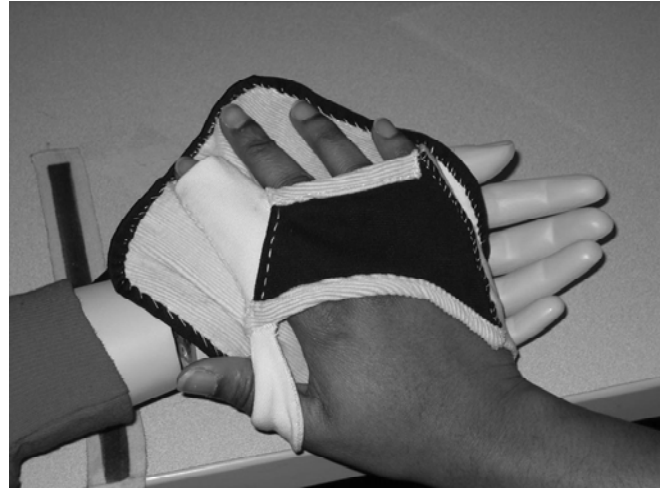


Fig. 1. Pneumatic Haptic Glove

psi compressed air tank and the other venting to the atmosphere. The valves are controlled by a GadgetMaster II controller board, and our embodied conversational agent dialogue engine [37] was extended with primitives that allowed the valves to be controlled within dialogue scripts and synchronized to word boundaries during an agent utterance.

Pilot observation studies of naturally occurring touch in human-human conversation and review of nurse-patient communication training videos, indicated that touch typically occurs at the beginning of the utterance it is semantically related to, so in all experimental stimuli in which agent touch and speech are used together, the stroke of the touch gesture is aligned with the beginning of the corresponding agent utterance.

Preliminary testing of the glove used in combination



Fig. 2. Experimental Setup with Mannequin

with an animated head on a desktop monitor indicated that users felt that the glove was not being controlled by the agent. To enhance the feeling of connectedness, we subsequently introduced a mannequin to visually connect the glove to the talking head (Figure 2). Users sit facing the mannequin with their hand in the glove, resting on the mannequin’s hand during a conversation (the glove is on the user, not the mannequin). To remove any complications arising from users using their hands for input control during an interaction, a wizard-of-oz control [38] was developed for pilot evaluation so that users could talk to the agent using speech.

## 4 STUDY 1: AFFECTIVE PERCEPTIONS OF TOUCH

Before attempting use of the haptic glove in conjunction with speech and facial animation we first sought to determine what affective information subjects could perceive from the glove alone. Based on the work of Herstein (Section 1.1) and Salminen (Section 2) we thought that it might be possible to convey a range of affective signals by varying parameters of the touch and asking study participants what emotion they felt was being conveyed. As this was an initial exploratory study, we were interested in both identification of discrete emotions (as used by Herstein) as well as more general identification of regions in the arousal/valence space of Russell’s circumplex theory of emotion [39] (as used by Salminen). Thus, our hypotheses in this study are:

**H1-1.** *Participants will reliably associate discrete emotion labels with unique touch patterns delivered through the glove.*

**H1-2.** *Participants will reliably associate ratings of affect arousal and valence with unique touch patterns delivered through the glove.*

This study (and all other studies reported) was approved by the Northeastern University IRB, and all participants provided informed consent prior to participation. All participants were recruited via craigslist.com and compensated for their time.

### 4.1 Apparatus and Stimuli

We used a combination of three different levels of intensity, duration, and number of pulses to create 27 unique touch gestures (Figure 3), of which 17 were presented to subjects. The particular levels were selected to span the ranges corresponding to human communicative squeeze behavior, with the 17 stimuli including the extremes of each parameter and a subset of the midpoint settings (to minimize study participant burden). For the intensity of the gesture (maximum pressure of the bladder), we adjusted how long the air bladder within the glove was allowed to inflate with the vent valve closed, ranging from 100 milliseconds inflation for low intensity, 150 milliseconds inflation for medium intensity, and 200 milliseconds inflation for high intensity. For the duration of the gesture, we varied how long the glove would stay inflated before opening the vent valve, ranging from 400 milliseconds for short duration, 500 milliseconds for medium duration, and 750 milliseconds for long duration.

