Contact Expressions for Touching Technologies

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ABSTRACT

Traditionally, most human-computer interfaces are based on limited tactile input and audio/visual output, and even when the interface has been enhanced with speech, gesture, and haptics, this is often done to supplement (or compensate for) audio/visual output. Even the most interesting and elaborate work on force-feedback does not seem to be yet envisioning the full expressive potential of physical contact, in particular, the "contact expressions" used routinely by people and animals in different contexts. People use contact expressions when other forms of communication are inappropriate or impossible, to supplement other forms of communication, or because the physical contact itself has significance. As robotic toys and embodied technological devices become smaller, more portable, more durable, and more commonplace, it is our belief that contact expressions will become an important area of interface design and will open up new areas of study for applied semiotics. This paper outlines an initial design taxonomy of basic contact expressions – and describes a "contact cushion" we have built and tested to explore some of the potential for contact expressive devices.

Keywords

Contact expressions, semiotics, tactile interfaces, haptic interfaces

1. INTRODUCTION

SCENARIO: Karo moves into the living room to find Janet lounging on the sofa with her infant son, Paul, who is sleeping beside her.

Young Paul starts to thrash in his sleep, so Karo crawls up and sprawls next to him. Paul smiles in his sleep and snuggles into the warmth of Karo, wrapping one arm around him. The two of them start to breathe deeply and evenly in tandem contact. At that moment, Janet's friend John calls, but Janet can tell from the signal that he is in a chatty mood and so decides not to answer.

Karo puts his nose under Janet's arm, nudging it up a few times until she gets the idea that he wants to be stroked; he settles his head into her lap. When Karo's head begins to get too heavy, Janet tries to push it off; but Karo notices that at that moment he would disturb the sleeping baby if he moved in the direction she is

pushing, so he resists – and when Janet stops pushing, he moves his head in a different direction. After a while, Janet drifts off to sleep – and wakes when the nearly-empty bowl of chips that was beside her slides off the sofa and spills onto the carpet. She reaches out her hand to confirm that Karo is still lying beside her, then pats/pushes him to indicate that he should take care of it; he responds by getting up, licking/eating up the spilled chips, and picking up the bowl in his mouth and taking it into the kitchen.

In this scenario of the not-too-distant-future, Karo is a robot – and all of this takes place silently in the dark.

The purpose of this scenario is to highlight some of the significant ways that the give and take of physical contact is an almost unnoticed part of everyday life – and to suggest ways in which such "contact expressions" can be fruitfully part of future computational devices.

What we mean by "contact expressions" is probably most evident in the range of examples from the scenario, but we can also say that by our view they involve mutual signification, are not simply "parasitic" on natural language (nor entirely subsumed within it, post-modern opinion notwithstanding), and include both instrumental and self-fulfilling touch. In other words, just as "facial expressions" involve significance beyond the display of certain movements, so, too, "contact expressions" involve significance beyond simple properties of touch.

In our daily lives, many contact expressions are possible, interesting, and useful because they are part of an ongoing, dynamic, and secure exchange. If the reader is still not convinced that contact expressive devices (together with other changes in the embodiment devices) will be part of a radical transformation of our relationship to computational technology, consider the following almost trivial example. Many of us have had the experience of finding a cat sleeping on a pile of papers on our desks at home. And, without thinking much about it, we slide the cat off the papers and it drops to the floor. Imagine if, instead of the cat, it was a laptop that someone slid off the edge of the table.

We believe there is enormous future potential for contact expressive computational devices that help with different kinds of tasks, that facilitate and enrich artistic, creative, and entertaining experiences – and for improving the life of those who are autistic, blind, deaf, allergic, elderly, or infirm. It seems to be an important long-term research agenda to begin answering the question, to paraphrase John Austin, of "How to (get computational devices to) Do Things With Contact Expressions." We now turn to look at the status of work on this problem.

2. SURVEY

Given that contact expressive devices can be beneficial in many ways, what is the current state of understanding and applying them? Surprisingly, although there is various work on different aspects of the topic, it is, on the whole, underserved. We now provide a short survey of relevant work in three traditions: studies in the behavioral sciences that attempt to show the significance of "touch"; attempts to create taxonomies (or "vocabularies") of physical touch; and the development of technologies that use physical contact as a significant part of the interface.

2.1 Behavioral Sciences

Although there is a fairly large body of research into what may be called "nonverbal communication", the majority of this work is on visual expression (facial expressions, physical appearance, direction of gaze, physical posture, orientation, movement, proximity and other visible forms of "body language") and paralinguistics (i.e., vocal inflection, pitch, volume, speech rate, etc.). A representative definition of what is meant by non-verbal communication makes this clear: "Nonverbal communication, then, could be defined as that part of a message, which is not words, but which may accompany words or occur separately from words – and includes facial expressions, gestures, posture, spacing, tone of voice, pitch, volume, speed of talking, etc." [21]. Although a typical survey of nonverbal communication will include references to studies of touch, there is usually very little detail; and a survey of the literature on nonverbal communication also reveals that a only a small percentage of it is devoted directly to studies of touch.

