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PROXIMITY ACROSS DISTANCE: A SMART GLOVE-SLEEVE SYSTEM FOR THE TRANSMISSION OF TOUCH

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Abstract

Background. Physical touch is essential for emotional bonding, yet long-distance relationships lack this sensory dimension, potentially leading to feelings of disconnection and increased mental health risks. Existing communication technologies enable auditory and visual interaction but fail to provide haptic feedback. This study explores touch patterns used to express emotions in face-to-face interactions to inform the development of a Glove-Sleeve System that integrates virtual touch into video calls. *Methods.* We conducted semi-structured interviews with 15 participants across three user groups (grandparents, grandchildren, and long-distance partners). Participants described how they use touch to respond to scenarios designed to elicit joy, fear, anger, sadness, stress, loneliness, thankfulness, and love. Descriptive statistics quantified touch gesture frequency, and Chi-square tests assessed variations across user groups. Heatmaps visualized the distribution of touch behaviors across emotions. *Results.* Participants most frequently reported hugging as their primary touch response. However, due to technological constraints, the study focused on hand and arm touch patterns, with hand holding (N = 35) and arm stroking (N = 30) being the most common gestures. Fear and stress were most associated with the absence of touch (N = 21 for arm, N = 20 for hand). Chi-square tests indicated no significant differences in touch patterns between user groups (p > .05), suggesting a universal reliance on similar touch interactions to convey emotions. *Conclusion.* Findings suggest that a customizable haptic system should focus on stroking and holding for arm-based interactions and holding, squeezing, and interlocking fingers for hand interactions. Given the frequent occurrence of pressure-based gestures, haptic feedback should incorporate force-sensitive actuation. Future research should explore full body mediated touch and adaptations of hugging in virtual interactions to enhance emotional closeness in remote communication.

Keywords: *Smart textiles, emotional closeness, social connectedness, affective communication, user centered design.*

1. Introduction

Physical touch is essential for building and maintaining emotional connections. It conveys affection, reassurance, and empathy, helping to strengthen relationships (Hertenstein and Weiss, 2011). However, for those separated by long distances, the lack of touch can lead to feelings of disconnection, putting a strain on relationships and increasing the risk of mental health challenges such as depression and anxiety (Field, 2010). While video calls and messaging allow people to see and hear each other, they lack physical interaction and emotional closeness (Gallace & Spence, 2010). To address this, we are developing a Glove-Sleeve System that enables virtual touch during video calls. A major focus is ensuring the system is practical, intuitive, and well-accepted, which is why we follow a user-centered design (UCD) approach that prioritizes understanding the needs and challenges of future users. This paper presents findings from a user requirements analysis, the first step in developing the Glove-Sleeve system. Through semi-structured interviews, we explored how grandparents, grandchildren, and long-distance couples stay emotionally close despite physical separation. The study examined common touch patterns used to express emotions such as joy, fear, anger, sadness, stress, loneliness, thankfulness, and love. These insights will inform design and technical decisions, helping integrate touch into video calls to support emotional bonds.

2. Methods

2.1. Study design and participants

We conducted semi-structured interviews that explored both the context of use of remote communication technologies — as defined by ISO 9241-11:2018 on ergonomics in human-system interaction — and the touch patterns used to respond to different emotions and user states in face-to-face interactions (ISO, 2018; as-is scenario). The study included 15 participants**,** categorized into three user groups: grandparents (n = 5, 4 women, 1 man), grandchildren (n = 5, 3 women, 2 men), and long-distance partners (n = 5, 3 women, 2 men), all of whom frequently used video calls and were receptive to physical touch. Participants' mean ages were M = 78.2 years (SD = 10.01) for grandparents, M = 26.8 years (SD = 7.22) for grandchildren, and M = 30.0 years (SD = 3.39) for long-distance partners. As part of the requirements analysis, this paper focuses on touch patterns, with findings on context of use to be reported elsewhere. The study received ethical approval from the Ethics Committee of the Faculty of Medicine of the Heinrich-Heine University Düsseldorf.

2.2. Data collection and analysis

Participants were presented with hypothetical scenarios which were designed to elicit specific emotions (e.g., joy). They were read aloud by the interviewer. They were then asked to describe how they would physically express their reaction through touch. Example: *"Imagine your grandchild shares exciting news that they won 500 Euros."* For each emotion, participants responded to three consecutive questions: General touch response: *"How would you touch them in this situation*?" Arm-specific touch: *"If you could only touch their arm, how would you do it?"* Hand-specific touch: *"If you could only touch their hand, how would you do it?"* These questions were asked while considering the future design of the Glove-Sleeve System. Interviews lasted between 45 and 60 minutes. All interviews were then audio-recorded and transcribed for analysis. At the beginning of each interview, participants provided their verbal consent to the audio recording. A systematic analysis of touch patterns was conducted using descriptive statistics, summarizing the frequency of each touch gesture across user groups and emotions. Chi-square tests were performed separately for arm and hand touch patterns to determine whether touch usage differed significantly across user groups. Heatmaps visualized the distribution of touch patterns for the different emotions, helping to identify associations between gestures and emotional states.