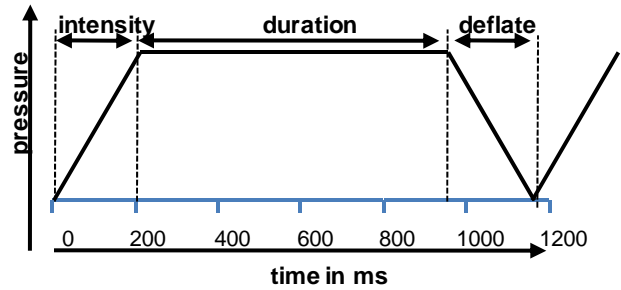


Fig. 3. Touch Control Parameters

Note that there is a partial confound between duration and intensity, in that higher intensities take longer durations to inflate. Deflation was always achieved by venting for 250 milliseconds prior to the start of the next gesture. The number of pulses simply specified the number of complete inflation, hold, and deflation cycles, ranging from one to three. Participants were presented with all combinations of duration and intensity with a single pulse, and all combinations of low and high duration and intensity with multiple pulses.

### 4.2 Participants

Twelve subjects (5 male, 7 female, aged 22-61) participated in the study. All were well educated (at least some college) and had high levels of reading and computer literacy.

### 4.3 Measures

Participants were asked to identify which one of 13 labeled emotions the gesture conveyed (basic six - anger, fear, sadness, disgust, happiness, surprise - plus sympathy, love, pride, embarrassment, envy, gratitude, “pay attention”, or none of the above). They were also asked to identify the location of the emotion on 7-point valence and arousal scales (presented separately).

### 4.4 Procedure

Participants were seated at a table and fitted with the touch glove (the mannequin shown in Figure 2 was not used for this study). They were told that the computer would play back a few gestures by controlling the inflation of the glove, and that they were to close their eyes and “think about what kind of an emotion the computer is trying to convey to you”. After this, each gesture was presented twice with a 10-second pause in between, after which participants were asked to open their eyes, select the closest emotion from the list of 14 emotion labels, then how positive or negative the emotion was (valence scale) and how intense it was (arousal scale), by pointing at their responses on three large print cards presented consecutively. The order of presentation of the 17 gestures was counterbalanced, and each participant had 5 additional gestures chosen at random and repeated during their session to allow assessment of within-subject test-retest reliability. Half way through the session participants were given a short break.

## 4.5 Results

### 4.5.1 Test-retest reliability

Participants chose the same emotion label on 5.8% of the repeated items. This is not significantly different from chance ( $\chi^2(1)=0.148, p=0.70$ ).

The within-subjects correlation of perceived arousal and valence on repeated items was assessed with analysis of covariance, following a procedure recommended by Bland and Altman [40]. There was a significant correlation between repeated ratings of arousal ( $r=0.37, p=0.01$ ), and a near-significant correlation between repeated ratings of valence ( $r=0.26, p=0.09$ ).

### 4.5.2 Rating of Discrete Emotions

There was no significant association between the touch stimulus and the discrete emotion label a participant identified ( $\chi^2(264)=269, p=0.40$ ).

### 4.5.3 Rating of Arousal and Valence

Inspection of the data showed that each of the 3 touch parameters had a roughly linear effect on perceived arousal and valence, although parameters vary in effect magnitude and polarity (i.e., that the “medium” setting of each resulted in an effect that was roughly halfway between the effects of the “low” and “high” settings, holding the other parameters constant). Therefore, we analyzed the parameters as linear predictors.

In order to justify this choice, we compared models with linear predictors and all possible interactions to models that did not assume linearity, but omitted all interactions of number of pulses with other parameters (a full factorial model could not be used, as not all combinations of parameters were tested). The second-order Akaike Information Criterion (AIC<sub>c</sub>) [41] was used as a selection criterion. The Akaike Information Criterion (AIC) is an estimate of the goodness of fit of a statistical model, penalized by the number of free parameters in the model (since more complex models, with more parameters, tend to overfit). AIC<sub>c</sub> is a modification of AIC with a correction for small sample sizes. Models with linear predictors were preferred for both arousal ( $\Delta AIC_c=7.93$ ) and for valence ( $\Delta AIC_c=4.62$ ).

We analyzed the data using random-intercept mixed-effect regression models, including as predictors the intensity, duration, number of pulses, and all possible interaction terms. Models were fit with the lme4 [42] package in R 2.10.1 [43]. Significance tests are derived from Markov Chain Monte Carlo sampling, performed with the languageR [44] package.