There does seem to be widespread acknowledgement of this neglect by the researchers who study nonverbal communication, and one suggested explanation [19] is that although this may partly be the result of touch-related inhibitions and taboos, it is almost certainly also related to the methodological difficulties of studying physical contact. These difficulties include the fact that casual contact among strangers is rare; intimate contact between friends or lovers is usually private; and the factors relevant to touch are difficult to isolate from other senses and forms of expression without creating further research challenges. All of these difficulties also help to explain why most of the research on touch is in the form of observational correlation studies. (For a survey of this research, see [18].)

Of the research that has been done, some has involved the relationship between physical contact and autism, and, in particular, on "contact gestures." These are "physical commands", often used by children, when they are not able to successfully indicate their needs with gestures. So, for example, a young child who wants an adult to open a container may use a contact gesture to actually place the adult's hands on the container and put them through the motions of opening it.

2.2 The Semiotics of Touch

Interestingly enough, physical contact is one of the areas that seems least explored by semioticians. To be sure, it is indicated (usually in a cursory manner) as part of the larger field of semiotics, but there seems to be very little detailed study, theory, or discussion about the signifying nature of physical contact.

And unlike the behavioral sciences, this does not seem to occasion as much comment among practitioners. We can imagine at least two possible contributing factors: the first is that semioticians tend to come from linguistic or philosophical traditions (rather than, say, physical therapy); the second is that many semioticians may still, in many ways, believe in the validity of separating form from function – in which case the "physical embodiment" of signifying systems is irrelevant to the signification processes themselves (and are therefore subsumed under more general semiotic taxonomic categories). There is indeed suggestive evidence for this second hypothesis if we look at the kinds of semiotic descriptions that have been proposed for physical contact.

Introductory texts on semiotics mention physical contact as a part of the overall field, but this is usually no more than a line or two to the effect that there are "bodily codes" (bodily contact, proximity, physical orientation, appearance, facial expressions, gaze, head nods, gestures and posture) – and that there are "group-specific codes" (gender, age, race, culture, status, etc.) of physical contact. As indicated above, many of these codes are what behavioral scientists typically consider part of nonverbal communication (rather than physical contact *per se*). Even scholarly discussions or surveys of the relationship between "semiotics in the large" [15] and the various dimensions of animal semiosis do not seem to have included much detailed investigation or analysis of physical contact as part of the larger study of human signification.

Beyond semiotics, there have some proposed taxonomies from the human sciences, including large taxonomies of types of bodily contact classifications of bodily contact common in Western Culture; a five-level taxonomy of type/meaning pairings; and proposals for modeling the possible relationships between physical contact and status (see [18] for an overview).

2.3 Tactile Technologies

Although some aspects of haptic research are as old as any work on human-computer interaction, in many ways touch is still a nascent field of HCI study. Indeed, journals, associations, and professional conferences devoted to haptic research have only started to be a regular occurrence in the last few years. There are, of course, a number of efforts to develop technologies that accept tactile (or haptic) input and, to a lesser degree, provide tactile output ("force feedback", etc.). Most of the work to develop "tactile interfaces" has concentrated on simulating different aspects of the physical world (game force-feedback devices, motion simulators, and the like) or providing additional feedback in multimodal systems for complex tasks (force-feedback for molecular docking systems, etc.); or "mapping" the movement of an on-screen pen over physical contours of a surface to a (force) feedback input device. (For a summary of the history of research on haptic and force-feedback interfaces, see [24].)

One of the earliest examples to use tactile conviviality as part of the interface was in the creation of Noobie, The Furry Computer [10]. It was a computer for small children, in the form of an over-sized, plush toy that they could climb up on, sit (or lay) in its lap, and so on. The emphasis in that project was to make the interface friendly and familiar. This theme, of using plush toys as interface devices, has been elaborated by a number of subsequent researchers [11,12,14,16], however very few projects seem to be elaborating the physical contact aspects of the original Noobie project.

A sampling of current projects gives an indication of both utilitarian and experiential applications of touch-oriented computational research. There are projects to develop telephones with various haptic qualities [4,20]; to develop various kinds of "musical objects" that respond to touch [23,27]; to develop physically embodied interface objects ("tangible bits") that can be manipulated in various ways [13]; to develop contact-responsive plush electronic toys (Furby, Barney, Tickle Me Elmo) [7,17,25]; and to develop hand-held devices with "ambient touch" interfaces [22] that can support different physical interactions such as tilting, dropping, spinning, rubbing the device against something else, and so on.

In addition to haptic computational devices, there are other attempts to apply the study of touch to the development of other technologies. One area is textile design, where online shopping is motivating research into methods for simulating tactile aspects of different materials [8]. In recent years, have been popular; and there have been semi-serious proposals for combining VR and force-feedback for "virtual sex" [3].

