Hidden Interaction Techniques: Concealed Information Acquisition and Texting on Smartphones and Wearables

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Figure 1: We explore how, and to what extent, users can hide their interactions on a smartphone and on a smartwatch. We evaluated two interaction techniques in realistic scenarios. LEFT: *HiddenHaptics*, a smartphone application that provides vibrotactile information on notifications. HiddenHaptics was evaluated in a hallway discussion scenario. MIDDLE: *HideWrite*, a smartwatch application where users can write text messages by drawing on a dimmed watch screen. RIGHT: HideWrite was evaluated in a meeting scenario, where one attendee attempted to write text messages with HideWrite without being exposed.

ABSTRACT

There are many situations where using personal devices is not socially acceptable, or where nearby people present a privacy risk. For these situations, we explore the concept of *hidden interaction techniques* through two prototype applications. HiddenHaptics allows users to receive information through vibrotactile cues on a smartphone, and HideWrite allows users to write text messages by drawing on a dimmed smartwatch screen. We conducted three user studies to investigate whether, and how, these techniques can be used without being exposed. Our primary findings are (1) users can effectively hide their interactions while attending to a social situation, (2) users seek to interact when another person is speaking, and they also tend to hide the interaction using their body or furniture, and (3) users can sufficiently focus on the social situation despite their interaction, whereas non-users feel that observing the user hinders their ability to focus on the social activity.

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CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous and mobile devices**; **Interaction techniques**.

KEYWORDS

hidden interaction, subtle interaction, smartphones, smartwatches, interaction techniques, interaction design, ubiquitous computing, mobile computing

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1 INTRODUCTION

People interact with their mobile devices very frequently. For example, we have developed a habit of continuously checking our smartphones [15, 40], as many people receive dozens or even hundreds of push notifications daily [43, 46]. At the same time, texting and other digital activities are an integral part of today's world. For young adults, texting has become the preferred form of communication over face-to-face talking, email, and phone calls [5].

However, there are many situations where using mobile devices is not possible, where it is not socially accepted, or where it might present privacy risks. In social situations ranging from work meetings to dinners, the use of personal devices is often perceived negatively and might upset others [8, 22, 28, 34, 41, 48]. At the same time, visible handling of mobile devices allows others to observe the screen content, which can lead to embarrassment [33] or a breach of privacy [17]. Visible technology use in some public spaces can even increase the risk of physical violence [42, 60].

To combat these issues, we envision interaction techniques that are truly *hidden*, that can be used around other people without them noticing the interaction. In this paper, we investigate two techniques:

HiddenHaptics allows users to receive information through vibrotacticle cues on a smartphone (Figure 1, left). We envision that subtle haptic feedback can be used to extract simple information from the smartphone, without looking at the smartphone or even taking it out of the pocket or bag. We envision many use cases for such vibro-tactile information, such as checking active notifications [32, 33] or receiving navigational instructions [44, 45, 50].

HideWrite allows users to write text messages by drawing on a dimmed smartwatch screen (Figure 1, middle). With HideWrite, we address a more advanced scenario where users can write entire messages without being exposed. We particularly envision HideWrite to be useful in situations where there is a need to type a short message, and halting the ongoing activity is not ideal or possible (e.g., a meeting at work).

The primary design goals for both techniques were that **(1)** users do not need to look at the device during interaction, **(2)** they do not provide any visual output, **(3)** they function on off-the-shelf devices without external hardware, so that the presence of the device in itself is not a cause for attention, and **(4)** they are easy to learn and require low effort.

In this paper, we explore how, and to what extent, these techniques can be used in realistic social situations. To this end, we conducted three user studies (N = 14, N = 10, N = 22) where we primarily focused on whether users could interact using our techniques without being caught by another person. Our main research questions were:

- **RQ1:** How effectively can users hide their interaction using hidden interaction techniques?
- **RQ2:** What tactics do users employ to hide their interaction?
- **RQ3:** Are users able to sufficiently attend to a social situation despite their interaction?