Participants reported significantly greater perceived arousal for stimuli with higher levels of intensity ( $b=0.47, SE=0.08, t=5.52, p<0.001$ ) and with more pulses ( $b=0.91, SE=0.09, t=9.91, p<0.001$ ). However, there was also a significant interaction effect ( $b=-0.21, SE=0.10, t=-2.14, p=0.04$ ): the combination of high intensity and multiple pulses produced lower perceived arousal than would be expected from the main effect of either parameter (Figure 4). There was no significant effect of pulse duration on arousal ( $b=0.10, SE=0.08, t=1.24, p=0.23$ ) and there were

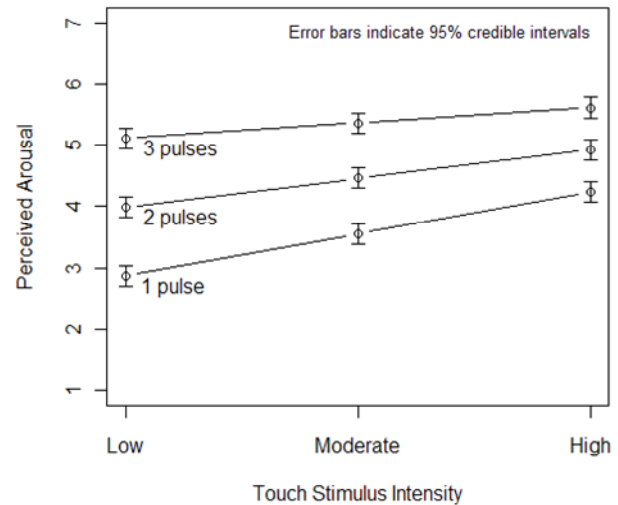


Fig. 4. Perceived Arousal as Function of Intensity and Pulses

no other significant interaction effects.

Participants reported significantly more positively valenced affect with more pulses ( $b=0.26, SE=.10, t=2.78, p=0.006$ ) and significantly more negatively valenced affect with longer squeeze durations ( $b=-0.19, SE=0.09, t=-2.13, p=0.04$ ). There was no significant effect of intensity on valence ( $b=-0.04, SE=0.09, t=-0.41, p=0.68$ ), and there were no significant interaction effects.

## 4.6 Discussion

H1-1 was not supported: participants could not reliably associate particular touch gestures with the emotion labels we used. In fact, individuals could not even reliably repeat their own labelling when presented with the same touch gesture multiple times. One explanation for this is that the glove simply did not have the degrees of freedom or resolution required to reliably convey distinct, labeled emotions, as demonstrated by Herstein. Another explanation is that the touch gestures we tested may be perceived as significantly different from those used by Herstein’s study participants, and these gestures do not unambiguously correspond with the affect labels we used, at least when presented without the social and communicative context typically required to decode the meaning of human touch [9].

However, H1-2 was supported: subjects could reliably associate different touch gestures with coarser assessments of affect arousal and valence. Thus, even though participants could not consistently map touch gestures to specific affect labels, they could at least agree on the relative rankings of the gestures on the arousal and valence axes.

Further development and experimentation is required to develop a robotic hand that can effectively (and safely) deliver strokes, rubs, pats, hits and other touch to users, in addition to simple squeezes.

## 5. STUDY 2: AFFECTIVE PERCEPTIONS OF TOUCH IN COMBINATION WITH SPEECH AND FACIAL DISPLAY

Since the fully-operational touchbot would be able to

convey affect through multiple modalities, including speech content, speech prosody, and facial display—in combination with touch—we next sought to determine how these channels could be used to combine affective signals from each channel, and what their relative contributions to overall user perceptions of affect would be. Following the methodology used in a study by Mehrabian in which he sought to assess the relative contributions of nonverbal and prosodic cues on communication of interpersonal attitude [45], we sought to select facial display, touch, and speech prosody cues that spanned the negative-neutral-positive range of affect valence, and then determine how these would be perceived by users when used in combination. Although we would have preferred to select cues that all had neutral (or at least similar) arousal levels, we were limited in the cues we could produce in each channel given the equipment and software available. Since variability in arousal of the various individual cues was unavoidable, we also sought to measure participants' arousal ratings of each gesture to see if we could determine the relative contributions of each channel in this affect dimension as well. Our hypothesis was:

*H2-1. Participants will reliably associate ratings of affect arousal and valence with unique combinations of touch gesture, facial display, and speech prosody delivered by the touchbot.*

### 5.1 Apparatus and Stimuli

The touchbot mannequin was used in this study, with the setup as shown in Figure 2. Following Mehrabian's methodology, we held the verbal content of all utterances spoken by the agent constant in this experiment, speaking only the phrase "Maybe" (determined by Mehrabian to be the most affectively neutral of the phrases he pre-tested).

