Heartbeats: A Methodology to Convey Interpersonal Distance through Touch

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Abstract
Individuals who are blind are at a disadvantage when interacting with sighted peers given that nearly 65% of interaction cues are non-verbal in nature [3]. Previously, we proposed an assistive device in the form of a vibrotactile belt capable of communicating interpersonal positions (direction and distance between users who are blind and the other participants involved in a social interaction). In this paper, we extend our work through use of novel tactile rhythms to provide access to the non-verbal cue of interpersonal distance, referred to as Proxemics in popular literature. Experimental results reveal that subjects found the proposed approach to be intuitive, and they could accurately recognize the rhythms, and hence, the interpersonal distances.

Keywords
Tactile rhythm, tactons, haptic belt, vibrotactile belt

ACM Classification Keywords
H.5.2 [User Interfaces]: Haptic I/O. K.4.2. [Computers and Society]: Assistive technologies for persons with disabilities.

General Terms
Design, Experimentation, Human Factors

Introduction

The need for everyday involvement in social interactions makes good social skills critical toward achieving success in both personal and professional endeavors. Acquiring good social skills early in life makes us more likely to have healthy, rewarding, successful lives [7]. Unfortunately, disabilities such as blindness can become a hindrance to both learning and displaying important social skills.

figure 1. The Social Interaction Assistant [4] consists of a pair of ordinary sunglasses with a discreetly embedded video camera (for image and video processing), earphones (for audio output), vibrotactile belt (for haptic output), accelerometers (for motion analysis) and a small, lightweight processing element that can be placed in a backpack.

Social interactions consist of verbal (speech and letter) and non-verbal communication cues. Typically, 65% of a social interaction consists of non-verbal cues [3]. Some non-verbal cues [3] include body language, touch, facial expressions, eye gaze and the relative location of those involved in the interaction. As individuals who are blind or visually impaired may not have access to these non-verbal cues, an incomplete understanding of the social interaction may arise, leading to misunderstandings or embarrassment. For example, in a group interaction, sighted participants often rely on eye gaze to convey turn taking or to direct a question to a specific individual. Without knowledge of a speaker's eye gaze, it can be difficult to judge to whom a question was directed, leading an individual who is blind to respond out of turn. While everyone encounters embarrassing social situations, individuals who are blind may encounter these situations more often, resulting in social anxiety that can lead to social isolation. Given the importance of good social skills, assistive technology that provides access to non-verbal cues is critical.

Recently, we've been exploring the design of effective aids for social interactions. Our Social Interaction Assistant [4], depicted in Figure 1, is a framework for exploring sensing and presentation of non-verbal cues. Some non-verbal cues we've previously explored include interpersonal position (in terms of relative direction [4] and interpersonal distance [5]), and the identity of people around the user [4]. Haptic (touch-based) output, in addition to audio output, is used in the Social Interaction Assistant; people who are blind often interpret their environment by listening to changes in ambient audio patterns, and hence auditory output can be intrusive.

This paper improves upon our previous work (see Background and Related Work), exploring a novel approach to convey the non-verbal cue of interpersonal distance based on an intuitive haptic encoding that resembles a human heartbeat, described in Design and Implementation. A comparative analysis between the current and previous approach is presented in Experimental Methodology.

Background and Related Work

Interpersonal location describes the relative position, in terms of direction and distance, of a person with whom a user is engaging socially. Although in some circumstances, individuals who are blind may be able to determine interpersonal location through audible cues, e.g., speech, such cues may not always be available. Previously, we proposed the use of a vibrotactile belt [4], depicted in Figure 2, to convey the relative direction of someone in the user's visual field. When interacting with someone, the camera on the Social Interaction Assistant is used to capture the social scene within which the location of the interaction partner's face is detected (see Figure 3).

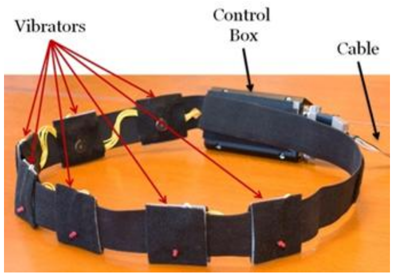

figure 2. Our belt consists of 7 equi-distantly spaced vibration motors arranged in a semi-circle. Inter-element spacing of pancake motors is 3 in. Each motor runs at 170Hz.