We found that **(1)** Users can effectively hide their interaction using our techniques. Interactions with HiddenHaptics went unnoticed 93.3% of the time, despite the observer knowing about the technique and being instructed to observe any interactions. With HideWrite, only one out of 11 observers noticed the interaction, but only after being asked to pay special attention to the user. **(2)** Users do not employ any deceptive or specialized tactics to hide their interaction. Users simply seek to identify moments when another person is speaking, as speakers tend to focus more on what they should say, and other nearby people tend to focus on the speaker. Users also tend to hide their interaction by breaking line of sight to the device using their body or other objects like tables, although this does not seem to be entirely necessary for successful hiding. **(3)** Despite their interaction, users can sufficiently commit to the ongoing activity, like a conversation or a meeting. In fact, our results suggest that the observers had a harder time focusing on the main activity when trying to expose the user, than the users did trying to hide the interaction.

Our main contribution in this work is the novel, empirical exploration of hidden interaction. First, we gain knowledge on what tactics people use to hide their interaction, how much effort it requires, and how well potential observers can detect the interaction. Second, we present four design guidelines for hidden interaction techniques that we validate in two different scenarios, using different devices. Third, we present the design of *HideWrite*, a novel text entry technique for smartwatches. Our results are useful for researchers and practitioners that seek to design interaction techniques that can be hidden in social situations.

2 BACKGROUND

Existing research recognizes the need for subtle interaction techniques [47]. Subtle interaction techniques can be utilized to overcome privacy issues [2, 10, 29], prevent upsetting others [4, 6, 42], and prevent disrupting ongoing tasks or discussions [2, 4, 6, 13, 38].

Many techniques and devices have been proposed for subtle interaction. These solutions range from small, wearable devices [4, 10] to body-worn devices [55] and augmented artefacts [2, 6]. For example, Ashbrook et al. developed an interactive ring [4], which could be rotated to make selections. Chan et al. developed a nail-mounted device [10] that enabled small pinch gestures using fingertips. Sumitomo et al. [55] presented a sensor wrapped around the upper body; users could move their abdomen for nominal input. In contrast, others have proposed augmenting familiar artefacts with additional capabilities for subtle interaction. Anderson et al. [2] experimented with a variety of specific scenarios, like augmenting a coffee cup with a small display at the bottom, or augmenting a notebook with touch capabilities to enable composing messages. In a similar spirit, Börütecene et al. [6] presented the Glance Mug, a touch-sensitive mug with an inner display, which was designed to provide relevant information to users during conversations.

Despite the considerable amount of work on subtle interaction, prior research largely focuses on the performance, accuracy, or usability of the proposed techniques. Very few studies actually *evaluate* the (in)visibility of an interaction or a device. In their literature review of subtle interaction, Pohl et al. also found that subtlety (or hiddenness) is often claimed, but little to no evidence of it is provided [47].

In the few studies where the (in)visibility of an interaction has been measured to some degree, the proposed techniques have had varying success [2, 6, 13, 29, 38]. The ability to hide an interaction has been heavily dependent on the exact conditions, for example, how much the observers know about the technique and the task [2], whether or not the interactive device can be fully concealed [13], and how mentally demanding the situation is [38]. Some lightweight investigations into the subtlety of an interaction have also been presented by a few other works [6, 29]. These studies provide interesting comparisons for our results, even though they deal with different contexts and interactions.

We also want to clarify the terminology surrounding our work. *Subtle interaction* is often used to describe interaction techniques that are not easily noticed. However, subtle interaction techniques may have various meanings and goals [47]; they may not necessarily be ideal or sufficient for fully hidden interaction. Therefore, because we want to focus on techniques that can remain truly hidden and that are also evaluated from this perspective, we will use the term *hidden interaction.* We see *subtle interaction* as the umbrella term, while *hidden interaction* is more specifically focused on the hidden aspects of subtle interaction.

Next, we review literature that is relevant to our investigated techniques. This includes existing vibrotactile solutions for smartphones, and existing text entry techniques for smartwatches.

2.1 Vibrotactile Cues on Mobile Devices

Haptic capabilities are included in almost any modern mobile device, and they are widely used for simple cues, such as to notify users of incoming calls. Existing research has proposed many ways to take further advantage of these capabilities, and also proposed additional technical solutions to improve haptics. The literature ranges from using vibrotactile cues for navigational instructions [44, 45, 50], to new solutions that enable communication through haptics [11]. Haptics have also been used to enrich existing interactions; for example, to communicate emotions with text messages [51].