The twelve participants in the previous study (Section 4) performed pre-ranking of separate facial display and speech prosody stimuli. They confirmed that the three facial expressions our animated agent could display (sad, neutral, happy; Figure 5) varied systematically across valence (repeated measures ANOVA  $F(2,22)=26.9$ ,  $p<.001$ ), with average ratings of 1.9, 4.0 and 5.7 for the three faces on a 1=very negative, 4=neutral, 7=very positive valence scale. There were no significant differences on ratings of arousal for the three faces.

We generated six prosodic variants of the way in which our speech synthesizer (English "Susan" voice from Loquendo) could pronounce the stimulus phrase. We designed these to span the valence scale, based on manipulations described in [46], and had participants in

the prior study rate these on arousal and valence. Based on these ratings, we selected the following stimuli for use in the study: 1) 0 pitch, 0 speed, emphasis on; 2) 52 pitch, 46 speed, emphasis off; and 3) 100 pitch, 100 speed, emphasis on (based on the Loquendo API parameters, which range from 0 to 100 for pitch and speed). Subjects in the prior study rated these three significantly different on valence (repeated measures ANOVA  $F(2,22)=14.7$ ,  $p<.001$ ), with average ratings of 2.1, 3.7, and 4.9. Subjects also rated these different on arousal ( $F(2,22)=14.7$ ,  $p<.001$ ), with average ratings of 4.1, 4.6, and 5.8.

Finally, from the prior study we selected three gestures that spanned the valence scale: 1) single shot, high intensity, long duration; 2) two shots, medium intensity, medium duration; and 3) three shots, low intensity, low duration. Subjects in the prior study rated these three significantly different on valence ( $F(2,22)=3.52$ ,  $p<.05$ ), with average ratings of 3.5, 4.1 and 4.4. Subjects also rated these different on arousal ( $F(2,22)=9.65$ ,  $p<.001$ ), with average ratings of 4.2, 3.0, and 5.1, respectively.

### 5.2 Participants

Twelve new subjects (7 male, 5 female, aged 20-72) participated in this study. Levels of education and computer experience were similar to the prior study.

### 5.3 Measures

The measures were the same as those used in the previous study (Section 4.3).

### 5.4 Procedure

Participants were seated as shown in Figure 2 and were fitted with the glove. They were told that they would be interacting with an automated health counselor, that the glove had an air bladder that is inflated with light puffs of air, and that the automated counselor could gently squeeze their hand while she was talking to them. They were also told that the automated counselor would try to communicate an emotion to them by speaking a short phrase, and they would then be asked what emotion she was trying to communicate.

After this, a series of 27 gestures was presented in counterbalanced order. For each gesture, the agent uttered "Maybe.", with one of the three facial displays (with the animated face lip-syching the utterance), one of the three speech prosodies, and one of the three touch gestures described above. Each gesture was presented twice with a 10-second pause in between, after which partici-



Fig. 5. Facial Stimuli Used in Experiment

pants were asked how positive or negative the emotion was (valence scale) and how intense it was (arousal scale), by pointing at their responses on three large print cards presented consecutively.

## 5.5 Results

A 3 X 3 X 3 repeated measures ANOVA was conducted, with independent variables of face, speech, and touch stimuli, and dependent variables of perceived arousal and valence. Mauchly's test of sphericity was significant on several variables, and the Greenhouse-Geisser corrected degrees of freedom were used when appropriate. As there are a variety of effect size statistics available for repeated measures ANOVA [47], we report two different effect sizes for these results:  $\eta^2$  is interpretable as the percentage in variance explained by each independent variable, while  $\eta_c^2$  (generalized  $\eta^2$  [48]) provides comparability across between-subjects and within-subjects designs.