3. PROBLEM STATEMENT

As we have seen in the survey, there does not seem to be much in the way of either semiotic analysis of – or applied research into – the extended possibilities of what we are here calling contact expressive devices. In some cases the absence of research is simply curious. For example, most human-computer interaction already involves what could be contact expressive input: we type at keyboards, move mice, draw with pens on tablets, and use pressure-sensitive screens. And although this is obviously a very limited subset of the full potential of contact expressive interfaces, it is almost inevitable that haptic interaction will be extended in various ways (not the least of which will be to make more expressive use of haptic *output*.)

In other cases, the absence of an explicit emphasis on contact expressions is actually startling. There are, for example, many robotics projects around the world with the stated intention of improving life for the elderly, the autistic, and the allergic; however, it is rare for these projects to include touching (or being touched by) these robots an explicit goal (for some important exceptions, see [5,9]). Even project reports devoted to robotics and "social interaction" tend to ignore almost all aspects of physical contact. So, for example, in the otherwise excellent survey article on the many dimensions of "embodied social interaction" [11], there is literally no mention of physical contact.

Beyond these limitations, there is also the almost total absence of any semiotic study of contact expressions – and virtually no work of which we are aware that attempts to leverage such analyses in the service of designing and implementing useful and experientially interesting contact expressive devices.

We feel, therefore, that there is still major work to be done studying, understanding, and making use of contact expressions. Our particular focus in this paper is to contribute to the development of this area of study by sketching an initial design taxonomy of contact expressions for computational devices

4. METHOD

Our approach emphasizes descriptions that are relevant to the designer/developer of contact expressive computational devices.

This involves a cycle of device implementation, study, and revision. It also involves analysis that draws on a number of traditions: Speech Act Theory, first-person studies [26], constructivist models of signification [2], and Pattern Languages [1].

In order to begin elaborating a vocabulary for contact expressions for computational devices, two small, exploratory studies with a contact expressive cushion (the PillO'Mate) were conducted. The first study explored the use of the cushion as a therapeutic presence, and illustrates a number of issues relevant to understanding the *self-fulfilling* (or "experiential") potential of contact expressive devices. The second study explored people's reactions to using the cushion as a telephone "beeper", and illustrates some issues relevant to their *instrumental* potential.

These studies involved qualitative explorations of the phenomenology of the person's contact expressive world ("what do different kinds of contact expressions mean to you?" and "why do you associate a specific contact expression with a specific type of person?", "if we changed the device so that it was contact expressive in this other way, what kind of person would you assume is trying to contact you?" etc.). These discussions are the basis for formulating initial descriptions of human contact acts – and for then creating a preliminary sketch of a "design Pattern Language" for contact expressive devices based on them.

The cushion, the studies, and Speech Act Theory, and Patterns Languages are now described in more detail.

4.1 PillO'Mate Device

The PillO'Mate is an oversized cushion, inside of which is the following technology: a fine wire-mesh proximity-sensor, a GSR (Galvanic Skin Resistance) sensor, a vibration motor, a heating pad, and a speaker. The electronics inside the cushion are surrounded with "granular" Tempur™, which was chosen so that the cushion would to be not too heavy, it would be pleasant to hold and hug, and yet it would still protect the electronics inside. The back of the cushion is covered in fleece (to conduct heat), and the front is covered in imitation leopard-skin to encourage stroking, cuddling, and nuzzling. (For the studies reported here, it was not possible to completely integrate all the necessary components directly into the cushion. The resulting solution has a "tail" which consists of cords that connect the heating pad to an external transformer for the heating pad, an amplifier for the speaker, and a PC for the audio clips. Although this tethered solution made certain kinds of studies impractical, it also made some users explicitly aware of and interested in the potential of more mobile contact expressive devices.)

People use the PillO'Mate in much the same way they do an ordinary, large cushion – they pick it up, put it on their laps (or hug it to their chests), fiddle with it, and lean, lay, or put their heads on it. The cushion switches to an active state when it detects an approaching object (such as a hand) within 5cm, but only by being stroked or touched in specific ways will it react with sound, vibrations, and/or changes of temperature. (For more detail, see [3].)

4.2 PillO'Mate Studies

Study 1: Warming Up to Contact Expressions. The original impetus behind the PillO'Mate was to develop a device that helped people relax. Using a pet (cat) as an initial source of inspiration, the device was developed as a way to explore certain

qualities that people find relaxing about having a cat sleeping on their laps. It is important to emphasize that the goal was not to simulate a real cat, but rather to explore and support different aspects of touching, feeling and listening. The first study, then, is based on observations of people (many of them attendees at Comdex 2003 in Gothenburg) sitting with the PillO'Mate and talking about it in terms of its soothing qualities. Below we use insights from this study to explore some of the self-fulfilling potential of contact expressions.