Despite extensive research on haptics, we are not aware of any research that investigates *hiding* haptic interactions. In this paper, we close this gap. We do not propose haptics as a *new* technique, rather, we conduct a novel investigation into the use of haptics. We hypothesize that vibrotacticle output is suitable for hidden interaction since there is no visual output, and because haptics are readily available on many typical devices like smartphones and smartwatches. However, it is unclear how much effort hiding and understanding vibrotactile output requires, especially in situations where users must keep up with a primary task, like a conversation.

Prior research has shown that it is possible to learn and understand large sets of vibro-tactile cues through practice [7, 14, 26] as well as through more advanced haptic capabilities on devices [52]. However, because other contexts suggest that users struggle with simultaneous tasks if they are too demanding [9, 30, 37], we focus on transmitting simple information. Depending on the results we receive through this work, more complex vibrotactile information could still be feasible in the context of hidden interaction.

2.2 Text Entry Techniques on Smartwatches

Many text entry techniques have been proposed for smartwatches. Much of existing research focuses on addressing the problem of small input space. Several techniques propose a two-step selection process, where users first select a subset of characters and then the exact character [12, 23, 27, 39]. Some techniques use other mechanics to select the exact key from a subset, e.g., based on finger detection [21], force [24], or swipe gestures [54]. Some techniques enable one-handed text entry by detecting finger movements [59, 61] or wrist movement [19]. Finally, some techniques utilize writing through touch gestures on the smartwatch screen [20, 35, 36, 56] or the edge of the screen [18, 57].

While the proposed techniques are successful in their own right, we believe that none of them are directly suitable for hidden interaction. Most techniques require looking at the watch while typing, which is not ideal. Still, some techniques can be used without looking, such as the one-handed techniques [19, 59, 61]. However, they require external hardware and often require practice and cognitive resources. Hence, they might receive unwanted attention and hinder the user's ability to attend to a social situation while typing.

Therefore, we believe that *there is need for a novel, mobile text entry technique* that supports hidden interaction. In our concept of HideWrite, we draw inspiration from a drawing metaphor, where users can draw characters on the screen one at a time. Such a metaphor has been used before for text input [25], but they are not built, nor evaluated, for hidden interaction (e.g., users need to look at the device). With HideWrite, we address these limitations.

2.3 Summary and Conclusions

In summary, prior research on subtle interaction has focused on the *performance* of the proposed techniques, and on proposing focused techniques for specific situations. Currently, we lack a comprehensive investigation into the *hiding* of interaction around other people. Furthermore, we do not yet have a good understanding of how hidden interaction techniques could be designed, and how we can best support hidden interaction in social situations.

In this paper, we distinguish ourselves from existing work in two significant ways: **(1)** We conduct a rigorous, in-depth investigation where we focus on the aspects of *hiding* the interaction in the presence of others. We address not only whether users can remain hidden while interacting, but also *how* they can achieve it, and to what extent it affects their primary task (e.g., a conversation). **(2)** We evaluate hidden interaction using typical, existing devices (smartphones and smartwatches) in different social situations. Prior research has largely focused on custom devices and additional hardware, which limits their applicability in everyday situations. Hence, we believe that our work provides more generalizable insights.

Specifically, we look into (1) receiving vibrotactile cues on smartphones, and (2) writing messages on smartwatches. Vibrotactile cues have been widely used for communication and many other situations, but they have not been evaluated in the context of hidden interaction. Similarly, prior research has not investigated hiding texting techniques on mobile devices. In addition, we argue that none of the existing input techniques for smartwatches are directly suitable for hidden interaction. Hence, we propose a new typing technique, HideWrite.

3 HIDDEN INTERACTION TECHNIQUES

In this section, we present our design goals, our two proposed interaction concepts, HiddenHaptics and HideWrite, and the implemented prototypes. Through these two concepts and the related user studies, we aim to gain insight on whether users can hide their interactions with their personal devices in realistic social situations, how much effort this requires, and what tactics users adopt to succeed. With these two different concepts, we aim to address a **lightweight interaction scenario** (HiddenHaptics; receiving vibrotactile cues on a smartphone), and an **advanced interaction scenario** (HideWrite; writing text messages on a smartwatch).