There was a significant main effect of face stimulus on valence ( $F(1.21, 13.32)=2.39, p<0.001, \eta^2=0.371, \eta_c^2=0.393$ ); the neutral and happy faces were perceived as higher valence than sad. There was also a significant effect on arousal ( $F(2, 22)=3.88, p=0.036, \eta^2=0.012, \eta_c^2=0.014$ ), in the same direction. The main effect of speech stimulus on valence was not significant ( $F(1.32, 14.56)=2.39, p=0.139, \eta^2=0.016, \eta_c^2=0.026$ ), and the effect on arousal was near-significant ( $F(1.03, 11.36)=4.50, p=0.056, \eta^2=0.105, \eta_c^2=0.111$ ); audio stimulus #1 (expected to be low valence and arousal) tended to be perceived as low arousal. The main effect of touch stimulus was not significant either on valence ( $F(2, 22)=0.57, p=0.575, \eta^2=0.002, \eta_c^2=0.003$ ) or on arousal ( $F(1.26, 13.83)=0.33, p=0.623, \eta^2=0.002, \eta_c^2=0.002$ ).

There were no significant interaction effects. However, the interaction of speech and face stimuli on valence was near-significant ( $F(4, 44)=2.49, p=0.057, \eta^2=0.010, \eta_c^2=0.017$ ), as was the interaction of touch stimulus and speech stimulus on arousal ( $F(4, 44)=2.14, p=0.092, \eta^2=0.010, \eta_c^2=0.012$ ); there was a trend for a strong touch stimulus to reduce perceived arousal when paired with a speech stimulus designed to be high arousal. No other interactions approached significance.

A planned linear contrast test showed a significant linear trend in the main effects of face stimulus, both on valence ( $F(1, 11)=32.18, p<0.001, \eta^2=0.371, \eta_c^2=0.393$ ) and on arousal ( $F(1, 11)=8.07, p=0.016, \eta^2=0.012, \eta_c^2=0.014$ ). Participants reported a roughly linear increase, both in perceived arousal and perceived valence, across the concerned, neutral, and happy conditions on the face stimulus.

## 5.6 Discussion

H2-1 was supported: we found that particular combinations of facial display, speech prosody, and touch used simultaneously by an agent were reliably associated with levels of arousal and valence. In particular, we found that when affect cues are present in these channels, we observed that facial display dominates user perceptions of affect valence—with effect sizes an order of magnitude larger than other manipulations—and that facial display and prosody are associated with affect arousal, while

touch had little effect. The results on relative contributions of facial display and speech prosody—with the effect size of facial display roughly four times that of prosody on valence—mirror those of Mehrabian, who found that facial display contributed 45% more information to subjects' assessments of interpersonal attitude compared to speech prosody [45].

The various stimuli displayed different characteristics when tested separately, in the prior study: for example the facial display varied more in perceived valence (a range of 3.8) than speech (2.8) or touch (0.9). However, all three modalities caused significant differences in perceived valence when applied individually (in the prior study); the smaller, but still significant, effects of varying speech and touch stimuli on valence were not observed when in combination with the facial stimulus. We give two possible explanations: first, that the stimulus perceived as farthest from neutral valence (in this study, facial display) dominates in the case of conflicting stimuli, and second, that the modality of facial display dominates over conflicting stimuli (not dependent on the range of the facial displays). However, we note that the range of facial displays used in this study represent a plausible range of expressions that would be used by an agent with human-like appearance, and therefore under either explanation, we would expect an agent's facial displays to dominate perceived valence.

## 6 STUDY 3: TOUCH RECEPTIVITY TRAIT ASSESSMENT

We found in pilot testing that many users seemed to respond very positively or very negatively to agent touch [49]. We originally thought this was driven by gender, as is consistent with many prior studies demonstrating gender effects on reactions to touch (e.g., [10, 14]). However, subsequent testing indicated that gender may not be the primary factor in determining how receptive someone is to being touched. Consequently, we developed a self-report questionnaire to assess touch receptivity. This measure is related to the Opposite-Sex Touch Avoidance Scale [50], although we needed a measure that was independent of gender and which focused more on comfort being touched by strangers in professional settings rather than touch by romantic partners. Figure 6 shows the items in the instrument.

Test-retest reliability was shown to be adequate ( $r=0.68, p<.05$ ) when administered twice to a group of nine subjects over a one week interval. Internal consistency was shown to be adequate with  $\alpha=0.87$  when given to a second group of 33 subjects. Convergent construct validity was demonstrated through correlation with a validated measure of extroversion [51],  $r=0.6, p<.001$ , when administered concurrently to the same group of 33 subjects.

## 7 STUDY 4: EFFECT OF EMPATHIC TOUCH ON USER-AGENT RELATIONSHIP

In our final study we wanted to explore the ability of a

In the following, “casual touch” refers to your being touched on the hand, arm or shoulder when interacting with a professional such as a doctor or nurse.