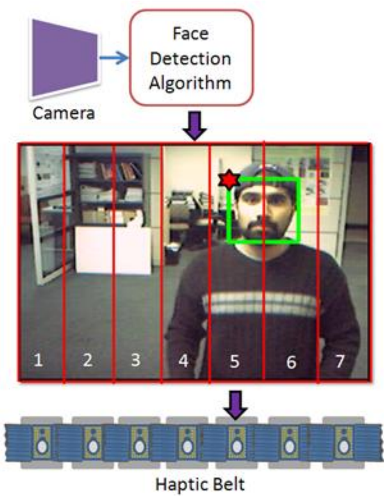

figure 3. The image containing the face is divided into 7 vertical regions of equal width, each represented by one of the 7 vibration motors on the belt. The motor corresponding to the region containing the face is then actuated to alert the user of the presence of an interaction partner.

In addition to relative direction, the other component of interpersonal location is interpersonal distance, which is the distance between two participants involved in a social interaction. Within a culture, interpersonal distances are typically divided into zones, which have associated purposes and meanings. The different zones found in American proxemics [2]—the study of interpersonal distance in man and animal—include intimate, personal, social and public distance, as well as close and far phases within each zone.

In [5], we chose to convey four interpersonal distances, namely intimate, personal, social (close phase) and social (far phase), using four distinct tactile rhythms consisting of a repeating 50ms vibratory pulse separated by pauses of 50ms, 250ms, 500ms and 1200ms, respectively. Our motivation for such a design came from the successful use of similar audible rhythms found in automobile parking sensors, where the length of the pause is proportional to the distance between two cars.

We evaluated how well subjects could identify these rhythms around their waist. Subjects found the rhythms for the close and far phases of social distance much more difficult to discriminate compared to the rhythms for intimate and personal distance. Many participants expressed the need for a more intuitive design, and a base rhythm that they could compare all the other rhythms against.

To address the concerns expressed by participants, we propose a novel tactile rhythm design, *heartbeats*, based on the rhythmic pattern of a human heartbeat. Inspiration for a rhythm design based on the human heartbeat came from its intuitiveness—feeling the beating of someone's heart is typically a personal interaction that conveys a sense of intimacy and closeness [8]. This symbolism lends itself nicely to close interpersonal distances such as intimate and personal distance; for larger interpersonal distances, we use variations of this scheme, described in more detail later. Moreover, as we are all familiar with our own normal heartbeat rate, using this rate as one of the tactile rhythm patterns provides a base rhythm upon which all other rhythms may be compared.

While a few tactile communication schemes [1, 6] have been proposed to convey distance information, we are most interested in the communication of interpersonal distance, an application area similar to [6]. The next section presents the design of the proposed scheme to communicate interpersonal distance.

Design and Implementation

Figure 4 depicts our proposed tactile rhythms: intimate, personal, social and public, which correspond to four interpersonal zones in American proxemics, and have corresponding lengths of 0-18 inches, 1.5-4 feet, 4-12 feet, and 12 or more feet, respectively. To improve the usability of the system, each of the four interpersonal zones is associated with a single, discrete rhythm, ignoring close and far phases. Our motivation for using the analogy of a pulsating heartbeat to convey interpersonal distance came from the rich symbolism of a heartbeat. Sensing and perceiving someone's heartbeat through touch is a personal interaction that requires close proximity and contact. One common association of a heartbeat is that it symbolizes love, intimacy and closeness [8]. It is this symbolism that lends itself well to close interpersonal distances.

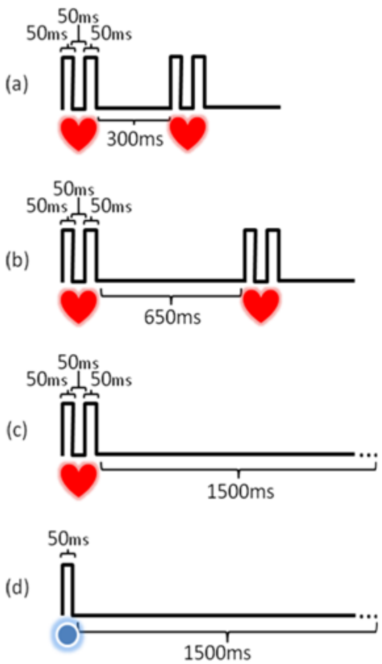

figure 4. Rhythm designs and timing parameters: (a) intimate; (b) personal; (c) social; and (d) public. The heartbeat pulse, found in intimate, personal and social rhythm, consists of two 50ms vibratory pulses separated by a 50ms pause. This particular design was found to feel similar to an actual heartbeat pulse, as evaluated through pilot tests.