Study 2: Contact Expressive Pager. In order to explore some of the instrumental potential of contact expressions, we did a very small study of how the PillO'Mate could be used or further developed as "contact expressive pager." This consisted of some exploratory meetings with six people in which they were asked to sit with the cushion on their laps, close their eyes, and imagine that when the cushion started vibrating it was an indication that someone was calling. They were then asked to describe characteristics of the imagined caller based on the characteristics of the contact expression. The study was divided into two parts: in the first part, participants discussed the significance of the current PillO'Mate for different categories of people calling, types of call, etc.; in the second part, they discussed how the contact expressions of the PillO'Mate could or should be changed in order to better match the person's experience and expectations of different callers, phone calls, and so on.

4.3 Applied Semiotic Analysis of Contact Expressions

There are a number of possible semiotic models that could be used as the basis for enriching our understanding and application of contact expressions.

Since we are interested in an understanding that can be applied to the development of devices with both instrumental and self-fulfilling contact expressions, we pursued a phenomenological analysis that emphasizes *action* (for an earlier example of a similar orientation, see the discussion in Winograd and Flores [28].) That is, we are trying to understand *contact acts* – and to model the "how and why" of contact expressions in the context of the world as experienced by the beings, biological or otherwise, in question. This last sentence should also signal one of our working assumptions, namely that there is no in-principle difference between studying and modeling the contact expressions of biological beings and non-biological beings. In other words, our approach here is mechanistic (in the broadest sense). This is, of course, a hotly contested position, but we mention it here simply to warn the reader, not to defend it. (Readers interested in the grim details of this debate are referred to any current book on the philosophical controversies of artificial intelligence.)

As a further elaboration of Speech Acts, we are also in the initial stages of trying to build the beginning of a design vocabulary for contact expressive devices.

4.3.1 Speech Act Theory
In order to frame the results and insights of our work, we now provide a brief overview of (a slightly generalized version of) Speech Act Theory (for a more detailed overview, see [28]). Speech Act theory emphasizes what people want to *do* with language (as opposed to trying to establish the truth-value of what any particular statement signifies), and proposes three major types of "acts": locutory, illocutory, and perlocutory. (In order to

provide relevant examples below, we reference "contact acts" which we will more fully elaborate later in the paper.)

The locutory dimension of a communication act has to do with its material generation – locutory differences in a contact act would be whether the contact expression was soft or hard, whether it vibrated or not, the rate of vibration, and so on. The illocutory dimension of a communication act has to do with the *intention* of the act – illocutory differences in a contact act could be whether the physical contact *asserted* ("someone is calling"), whether it *expressed* ("I am happy"), whether it *directed* ("move over there"), whether it *interrogated* ("what is this thing?"), and so on. The perlocutory dimension of a communication act has to do with the effects it can have on the receiver's actions, beliefs, or judgments – perlocutory differences in a contact act would be whether *the person being touched* calmed down, had a change of mind, was physically displaced by the contact, leaned into it, and so on.

In addition, an important aspect of the Speech Act model is the emphasis on the *felicity* conditions of an act – that is, on the conditions that make such acts appropriate.

Some limitations of this model will become clear as we start to apply it to the analysis of instrumental and self-fulfilling contact expressions. Here we briefly highlight two of them: first, it is not clear whether all illocutory dimensions of speech acts are present in contact expressions (nor whether the speech act illocutory categories account for all aspects of contact expressions); and second, it is not clear how the current instrumental emphasis of the model can account for such acts as jokes, play, altruism, creative expression (singing, poetry), and other self-fulfilling forms of expression.

4.3.2 Pattern Languages
Christopher Alexander developed Pattern Languages [1] as a way to effectively identify and describe both what is structurally necessary – but also what "feels right" as inhabitants of architectural structures

For our purposes, the significant aspects of Patterns are that they describe an effective (architectural) **feature** that resolves certain conflicting **forces** in some **context**. So, a classic example is Alexander's proposal for (natural) "Light on Two Sides" as pattern that needs to be addressed in order for a room to be "good." This example illustrates that Patterns are specific, flexible, sharable, and testable. This particular Pattern is specific enough for anyone to be able to determine whether or not it is satisfied for a particular room; it is flexible enough that it may be satisfied many different ways; it is sharable in that it can clearly be described for someone else; and it is testable in that people can determine whether or not the proposed feature does, in fact, improve the quality of rooms where it is present.

5. PILLO'MATE STUDIES
Below we highlight some of the insights from the two PillO'Mate studies. For each study, we examine the contact expressions of both the people and the cushion in terms of any locutory, Illocutory, and perlocutory acts that seem present. Additionally, we note if there seem to be contact expressive acts that do not seem to fit the existing framework. Note that although there is some redundancy in describing interactions from both the perspective of the user and from the perspective of the cushion,

these perspectives are not entirely symmetrical so we feel it is worth doing.

5.1 Warming Up to Contact Expressions

The first study was in the form of informal feedback about the PillO'Mate from a large number of users (consisting mostly of male attendees at a trade show). In this study we were exploring whether and how people would "warm up" to a contact expressive device that was "warming up" (literally and metaphorically) to them.