1. \*I feel uncomfortable when someone casually touches me.
2. I go out of my way to interact with people who casually touch a lot.
3. When someone is comforting me, it helps if they casually touch me.
4. I like people who casually touch a lot.
5. I would be comfortable if a health professional were to casually touch me during a consultation.
6. I like people who shake hands with me.
7. \*During a medical checkup, I feel uncomfortable when the doctor or nurse touches me.
8. If I were in pain, comforting touch from someone would make me feel better.
9. \*I find it uncomfortable if someone touches my arm during a conversation.
10. I am likely to touch someone on their arm during a conversation.

Fig. 6. Touch Receptivity Questionnaire Items  
Items preceded by \* are negated.  
All items on 7-point Likert scales  
(1=Disagree completely to 7=Agree completely)

conversational agent to use touch as part of empathic communication, and the effect this would have on user attitudes towards the agent compared to the same communication without touch. Following previous studies on relational agents [4], we used health counseling as the application domain and working alliance as the primary measure of user-agent relationship. We wanted the agent to have the opportunity to express empathy regarding a potentially emotionally-charged topic, so cancer prevention was selected as the health counseling domain. Our hypothesis for this study was:

**H3-1.** *Participants will rate the touchbot agent higher on working alliance following an empathic interaction in which the agent uses comforting touch gestures compared to the same interaction without touch.*

### 7.1 Apparatus and Stimuli

The touchbot mannequin was again used in this study, with the setup as shown in Figure 2. Dialogue was controlled via a constrained Wizard-of-Oz setup [38] in which participants were told to say one of the options displayed on the screen when it was their turn to talk, and that the agent could recognize their speech. In fact a research assistant listened to them and controlled the agent.

Two dialogue scripts were used. The first was a tutorial dialogue of about 10 minutes where the agent attempted to educate the participant about skin cancer. The second dialogue was about 3 minutes in duration and combined social chat (weather etc.) with a discussion in which the agent asked the participant how he or she felt about cancer. During this dialogue, the agent provided empathic responses appropriate to the participant’s answers. For example, if the participant indicated that they knew someone who had skin cancer, the agent responded with “I am sorry to hear that. That must have made you feel terrible”. All dialogues always provided two instances of

empathic feedback. In order to maximize the effects of the touch manipulation while having the touch be perceived as empathic, empathic messages were delivered with the neutral facial display and neutral speech prosody, and with or without a negative valenced touch gesture as dictated by experimental condition. As before, all speech was accompanied by appropriate lip-synchronization facial animation. The neutral face used throughout all dialogue, and the touch gesture—when used—was aligned with the start of the accompanying utterance.

### 7.2 Participants

Forty new subjects (20 men, 20 women, aged 18-59) participated in this study, and had high levels of education and computer literacy as in the prior studies. Females did score higher on touch receptivity compared to males (5.2 vs. 4.8 on a 1-to-7 scale) but this difference was not significant.

### 7.3 Measures

Demographic information was collected at the start of the session. All participants also filled out the touch receptivity measure (Section 6) at the end of their session.

Several self-report outcome measures were collected at two time points in the study. The primary outcome measure was the bond subscale of the working alliance inventory [52], which measures the emotional dimension of the working relationship between a patient and health provider. Additional scale item outcome measures were asked about the degree participants enjoyed interacting with the agent, their desire to continue interacting with the agent, and the naturalness of their interaction.

### 7.4 Procedure

Following consent and background questionnaires, a participant was randomized into TOUCH or NO-TOUCH condition. The participant was then seated in front of the agent (as in Figure 2), but the participant was instructed to keep their hands in their lap. The researcher then instructed the participant in how to interact with the agent (by speaking one of the options displayed on the screen), and told that they should pay attention to the information the agent tells them because they would be tested on it later. The researcher then left the room, and the participant conducted the initial 10 minute educational conversation about skin cancer. In actuality, this conversation was only used to establish a baseline assessment of outcome measures prior to any social, empathic or touch-related communication. Following this conversation, the participant was led into another room to fill out the questionnaires assessing the outcome measures.

Next, the participant was seated facing the agent again, and this time outfitted with the touch glove. After the researcher left the room, the participant conducted the 3-minute social and empathic conversation either with or without touch, according to the condition the participant had been randomized into. Following this conversation, the participant was led into the other room to fill out the outcome questionnaires a second time, before being debriefed and dismissed.