The spacing of the heartbeat pulses for personal rhythm provides 75 beats per minute (bpm), which is the average (resting) human heartbeat rate (more specifically, 70 bpm for males, and 75 bpm for females). The normal heartbeat rate was chosen for personal distance given the personal nature of interactions that occur at this distance: handshakes, pats on the back, etc. Since we are all familiar with our normal heartbeat rate, personal rhythm is also used as the base rhythm. The base rhythm may be compared to all other rhythms for improved recognition.

For intimate rhythm, the spacing of the heartbeat pulses provides 133 bpm, which is a rapid heartbeat rate for humans (heartbeat rates above 100 bpm are considered rapid). The rate of 133 bpm was chosen through pilot tests; it simulates a realistic, rapid heartbeat, and provides sufficient separation from personal rhythm. Interactions at intimate distance are typically much more personal compared to interactions that happen at personal distance; experiences of intimacy, bodily contact and closeness, commonly encountered at intimate distances, may led to a variety of emotional responses, increasing heart rate.

Social distance typically facilitates less personal interactions (e.g., group interactions) compared to personal distance. Therefore, social rhythm is conveyed through a slower-than-normal heartbeat rate, specifically 36 bpm (human heartbeat rates below 60 bpm are slow). Pilot tests revealed that this design provides a realistic heartbeat rate that is slower-than-normal and distinct from intimate and personal rhythm.

Interactions occurring within public distance may not be personal at all (e.g., listening to a classroom lecture). The proposed public rhythm, therefore, does not simulate a heartbeat; instead, it consists of a single pulse separated by long pauses, similar to sonar. Pilot tests revealed that this design was distinct from intimate, personal and social rhythm.

Experimental Methodology

The aim of this experiment was to assess how well subjects can discriminate between the proposed tactile rhythms. Moreover, to verify previous experiments, we assessed how well subjects can localize vibrations around their waist. Lastly, we investigated possible interactions between rhythm and vibration location to learn if the proposed tactile rhythms affect subjects' ability to localize vibrations, or vice versa. Given that the goal of this experiment was to assess human haptic perception of the proposed rhythms—for eventual use as part of the Social Interaction Assistant—our subject population was not restricted to individuals who are blind, enabling use of a larger subject population. Participants included 12 males and 2 females. Ages ranged from 22 to 60 (the average age was 30). All subjects were sighted. Our vibrotactile belt, described in Background and Related Work, was used.

Hypotheses: The motivation for this work centered on developing tactile rhythms that are intuitive such that recognition accuracy is similar to or better than what was reported in [5]. Hence, as shown below, hypotheses (1)-(3) are motivated by previous results where participants achieved recognition accuracies of 92% for tactile rhythm, 95% for vibration location, and 87% for the complete *tacton* (or tactile icon), i.e., both vibration location and rhythm combined into a single vibration. For the current study, our hypotheses include: (1) Subjects will achieve at least 92%

recognition accuracy for tactile rhythm; (2) Subjects will achieve at least 95% localization accuracy for vibration location; (3) Subjects will achieve at least 87% recognition accuracy for the complete tacton; (4) Subjects' ability to identify tactile rhythms will not depend on rhythm type; (5) Subjects' ability to localize vibrations will not depend on the location of the vibration; and (6) Subjects' ability to localize vibrations will not depend on rhythm type, and vice versa.

Procedure: The experimenter helped each subject put on the belt, which was worn underneath clothing on the skin, helping mask noise generated by the vibrations. Subjects were then asked to sit down in a chair. Subjects were first familiarized with vibration location. All 7 vibration motors, from motor #1 (at the user's left side) through motor #7 (at the user's right side) were actuated, in order, for 3 seconds each, during which the number of the vibration motor was spoken aloud by the experimenter. Next, subjects were familiarized with the tactile rhythms by feeling each tactile rhythm for 7 seconds at vibration motor #4. The experimenter explained that each rhythm symbolizes a different heartbeat rate (e.g., personal rhythm is a normal heartbeat rate), and that personal rhythm is a base rhythm to which all other rhythms may be compared.