5.1.1 Warming Up: Human Contact Acts

Here we summarize the different contact expressive acts that people used in their interaction with the PillO'Mate.

Locutory contact acts. The locutory dimension of human contact acts in this study involved different parts of the human body (hands, faces, etc.)

Illocutory contact acts. Most of the observed human illocutory contact acts were either interrogative or directive. The interrogative acts involved various kinds of explorations of the cushion's surface texture and grain; its heat, softness and weight; and its reaction to different kinds of stroking, squeezing, patting, and so on. Examples of the directive acts included attempts to restart the purring of the cushion if it stopped

Perlocutory contact acts. Examples include: whether or not individuals were actually successful at restarting the purring.

Other issues. One of the major observations was the number of "non-acts" – namely, the number of people who saw the cushion and by various means indicated that they didn't want to touch or hold it. In this regard, there is probably a significant correlation between the (predominantly) male attendees at Comdex, and the "affordances" (texture, pattern, size, etc.) of the particular cushion. We did see, however, a significant change in attitude over the course of the trade show. This seems partly the result of word of mouth ("it looks weird, but try it"). In fact, once people tried the cushion, it was quite common for them to try and persuade their companions – and some even went running to get friends to try it. Based on overall feedback and observations, although there was resistance to trying the cushion, the response of practically everyone who tried it was overwhelmingly positive. (Indeed, many people were reluctant to stop using it once they started, although this could have had as much to do with trade-show exhaustion as anything else.)

5.1.2 Warming Up: PillO'Mate Contact Acts

Here we summarize the different contact expressive acts that the PillO'Mate used in its "warming up" interaction with people.

Locutory contact acts. In general, the locutory contact acts of the cushion remained fairly constant: physical vibrations, heat, and surface texture. It was possible to reduce or increase the vibrations, and this was done a few times at the request of a few people.

Although we did not specifically ask for suggestions about how the cushion might be changed or improved, there were a number of spontaneous proposals for changing some locutory aspects. Many people commented on the "purring", wishing that it were different in various ways (faster, slower, stronger, softer, more varied, etc.). For many, this seemed related to their model of it as a substitute cat – which itself also occasioned suggestions for making another, more "dog-like" cushion. (Note that they didn't want it to have the *form* of a dog, but rather its contact expressivity.) There were very few spontaneous suggestions about other locutory contact acts (weight, size, shape, heat, etc.)

Illocutory contact acts. Although this is the most well-developed aspect of Speech Act theory, for obvious reasons it is largely absent from the PillO'Mate. (The question of whether truly intentional contact acts ever *could* be part of some mechanical device raises many of the standard philosophical controversies of artificial intelligence. In particular, it raises questions about whether a designed device is illocutory in its own right – or whether it is expressing the illocution of the designer. We leave it to the reader to consider whether or not it is reasonable to describe the PillO'Mate's ability to stop purring under certain conditions as an "excercitive" attempt to demand stroking.)

Perlocutory contact acts. In the spirit of the last point, we also leave open the question about whether the PillO'Mate actually achieved its goal (in the case where people started stroking it in order to have it start purring again).

5.2 Contact Expressive Pager

The second study was in the form of informal discussion with a number of users of the PillO'Mate in order to learn whether and how the PillO'Mate could be used or (further improved) as a "contact expressive pager."

Below we describe the contact expressive acts of the person calling – rather than the cushion itself. This is because most of the participants shifted their attention entirely from the cushion as an expressive device to the *person calling* as the expressive agent.

5.2.1 Current PillO'Mate: Caller Contact Acts

Here we summarize the different contact expressive acts that people used in their "pager" interaction with the cushion. In each case, individuals began by sitting with the PillO'Mate on their laps.

Locutory contact acts. For these scenarios, the cushion is purring/vibrating. One interesting phenomenon here is that people became interested in the locutory qualities of the cushion itself (and their relationship to the caller). So, for example, people were able to make definition assertions about the possible caller based on the purring/vibrations ("definitely not someone from work," "possibly my mother," etc.).

One set of discussions involved talking about issues related to whether the existing PillO'Mate vibrations felt like a phone ringing. This brought out some aspects of what the participants find important about phone signals. The current PillO'Mate, for example, was built with design goal to be *comforting* – that is, to vibrate and sound "content." So, one thing about the cushion that ran counter to people's expectations about a phone ringing: it does not "pulse" or "change" in some way that they have come to expect from a ringing phone. This raises a number of interesting questions about conventions of phone expectations (that the phone is a device that is aggressive and interrupts).

Illocutory contact acts. When asked why they thought a person was paging them, most people felt it was "for just a small chat, no special reason, maybe guidance in a problem that I may have."

Perlocutory contact acts. Interestingly enough, people also found it easy to say whether they were inclined to answer based on who

they thought was calling (and why). Typically, people said that the purring was so calm that they actually felt unusually relaxed about the thought of talking on the phone. Indeed, some said that it was hard for them to imagine a situation where they would not answer the phone, but the fact that the ringing was a gentle vibration might mean that they felt more relaxed and positive about answering and talking. As one person said, "the telephone signal can often be very disturbing. By making it softer and more subtle it would be less stressful and leave it up to me if I want to answer it or not. I would probably still always answer the phone, but I would be calmer doing it!"