## 7.5 Results

Participants were split into high and low touch receptivity based on the median value of this measure, with 21 in the high receptivity group (mean 5.49, SD 0.50) and 19 in the low receptivity group (mean 3.18, SD 0.79).

Changes between baseline and post-intervention outcome measures were assessed using a 2x2x2 repeated measures ANOVA with study condition (TOUCH vs. NO-TOUCH) and touch receptivity category as between-subjects factors and time (baseline vs. post-empathic conversation) as the within subjects factor. There was a near-significant interaction of study condition and touch receptivity on change in working alliance scores,  $F(1,36)=3.58$ ,  $p=.067$ , such that participants who were comfortable with touch had greater increases in working alliance when they were touched; those who were less comfortable being touched had greater increases in working alliance when they were not touched (Figure 7). There were trends towards main effects of touch on change in ratings of enjoyment with ( $F(1,36)=2.27$ ,  $p=.14$ ) and naturalness of ( $F(1,36)=1.94$ ,  $p=.17$ ) the interaction compared to no-touch, but these were not significant. There were no other main or interaction effects of study condition or touch receptivity on outcome measures.

There were no significant gender effects.

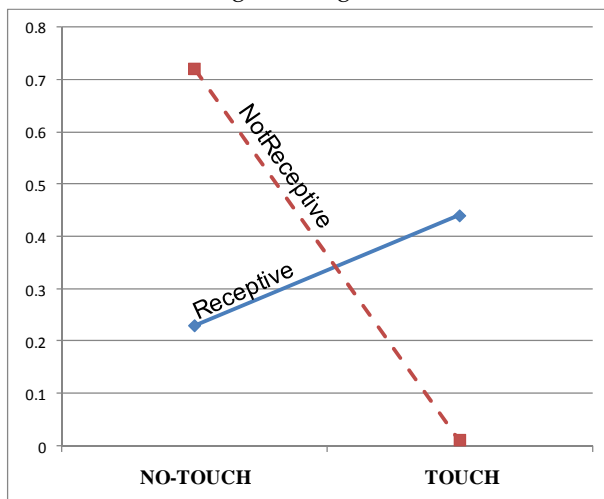


Fig. 7. Interaction of Touch and Receptivity on Average Change in Working Alliance

### 7.5.1 Qualitative Results

When participants in the touch condition were asked about their overall impressions of their experience, the most common response was that it was unusual, weird or awkward:

- *"It was definitely a different experience, it was more conversational I guess. It gives the sensation of human touch to an extent. It was just kind of awkward having that, interacting with a computer I guess."*

When asked for their reactions to the touch specifically, there were mixed opinions:

- *"The second conversation actually felt a little bit more natural, I dont know if that was just because of the whole handshake touch thing, I felt a lot more comfortable ... It made me feel a little bit more relaxed, .... After that it ac-*

*tually was reassuring."*

- *"It didn't really do anything for me. ...I don't think it adds a lot frankly. I think some people might really object to it."*
- *"I think it's a little different for guys and girls. Being a guy, I definitely find it a bit weird. You know, if a doctor reached out and squeezed my hand as he gave me bad news, I'd you know...I would find that more strange than anything else"*

There were also mixed responses when we asked participants what the agent was trying to communicate with the touch, but most felt it was expressing empathy, sympathy or reassurance (8 of 15 respondents). The second most-frequently cited meaning was emphasis (2 of 15).

- *"I didn't know the purpose of the squeezes but it seemed to correspond with friendly words."*
- *"I saw it as an expression of sympathy or empathy"*
- *"Probably sympathy, compassion..."*
- *"I guess if it was like a real situation, I would interpret it as caring, and you know, really being in to the conversation, and not like talking to me, but talking with me."*
- *"Definitely felt... like a hand squeeze... like sympathy. No, I guess not sympathy, not empathy, sort of - reassuring. Reassuring is the word."*
- *"...it was like another way to accent a response I gave her. It was a good way to bring my attention back."*

## 7.6 Discussion

H3-1 received partial support. We found that when touch is used in the context of an empathic, comforting interaction, that it can lead to better perceptions of working alliance with the agent, but only for users who are comfortable being touched by other people; for users who are uncomfortable being touched, working alliance increased the most when they were not touched. Some individual items of the working alliance inventory related to empathy showed the same response pattern: "The advisor and I understand each other." ( $F(1,36)=16.2$ ,  $p<.05$ ); and "I feel that the advisor is totally honest about her feelings toward me." ( $F(1,36)=14.1$ ,  $p=.010$ ).