3.1 Design Goals for Hidden Interaction

We established four primary design goals for hidden interaction:

Design Goal 1: Eyes-Free Interaction. The technique should be usable without looking at the device, opening opportunities to hide the interaction. Not looking should not result in a significant drop in performance.

Design Goal 2: No Visual Output. The technique should not provide visual output, so that the device appears inactive and does not reveal the interaction through its screen or other components.

Design Goal 3: Naturally Deployed. The technique should function on a device that users can naturally carry or wear in almost any situation, and that does not in itself attract unwanted attention (e.g., due to an unusual form factor or additional hardware). Suitable devices include typical off-the-shelf devices like smartphones and smartwatches, and some specialized devices like small, interactive rings [4].

Design Goal 4: Ease of Use and Low Effort. The technique should be easy to learn and require low cognitive effort, so that users can still attend to other activities (e.g., conversations, meetings) at the same time.

We hypothesize that these four design goals form a good basis for designing hidden interaction techniques. We validate them with our evaluations of HiddenHaptics and HideWrite. Even though they are very different techniques, they both meet our four design goals.

3.2 HiddenHaptics

Through HiddenHaptics, we investigated whether users can receive and understand vibrotactile cues from their smartphones while concealing the activity in a social situation. We imagine that vibrotactile cues could be used to receive simple information privately, such as navigational instructions [44, 45, 50] or information on active notifications [32, 33]. For example, a person might be expecting a sensitive phone call or a message, and during a conversation they might want to check whether they have received a corresponding notification instead of visibly pulling out their smartphone. People also check their smartphones dozens of times per day [15], and we imagine that the concept of HiddenHaptics could reduce excessive smartphone use [49], as people could check whether they have anything noteworthy on their phones before looking at it.

To test our concept in a study, we developed a smartphone prototype application that contains six vibrotactile patterns (Figure 2) that are based on previous work [53]. The patterns are intended to be distinguishable from each other based on, e.g., their length and number of gaps. Users can choose up to three patterns and order them based on their perceived sense of urgency. Users can then trigger a random sequence of the chosen vibrotactile patterns by pressing the volume button on the side of the smartphone. The sequences can contain one, two or three patterns. This simulates a situation where each vibrotactile pattern represents a specific piece of information; users can trigger the vibrations at any point and decipher their meaning by just holding or touching the smartphone.

We set the vibration strengths rather low, so they could not be easily heard in a quiet setting. We used amplitudes between 100–200 (as defined by the Android vibration API). This was tuned based on pilot tests, so that each vibration felt similar in strength. Generally, brief pulses required a higher amplitude.

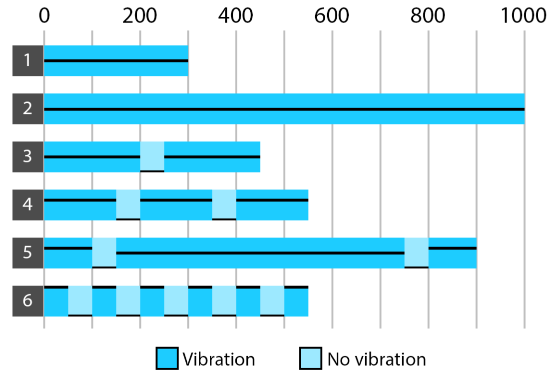

Figure 2: The vibrotactile patterns used in the evaluation of haptic patterns. The black lines represent vibration strength, and higher lines mean stronger vibrations. The strength was varied based on vibration length; the shortest vibrations (pattern 6) were the strongest.

3.3 HideWrite

As an advanced hidden interaction technique, we designed and implemented HideWrite, an eyes-free text entry technique for smartwatches. The concept is based on a drawing metaphor; users can draw characters on the watch screen one at a time. The screen is turned off throughout the interaction, making it seem like no apps are active. This also creates an opportunity to disguise the interaction as "idle doodling" or "casual fidgeting" in situations where someone might observe the watch being touched [2].

The different functions of HideWrite are illustrated in Figure 3. First, users select the recipient by making a predefined gesture. Even though we did not fully focus on this phase in our studies, we envision that users could set gestures to specific contacts, thereby allowing a recipient to be quickly selected using the watch. After selecting the recipient, users can start writing their message. We added a delay of 400 ms; within this time frame users can lift their finger and touch another part of the screen, and both drawings will register in the same character – this can be used to add dots and other details. After the delay has passed, the current drawing is registered and users can start drawing the next character. Double-tap adds a space between characters. For deleting the last character, a button can be pressed on the watch. Pressing another button sends the message to the recipient. For study purposes, in our prototype the submitted message is sent to the paired smartphone for display.