Other issues. We also had people explore putting the cushion against different parts of their bodies (back, face, etc.) to see whether it made any difference to who they thought was calling, why, and whether they were inclined to answer. These changes did not seem to make any difference and in future studies we will explore whether different locutory qualities of the contact expressions make a difference in this regard.

5.2.2 Future PillO'Mate: Caller Contact Acts
Here we summarize the different contact expressive acts that the PillO'Mate used in its "pager" interaction with people. For this series of explorations, we proposed different scenarios (callers, reasons for calling, etc.) and asked people how they might change the contact expressivity of the cushion to bring it into line with their expectations.

Locutory contact acts: Mostly people found it easy to imagine how to change the locutory dimension to express the mood of the caller ("if it is an angry caller the vibration should be very aggravating, uneven, and have wild swings of intensity"). There is also some indication that some of the people in the study were able to imagine contexts when "vibrating gently" is exactly the way they would prefer to have a phone "ring." So, for example, one person said, "It's perfect as it is! The reason why is that I find telephones to be disturbing and I easily get stressed by ringing signal on the phones, they are always so loud!"

Illocutory contact acts: Similarly, it was easy to imagine the appropriate contact expression for certain kinds of calls ("if the caller is from work and it is important it would have been a pulsating vibration; an important vibration that is hard to ignore").

Perlocutory contact acts. We also explored various "manual" versions of different contact expressions and asked people to talk about how people felt about answering these calls. One example involved "pressing" (with a hand from inside the pillow) against the person; this struck people as annoying and they said they might answer, but only because it would otherwise become unbearable. We also experimented with having the inside of the pillow "roll/move" against its covering (and the body of the person); people indicated that they would answer because they were intrigued – and suggested various ways of transforming the contact expression to suit different kinds of calls. Heat and cold were interesting expressive variations; people felt they would have a difficult time noticing unless the transition was clear, and preferably from one extreme to the other.

Other issues. We can summarize this study by saying that there were a number of "standard" interface insights. It became clear, for example, that the response to the usefulness of such a phone was very much connected to the person's individual experience with, and expectations of, mobile phones. On the other hand,

there were also insights directly relevant to understanding contact expressive devices. Most of the participants wanted the PillO'Mate to be "more aggressive" and to "clamor for attention" and to have "a lot more vibrating, a more intense vibrating." Most of the participants liked the idea of a phone that could be calmer, and that would inform them when someone was calling but in a more "casual" way. It often seemed hard to separate the experience of different moods, durations, and functions of phone conversations from the (mostly) "one size fits all" audio signaling of current phones. This is a subtle issue and requires more study. Given that this study was brief, it seems possible that a more relaxed and longer study would enable participants to imagine situations where they might like a phone that used contact expressions to indicate the "phone call" equivalent of, for example, a friend dropping by for the pleasure of spending some time together, or someone returning a call.

Some of the responses also suggest that people have a hard time imagining anything like a "distributed phone interface." In other words, one person did not like the idea of a cushion that signaled a phone call because a phone call happens on a device (so the person kept imagining that it would be necessary to carry the cushion around the house in order to know when the phone rang). This does, however, raise an interesting point about contact expressive devices that include additional modalities for input and output. There are obvious advantages of a cushion that uses contact expressive signals when someone is calling on the phone: it can be useful when it is important not to have disturbing noises or when we cannot see visual cues. But there are also situations when they are not lying on the sofa – when, in fact, it is the sound which is able to "reach" them (because of distance, for example).

This is why we caution readers not to focus too much on this *particular* embodiment (i.e., the PillO'Mate) of a contact expressive device. The same idea can obviously be generalized to work for situations where people are up and moving around and still do not want to be disturbed by a ringing telephone. We could imagine using the floor of the apartment or the clothes that people wear. That is, there are two classic approaches to mobile communication: mobile devices (cell phones, etc.) or embedded technologies (phones where people are located). Clearly contact expressive devices can be developed for either approach. We did discuss this possibility with the participants, with mixed results. Our feeling is that it was easier for them to imagine the use of the cushion to signal a phone call because they were sitting and holding the cushion. It seemed more difficult for them to imagine more distributed versions of contact expressive interfaces.

6. CONTACT EXPRESSION ACTS
As already noted, the illocutory speech acts are the ones most frequently studied and analyzed. Based on what we have seen – and on the basis of developments of innovative sensors, actuators, and new materials – we believe that future contact expressive devices will make significant use of the potential of locutory acts. Similarly, the potential for very diverse embodiments of contact expressive devices suggests that there will similarly be many dimensions of perlocutory contact acts that will only first be seen (or perhaps only exist at all) in the context of such devices. Finally, consider the self-fulfilling contact acts that are largely ignored by most speech act theory; one could argue that these arise in the context of "satisfying" needs or desires as they exist in some particular embodiment.