3. Results

General Touch Patterns. Across all emotions, participants most frequently reported hugging as their primary touch response. However, due to technological and practical constraints, this study focused on arm and hand touch patterns.

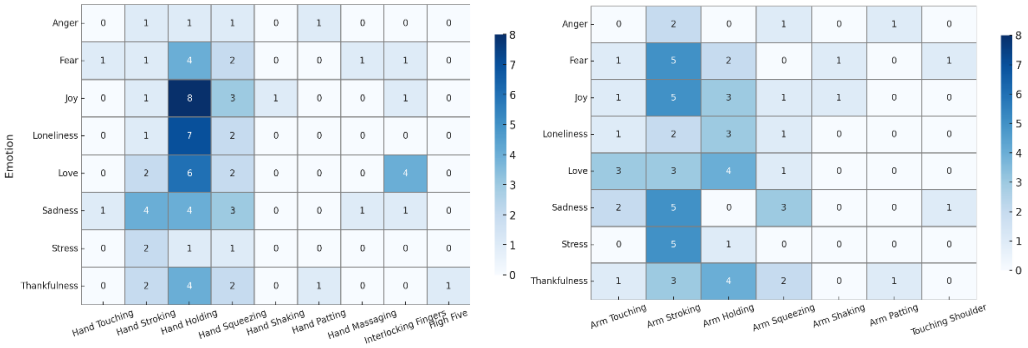
3.1. Arm and hand touch patterns across emotions

The analysis identified ten hand and eight arm touch patterns (including "None"). The six most frequent interactions were Hand Holding (N = 35), Arm Stroking (N = 30), Arm Holding (N = 17), Hand Squeezing (N = 16), Hand Stroking (N = 14), and Arm Touching (N = 9) (see Figure 1). The emotional states of fear and stress were most associated with the absence of touch (N = 21 for arm, N = 20 for hand), indicating that participants often preferred not to engage in touch when confronted with these emotions, see Figure 1.

3.2. Arm and hand touch patterns across user groups

A Chi-Square test for independence examined whether touch pattern usage differed among grandparents, grandchildren, and long-distance partners for both arm and hand touch behaviors. Results were not statistically significant for arm touch patterns, $\chi^2(14, N = 112) = 19.57$, $p = .144$, nor for hand touch patterns, $\chi^2(18, N = 116) = 28.38$, $p = .057$. These findings suggest that all user groups rely on similar types of touch interactions to express emotions.

Figure 1. Heatmaps showing the frequency of hand touch patterns (left) and arm touch patterns (right) across all emotions.



4. Discussion and implications for haptic technology design

Hugging was frequently mentioned in this study, aligning with previous research indicating that it is a common way to express affection and strengthen social bonds in Western cultures (Forsell & Åström, 2012; Gallace & Spence, 2010). However, because full-body touch could not be implemented due to technological limitations, this study focused on alternative forms of physical interaction that might serve a similar function. Participants described hand and arm touch gestures, the most common being holding, squeezing, and stroking. Stroking was the preferred gesture for arm-based interactions, and holding was more frequently used for hand gestures. The frequent use of pressure-based gestures, such as squeezing, tells us that force-sensitive feedback could be especially important for replicating realistic touch in mediated communication. These findings show that haptic sleeves should emphasize stroking and holding, granting smooth, continuous movements with varying intensity. The gloves, on the other hand, should be designed to support holding, squeezing, and interlocking fingers and incorporate pressure feedback for greater precision. Since participants across all user groups showed similar touch patterns, an individualized system that incorporated customization rather than group-based presets would likely be more effective. Gooch and Watts (2012) found that personalization strengthens emotional connections between users and their devices, which suggests that offering users control over touch intensity and gesture selection—including the ability to disable certain gestures, such as face or shoulder contact—could improve both comfort and acceptance.

5. Future research and limitations

Even though this study focused exclusively on arm and hand touch patterns, future research should explore ways to replicate full-body touch, such as hugging. Although hugging was not included in the system, its emotional importance shows the need for more investigation into how users respond to alternative forms of mediated touch. Additionally, since touch behaviors and preferences do vary in different cultures, future studies should look into those differences to develop haptic systems that are both culturally sensitive and universally applicable.

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