All interactions are supported with a subtle vibration cue. This is especially useful for recognizing the delay, as users then know exactly when a character is registered and they can start drawing the next character.

HideWrite utilizes bitmaps as an output format, directly displaying the message as it was drawn (Figure 4). While we envision that in the future, text recognition software could be used to transform the output into digital text, we also see many possibilities with the current format. Due to the drawing metaphor, users are not restricted to text and numbers, but they can also draw anything they want, and come up with their own creative ways of communication. We see this as an interesting direction for future work.

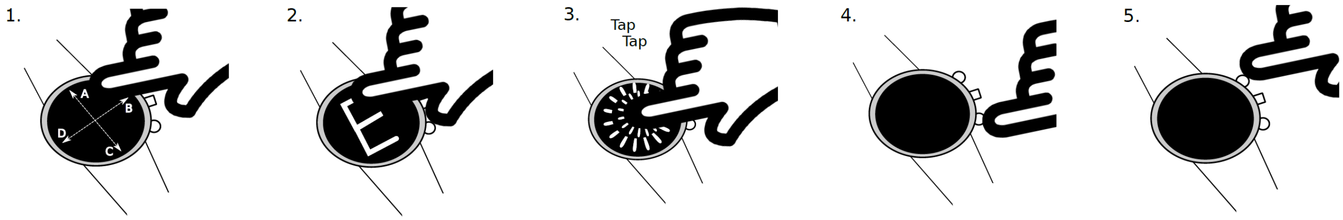

Figure 3: HideWrite interactions. The watch screen is dimmed throughout the interaction; the signs appearing on the screen here are for illustrative purposes only. 1: Users can choose a recipient with a predefined gesture. 2: Users draw characters (or anything they want) one at a time. After a delay of 400 ms, the character is registered and a new character can be drawn. 3: Double tap adds a space. 4: Pressing the lower button on the watch deletes the last character. 5: Pressing the upper button on the watch sends the message and clears the drawing space.

Figure 4: A message written with HideWrite.

3.4 Research Approach

To understand hidden interaction techniques in different scenarios, we conducted three user studies. In study 1, we evaluated HiddenHaptics in a hallway discussion scenario. In study 2, we evaluated the usability and performance of HideWrite. We did this because of the more advanced scenarios that HideWrite was designed to address, so that we could first understand potential pitfalls and usability issues before testing it in a realistic situation. Finally, in study 3, we evaluated HideWrite in a meeting scenario. Next, we will present the three user studies and briefly discuss their results separately. Afterwards, we synthesize our findings and discuss the implications at large.

4 STUDY 1: HIDDEN HAPTICS

We evaluated HiddenHaptics in a simulated hallway discussion scenario. Two participants were tasked with having a conversation about various topics, while one participant attempted to use HiddenHaptics without being exposed, and the other participant attempted to expose them. The roles were then switched and the study was repeated.

4.1 Participants

We invited 14 participants (7 females, 7 males) to a study session which they attended in pairs. The average age was 31 (SD = 5.66). Four participants were students, the rest were professionals from various fields. The pairs had diverse relationships, consisting of couples, colleagues, and study peers.

4.2 Study Tasks

4.2.1 Conversation Task. Both participants had a *shared conversation task*, which was an icebreaker-type conversation. Participants were given a list of 20 topics that they could choose from and ask their study partner to talk about. Participants took turns: one would pick a topic, the other one would talk about it, and then the one who gave an answer picked the next topic. The available topics were such that anyone could answer them or have an opinion on them, e.g., describing where they would want to travel, or what things they are looking forward to. We informed the participants that their answers are not evaluated, and they can talk about the topics in any way they want. We advised that they should aim to talk about each topic for around one minute, although this was not measured or enforced. Participants went through a total of 12 discussion topics.