Given this, it seems plausible that the technical and computational potential of contact expressive devices will result in both radically new forms of instrumental and self-fulfilling contact expressions. (And, according to the more radical phenomenological positions, this may actually facilitate similar novelty in human contact expressions.)

We now sketch an initial Contact Act taxonomy, an outline for a Contact Expression Pattern Language, and provide two short examples of their use.

6.1 Contact Expression Acts

Consider again the three main speech act components:

Locutory contact acts. To indicate the potential range of locutory contact expressive acts, we here list some of the possible sensors that can currently be included in computational devices: acceleration, altitude, chemical, displacement, electrical, fluidity, force of impact, frequency (of contact), friction, height/level, moisture, momentum (angular and rotational), movement, odor, orientation/angle, position, pressure, resistance, roughness, shape, size, spatial distribution, squishiness, stiffness, taste, temperature, tensile strength, texture, thickness, tilt, torque, turbidity, velocity, viscosity, wavelength, and weight.

Illocutory contact acts. The most elaborated aspects of this model are the illocutory acts, these have been further classified as: assertives, declaratives, directives (interrogatives and exercitives), expressives, and promissives. These seem clearly relevant for contact expressions initiated by people in their interactions with contact expressive devices. However, as noted earlier, it is a controversial question whether computational devices can (or ever will) be able to perform truly illocutory contact acts in any meaningful sense of the word. Nonetheless, it does seem reasonable to us that people will be willing to take the "intentional stance" on this question for many kinds of contact expressions initiated by computational devices – we therefore consider it worth including these as relevant to the description of them.

Perlocutory contact acts. The status of many perlocutory contact acts seems relatively uncontroversial. If, for example, one pushes a robot out of the way and it actively resists, it seems reasonable to say that the perlocutory component of the contact act has not been satisfied. However, the development of new sensors, actuators, materials, and other kinds of computational mechanisms may also start to challenge some of our existing notions about the boundaries of perlocutory contact acts initiated by computational devices. The potential, then, for perlocutory contact acts seems as promising as it does immature; we therefore feel this is a rich area for future exploration, but close this section without speculating about which aspects of perlocutory contact acts may or may not be realized.

6.2 A Contact Expression Pattern Language

Although we cannot say much within the confines of this short paper, we do feel it is important to at least indicate how Contact Acts can be used as the basis of a more expressive and usable design language – and how that design language can be helpful in the design of contact expressive devices.

The key link between Contact Acts and a Contact Expression Pattern Language is to look at the specific locutory, illocutory, and perlocutory aspects of good contact acts and answer the Pattern questions: *what* is the precise feature of a particular, successful contact act; *why* is this feature helping to make the contact act successful ("what forces does it resolve?"); and *when* (or *where*) will this feature work ("context")? Said another way, features of contact expressions are those locutory embodiments that resolve some set of forces (including the illocutory and perlocutory dimensions of both parties interacting through contact acts – as well as the felicity conditions for those acts).

In the tradition of work on Patterns, the following is offered as an initial attempt to solicit feedback and suggestions for improvement.

Pattern: A Private Contact Signal

Feature. For situations where it is not possible, appropriate, or desired that other people become aware that a person is being paged, use contact expressions that cannot be seen, heard, or felt by others.

Forces. Someone needs or wants to receive a phone call, but auditory or visual signaling isn't possible or appropriate; similarly, the movement of the person being called may also be restricted.

Example. One possibility is a body-suit that is less like a suit of clothing and more like a living companion. Such a suit could act as a telephone pager, using various contact expressions (such as constriction, change of temperature, movement of "grain" of body-suit, "tilting" the wearer, making the person's movement more "viscous," etc.) to let the person know many aspects about a phone call.

In practical terms, the development of a Pattern Language for contact expressions will probably parallel the two approaches identified by Alexander for architectural Patterns. First, it will involve the identification of *existing* Patterns of forces effectively resolved by contact expressions among humans. And, second, it will involve the invention of *new* Patterns of contact expressions, based on the various unresolved forces in people's lives.

7. FUTURE WORK

Our work with the PillO'Mate thus far suggests a number of studies that can help further develop the potential of contact expressions, in particular we believe that a fruitful approach involves studying and modeling many aspects of the phenomenology of both human and device contact expressions. Our main goal is to further develop the design language of contact expressions; to this end, we now highlight some future aspects of that work.

7.1 Studying Contact Expressions

One of the most important aspects of future research on contact expressions will be to conduct thorough observational and qualitative studies to understand better the relevant issues. In our quick studies so far, we have not had the chance to engage deeply enough with either the human needs and concerns, nor with the relatively unexplored potential of contact expressions to facilitate and participate in self-fulfilling activities.

It will also be important to explore and understand better the way other forms of sensory experience interact with and complement contact – and also to explore the potential of other types of semiotic analysis of contact expressions.