## 8 CONCLUSION

Our series of experiments has provided further evidence that people will project affective meaning onto even the simplest of communicative behaviors. In our studies, a simple, two degree-of-freedom device that could squeeze users' hands could be manipulated to produce reliable reports of affective meaning in the circumplex model of arousal and valence.

We also confirmed earlier results indicating that when multiple communicative channels of affective information are used in synchrony, the channels are not given equal weight in users' overall, integrative assessment of affective meaning. Of course, these results depend crucially not only on the particular channels used, but on the minutest details of the particular cues used within each channel, as well as the broader context in which the message is conveyed.

Finally, we demonstrated a practical application of au-

tomated conversational touch in delivering empathic messages to patients in the context of health counseling conversations. We found that, for many individuals, empathic touch contributed to their feeling understood by the automated counselor and to their feelings of positive working relationship with the counselor. Given the importance of empathy in health communication, and working alliance in health outcomes, these findings could pave the way to a future generation of robotic health counselors that use touch to comfort patients in pain or distress, to emphasize important health information, and to persuade patients to adhere to their self-care regimens.

### 8.1 Limitations

There are several limitations in the design of our touchbot apparatus and experimental design that should be noted. First, due to technical limitations of our apparatus, the touchbot is not able to initiate touch; users must hold hands continuously with it during their dialogue. Continuous hand-holding is not normal behavior for strangers (including nurses and patients) in Western culture, and may have negatively impacted the ecological validity of our results. Also, with the current apparatus, users primarily feel pressure in their palms, whereas with typical human hand squeezes the pressure is felt throughout the grasped area. Some users might have felt that the working alliance inventory was inappropriate to use in rating their relationship with a computer agent and this might have led to an unnecessarily high error variance in our measure of working relationship (although it has been used in several prior user-agent studies, e.g. [4]). There may also have been gender concordance effects that we did not control for given that the agent was always female. However, even with these various limitations, we still observed relational effects of touch for receptive individuals. One explanation for this could be that the simulation we presented to users was successful precisely because it had such low fidelity; attempts to make the experience more human-like could lead to the “uncanny valley” effect and resulting overall negative reactions to the touchbot from all users [53].

Finally, despite our pre-testing in the first study, users may have mis-interpreted the meaning of the touch, for example they may have interpreted it as attention getting or emphasis. This could have either resulted in the touch simply failing to convey an empathic message, yielding decreased power, or it could have resulted in an actual confound, with the touch simply drawing attention to the empathic message delivered via the touchbot’s speech.

### 8.2 Future Work

We have found from debrief interviews that study participants still feel that the hand is not being controlled by the agent. For this reason, and to gain finer control over the touch dynamics (e.g., to replicate the results by Herstein [11]), we have fabricated a mechanical hand that we are starting to experiment with (Figure 8). We feel that by having the agent’s physical hand administer touch, users will feel more inclined to attribute the touch behavior to the agent and make the touch a more effective communi-



Fig. 8. Robotic Touch Hand

cation channel. There are also a variety of other promising haptic technologies that could be investigated for conveying empathic touch, including Shape Memory Alloys for squeezing (as in [54]), and robotic hands with much higher degrees of dexterity [55].

We are interested in exploring additional functions of touch used by conversational agents, particularly in health education and counseling applications. We are exploring the role of conversational touch in emphasizing important information during tutorial dialogues, as well as its role in compliance gaining in the context of counseling conversations. More observational research on the forms and functions of human-human conversational touch are required to inform this work. Further development of study protocols for generating spontaneous conversational touch between strangers in the laboratory setting is also required as we have yet to find a reliable methodology for this.

An important follow up study is to compare acceptance of the touchbot with acceptance of touch from a person for comforting across a wide range of individuals and situations. Some researchers have demonstrated that children with autism may feel safer interacting with a robot compared to another person (e.g., [56]), so these and other populations may actually feel more comforted receiving empathy from the touchbot. Experimentation in situations of more extreme user distress (e.g., after receiving devastating news) may also better illuminate those situations in which the touchbot is accepted.

We also plan to further investigate the role of gender in these interactions, and, in light of our study results, how an agent might determine an individual’s touch receptivity before attempting touch. The issues related to how user perceptions of touch change over time as the user-agent relationship evolves also represents an interesting area of investigation.

Conversational touch represents an important and unexplored modality for conversational agents, especially those deployed in the healthcare environment.

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