4.2.2 Checking Task. One participant was assigned to the role of *user*. Their task was to *receive and understand vibro-tactile feedback through HiddenHaptics, without the other participant noticing*. This was to be done once during each topic discussion, although participants were allowed to check it more than once if they needed to (the result stayed the same during one topic, and changed for the next one). After each topic discussion, the user reported the vibro-tactile pattern (by referring to the vibrations as A, B and C, as they had assigned them). Since we controlled the turns that participants took to speak, half of the checks happened while the user was **speaking**, and half while **listening** to the other participant.

Both participants were present during the briefing, so observers knew exactly what the user's task was and how the interaction with HiddenHaptics worked. Similarly, users were aware of what the observers attempted to do.

The first participant taking the role of the user only chose two haptic patterns. The roles were flipped midway (after six discussion topics). In the second round, the new user chose three haptic patterns instead, making it potentially more difficult to identify the vibrations and hide the interaction. The primary goal of having users report the vibro-tactile cues back to the experimenter was to ensure that users would really pay attention to the vibro-tactile cues and attempt to decipher them, instead of merely triggering the vibrations, which would presumably be significantly easier.

4.2.3 Observation Task. The other participant assumed the role of *observer*. Their task was to **expose the user's interaction** during the discussion. The observer was also given a smartphone; they could press the volume button to log when they thought this act was happening. Hence, the user did not know whether they had been caught. The observer was instructed to keep their finger on the volume button so they could log their observation immediately.

4.3 Apparatus

The study was conducted in a room with a table and chairs, and plenty of space around the table. Participants were asked to stand during the tasks and were originally positioned next to a wall, although there was no further control about how they could move or position themselves. We set up two laptops on the table, which participants used to provide feedback after experiencing either one of the roles. Both participants were given a Google Pixel 3 smartphone with the HiddenHaptics prototype application installed. The user used the main functions of the application; the observer used a separate observation mode, where the only feature was to log their observations by pressing the volume button.

4.4 Procedure

The participants were first handed written information about the study and data collection. Participants then signed a consent form and filled in a background questionnaire. Following, we introduced participants to the shared conversation task and the checking and observation tasks. The user was introduced to the HiddenHaptics application and was asked to pick two vibrations from the six available ones, and assign them to groups A and B. The observer was then introduced to their task and the application.

Participants were asked to **stand** during the tasks. This was to simulate a spontaneous social situation (e.g., discussing with a colleague in a hallway, running into someone and stopping for a chat), and also to give the observer an unobstructed view of the user. Participants were otherwise allowed to do whatever they thought was natural behavior during a discussion – including leaning against a wall, moving to another position, or taking a different pose. They were also allowed to hold the smartphone any way they wanted.

The participants went though six different conversation topics, after which they filled in questionnaires about their experience. The roles were then switched. The newly assigned user chose three haptic patterns instead of two (assigning them to groups A, B and C). We hypothesized that more complex vibro-tactile feedback would be more difficult to hide. After both rounds, participants filled in one more questionnaire. Participants were given 10€ in cash as compensation. The sessions lasted around 70–90 minutes.

4.5 Results

4.5.1 Invisibility and Success of the Interaction. To define the success of smartphone checks and guesses, we set a window within which the observer's logging would be considered successful. Based on our observations from the study, we considered a successful time frame from two seconds before the vibrations started until two seconds after the vibrations finished. Hence, the total guessing window was around 5–6 seconds, depending on the vibration sequence. This window was somewhat more generous than in previous work, wherein an observation was considered successful if it was within 1.5 seconds from the interaction [13].

We calculated separate success rates for the user and the observer. If the observer did not log anything during a task, it was counted as a single failed attempt. **Users successfully hid (93.3%) of their checking attempts** (125/134). Observers made 107 guessing attempts, of which 9 (8.4%) were successful: five of them while the user was speaking, and four while the user was listening.

Users reported the perceived vibration patterns to the experimenter at the end of each topic discussion. In both conditions (2 and 3 vibration patterns), participants had the exact same total success rate of 92.9% (39 out of 42). Of the six failed tasks, five happened when the user was speaking.

4.5.2 Tactics and Planning. The majority of participants (9) used their body to block the observer's line of sight to the smartphone, for example, by holding their hands together behind their backs or leaning against a wall. Six participants commonly held the phone in their pocket, usually with the free hand in the other pocket. Most participants stuck with the same tactic throughout the study, but some experimented with different tactics when a conversation topic was changed. During some of the tasks, some participants made no attempt to keep the smartphone out of the observer's view. In these cases, users commonly let their smartphone-holding arm hang freely on the side.