As we mentioned earlier, we think of this strand of the work as identifying and describing the existing and potential Patterns of effective and significant human contact expressions. This will obviously involve more detailed work on Contact Acts – and the various ways those contribute to Patterns of contact expressions.

7.2 Implementing Contact Expressive Devices

There are three obvious areas in which it will be interesting to develop future contact expressive implementations: variations on the PillO'Mate, adding computational intelligence, and developing other types of contact expressive devices (for other domains and user-types).

As indicated in our preliminary taxonomy, it will be interesting to imbue the PillO'Mate with more contact expressions: it should be able to move, distribute its contact (multiple "fingers"), embrace, constrict, react to changes in heart rate, perspiration, heart-rate, and so on. We also believe that in order for contact expressive devices to be truly convivial, they will need various means of adapting to the individual characteristics of different people. And, as noted, an important aspect of being contact expressive is responding appropriately to the contact expressions initiated by others; it will be important to begin exploring what aspects of perlocutory contact acts can actually be embodied in a computational device. Finally, it will be important to model contact expressions across a wider range of devices, domains, and user-types.

The Karo scenario also suggested a plausible model whereby the embodiment "needs" of the device can be related to aspects of its contact abilities. Thus, it seems reasonable and practical to suggest that an embodied contact device might meet some of its power needs ("power is low") with different contact expressions ("stroke me"). It will be interesting to explore the viability of these and similar proposals.

Finally, there is another dimension of contact expressions that is not evident in the examples above, but which may, eventually, be just as significant for the design of contact expressive computational technologies. All of the examples above illustrate some aspect of "surface" contact. However, there are a number of physical signs that we experience from inside our bodies (bladder pressure, inhaled smoke, something caught in the throat, etc.). It is not difficult to generalize the notion of contact expressive devices to include those that could be ingested, and which, for a variety of reasons, will engage in contact expressive interaction with us – from within.

7.3 The Future Phenomenology of Contact Expressive Devices

We will also intend to study aspects of contact expressions in the context of what could be called the "phenomenological potential" of computational devices. By this we mean to emphasize two key ideas: first, the physical embodiment of a device (its particular sensors, actuators, material properties, etc.) will be intimately linked to the kinds and quality of its contact expressivity; and second, that a device's version of the "world" upon which it acts may be radically different than anything we, as humans interacting with that same device, experience as a world.

One well-known consequence of phenomenological approaches to artificial intelligence is that the role of "the world" as a determining force is diminished. In this regard, the PillO'Mate is a fairly standard sensor-device, so we do not claim to have investigated its phenomenological potential in much detail so far. Nonetheless, we do feel that such issues will become more and more relevant as the sophistication of contact expressive devices increases. We make a similar caveat with regard to the qualitative studies we have done so far: they have been extremely brief and shallow, giving only the smallest of indications about the rich texture of experiences and expectations people associate with various aspects of contact expressions. (One of the directions for future research will obviously be to do fuller, more extensive qualitative studies in the Piagetian tradition.)

We are, of course, aware that there are deep philosophical disagreements about the status of "phenomenological experience" for any being, biological or otherwise. These debates include such controversies as whether phenomenological experience is an illusion or not, what embodiment is required for a being to have phenomenological experiences, and so on. We feel that the possibility of phenomenal experience by computational devices (broadly construed) is an open question, which is one reason we are not always consistent about putting quotation marks around phrases such as "the phenomenal world of the device." Readers who believe that our use of these terms can, at best, be only metaphorical are welcome to (mentally) put such phrases in quotes as they encounter them; similarly, readers who question the entire notion of phenomenal experience are welcome to put all of human existence in quotes.

7.4 Closing

We began by considering various human benefits, but in our consideration of sign systems and technology it may seem as if we have lost touch with the original concerns. Therefore, in closing, we would like to once again return to the human importance of contact expressions.

We were originally made aware of the significance of contact expressions when one of us (McGee) had a student with Tourette's Syndrome, which in her case manifested itself in mild autism and occasional debilitating depressions. She was interested in doing a project involving robot pets, but it was clear that she found most personal robots frustrating, indeed offensive. It took a number of conversations before we were able to articulate together what it was that horrified her about them: it was the fact that most of them neither supported nor encouraged contact expressions. Based on her own life-experience and needs, she began to formulate a goal of developing robots that were more contact expressive for others like her who she feels could benefit from them. It is one of the sad paradoxes of her condition that it actually prevents her from making sustained progress on this kind of effort – or even working with us on this paper.

We continue to be surprised that there seems to be so little work as yet on what we here call contact expressions, but our own experience of initially ignoring them makes this both plausible and disturbing. Our most optimistic hope for this paper is that it will play some role in changing the current state of affairs – whether by inspiring more research and development where there currently seems to be so little, or by encouraging others to make more readily available any relevant work of which we are currently unaware.

There are many people in the world who could seriously benefit from further contact expressions of effort and interest.

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