Subjects now began the training phase in which a total of 28 complete tactons (7 vibration locations times 4 rhythms) were presented to subjects in a random order for 10 seconds each. Subjects had to respond with a vibration location number (#1 through #7) and rhythm label (intimate, personal, social or public). The experimenter confirmed correct guesses, and corrected incorrect guesses. Subjects had to score above 70% recognition accuracy on both vibration location and rhythm to move on to the testing phase. The testing phase was similar to the training phase except the experimenter did not provide feedback to subjects, and each complete tacton was randomly presented three times, providing a total of 84 trials.

Results: Overall recognition accuracies are shown in Figure 5. These accuracies support hypotheses (1)-(3). Comparing these results to our previous approach [5] (see Figure 5), we see an increase in overall recognition accuracy of rhythm, and the complete tacton; overall recognition accuracy of vibration location seems comparable. The overall recognition accuracies for tactile rhythm are 95.9% (SD: 8.7%) for intimate rhythm, 94.6% (SD: 6.7%) for personal rhythm, 93.9% (SD: 10.6%) for social rhythm, and 92.9% (SD: 10.4%) for public rhythm; a one-way ANOVA showed no significant difference [$F(3, 52)=0.27$, $p=0.8465$], supporting hypothesis (4). The overall recognition accuracies for vibration location are 97% (SD: 9%), 93.5% (SD: 10.9%), 98.2% (SD: 3.5%), 99.4% (SD: 2.2%), 95.8% (SD: 5.4%), 92.3% (SD: 10.1%), and 91.7% (SD: 13.9%), for vibration motors #1 through #7, respectively; a one-way ANOVA showed no significant difference [$F(6, 91)=1.64$, $p=0.1449$], supporting hypothesis (5). A two-way ANOVA was performed on the overall complete tacton recognition accuracies to learn about interactions. No interaction [$F(18, 364)=0.9$, $p=0.5824$] was found between tactile rhythm and vibration location, which supports hypothesis (6). This shows that our design for tactile rhythms does not hamper subjects' ability to localize vibrations around their waist, and vice versa. Feedback received from participant questionnaires was positive. The majority of subjects liked the idea of using heartbeats to convey interpersonal distance, and they found the base rhythm to be useful. Overall, subjects found the presentation scheme for interpersonal location to be easy to use and intuitive.

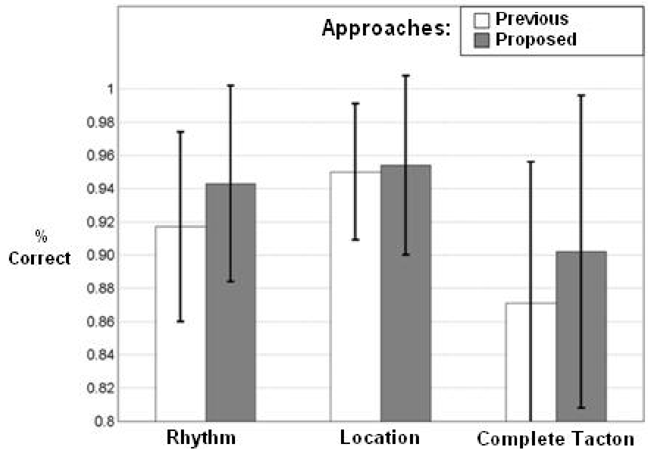

figure 5. A comparison between approaches with respect to overall recognition accuracies for rhythm, location and the complete tacton. Error bars are standard deviations.

Conclusion and Future Work

This paper presented a new approach to delivering interpersonal distance information through touch, inspired by the application of social interaction assistants for individuals who are blind. Our experimental methodology seems to suggest that the proposed approach is an improvement—in terms of user performance and subjective feedback—over our previous approach. The results presented here will help validate and guide the design of our proposed rhythms as we progress toward usability studies involving individuals who are blind. In these future usability studies, individuals who are blind will use the Social Interaction Assistant during real-time social interactions, and the ability of subjects to perceive, understand and utilize real-time information about non-verbal cues will be explored.

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