Despite their tactics, users acted seemingly natural, maintained eye contact with their conversation partner, and demonstrated other natural movements. Users often gestured with their hands while speaking, made small turns with their body or took small steps, and sometimes leaned against a wall instead of standing upright.

Only two users reported to have used explicit distractions:

> *"I occasionally raised my phone when I wasn't really using it, to make my partner focus on it at the wrong time."* - Male, 26

> *"I deployed three different fake maneuvers, which I figured could seem like involuntary actions: blinking more, sneezing, and moving my leg."* - Male, 35

Users commonly reported that they aimed to maintain eye contact and look for moments when their conversation partner was looking away or seemed distracted. Such moments reportedly came more frequently when the observer was speaking, as they were more mentally invested in the discussion, thinking about what to say and searching for the right words.

4.5.3 Perceived Success and Workload. Participants answered statements on a 7-point scale (Figure 5). *Users* were very positive about their performance (Md = 6), and smartphone checking while listening was rated slightly easier (Md = 6) than while speaking (Md = 5). Users also felt they could act naturally (Md = 5.5) and focus on the conversation (Md = 5). *Observers* were much more negative about their experience, feeling that they were not successful (Md = 2). They felt that observing while listening was relatively difficult (Md = 3), and observing while speaking was very difficult (Md = 1). Observers also felt that they were not able to focus on the conversation while observing the user (Md = 3).

We also observed the participants' engagement in the conversations. The icebreaker questions worked very well. All participants, regardless of their role and relationship, were actively engaged in the conversations and many commented how interesting some of the topics were to them. For example, two colleagues discovered their mutual love for football through the discussion. Another participant was very happy to hear from her boyfriend about how recent changes to his work assignments had made him more positive about his job. These observations suggest that the quality of the discussion did not suffer from either of the individual tasks.

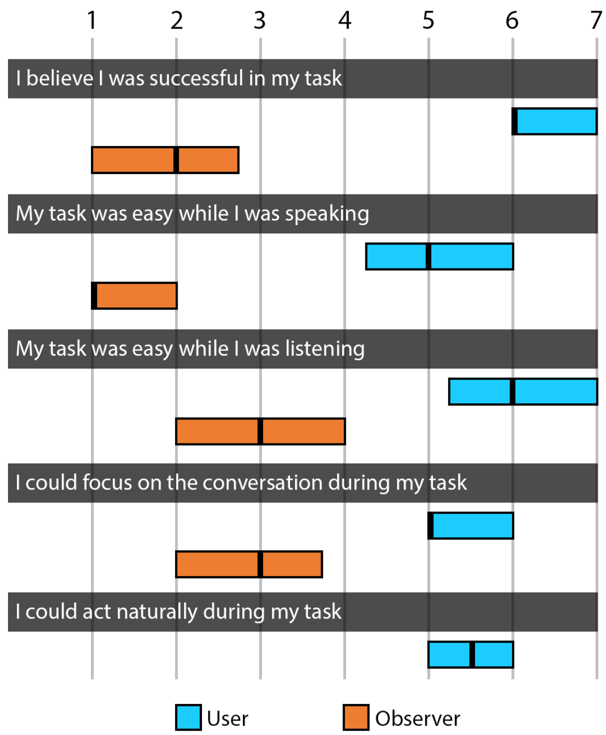

Figure 5: Users' and observers' assessments of their task success. The black, thick lines represent the medians, and the boxes represent the inner quartiles.

4.5.4 Summary and Discussion. The results suggest that users can easily hide vibration-based output on smartphones using HiddenHaptics. Users were very successful with hiding the interaction, as 93.3% of their checking attempts went unnoticed. It is also possible that some of the failed attempts were lucky guesses from the observer, as the successful guessing window covered roughly 5–10% of the total discussion time. This is further supported by the observers' low confidence regarding their success, and their reports that observing in general was very difficult. Moreover, the study setting favored the observer, as they had exact knowledge about the technique and the user's task.

Participants were successful in identifying the vibro-tactile cues (92.9% on both conditions); participants taking the user role in the second round were equally successful despite the increased difficulty. Therefore, we believe that more complex vibro-tactile cues could be used while still remaining hidden; however, more studies are required.

Users reported surprisingly few tactics where they aimed to distract their conversation partner. Most participants settled with breaking line of sight between the smartphone and the observer (although this did not seem to be necessary), and then focusing on having a normal conversation while maintaining eye contact. Maintaining eye contact was also commonly reported in another study [38] as a means to show focus on the discussion. Regardless of tactic, users were consistently successful in hiding their interaction.

Hiding vibro-tactile cues was deemed easier when the conversation partner was speaking. Participants reported that listening is significantly less demanding than speaking. Moreover, their conversation partner's speaking turn more frequently opens up ideal opportunities for hiding the vibro-tactile output.

5 STUDY 2: HIDEWRITE - PERFORMANCE AND USABILITY

Because HideWrite represented a more advanced form of hidden interaction, we first conducted a usability study. Our main focus was to uncover any major design flaws or **usability issues** before moving on to a realistic scenario. We also wanted to gain a preliminary understanding of how **fast** HideWrite is as a writing technique, and how **readable** the resulting messages are. Because HideWrite is designed to emphasize unobtrusiveness over efficiency, we expect that HideWrite might be slower than competing techniques. The readability of the output, however, is an important factor in defining whether or not HideWrite is a successful text entry technique.

Studies 2 and 3 were conducted during the COVID-19 pandemic. Prior to starting the studies, they were evaluated and approved by the ethics committee at LMU Munich, Germany, with reference EK-MIS-2020-025.

5.1 Participants

We recruited 10 participants (4 female, 6 male; aged 19–25) from the local universities. Nine were right-handed and one was left-handed. Nine participants had little to no experience with smartwatches, while one used a smartwatch daily.

5.2 Study Tasks

The participants' task was to write 20 messages using HideWrite. The messages were pre-defined, short messages such as "In a meeting" and "I will be 10 minutes late". We imagine that HideWrite is best used for such brief messages. The messages were divided into two sets. For the first 10 messages, users were allowed to observe the smartwatch. For the last 10 messages, users were told to not look at the smartwatch at all. We did this to observe whether writing eyes-off impacts efficiency or readability.

In addition to the writing task, participants were tasked with reading the messages written by another participant and rate their readability. We did this to gather unbiased opinions on the overall output quality of the technique.

5.3 Apparatus

We seated participants in front of a table, and they put on the smartwatch (a Fossil Gen 5 with a black leather strap) on either arm. A laptop was placed in front of them that displayed the messages that they were tasked with writing, one at a time. We also positioned a smartphone in front of them that displayed the participants' output once they had pressed send, allowing them to observe the quality of their writing. We logged all the interactions with the smartwatch and stored all the written messages. Also, due to the COVID-19 pandemic, we followed the recommended hygiene standards. The experimenter wore a mask and kept a minimum distance of 1.5 meters to the participant. All furniture and equipment were disinfected and the room was ventilated before every study session.

Figure 6: The same message written by three different participants using HideWrite.

5.4 Procedure

Participants were first introduced to the HideWrite application and they were given a brief period of time to practice. After that, the participant read the written messages from the previous participant out loud. For incorrectly read messages, we noted down which exact part or character of the message was not correct. Participants also rated the readability of each message on a 1–5 scale. The first participant did not rate any messages.

Next, participants completed their 20 writing tasks, first eyes-on and then eyes-off. They were instructed to balance speed and readability, i.e., write as fast as they could without sacrificing output quality. After each message, participants could observe the result on the smartphone. Finally, participants were interviewed, where we focused on identifying usability issues. The sessions took around 40 minutes, and participants were compensated with 5€ in cash.

5.5 Results

5.5.1 Writing Speed. Because the study focused on short messages, we calculated the text entry speed using characters per minute (CPM). All messages combined, the average typing speed was 36.9 CPM (SD = 4.63). The fastest participant reached 45.2 CPM. The average CPM converts to 7.37 words per minute (WPM), considering the assumption of five characters being the average length of a word [3]. The average entry speed for the eyes-on condition (which every participant did first) was 35.62 CPM (SD = 5.00), while for the eyes-off condition, the speed was 38.11 (SD = 4.11).

5.5.2 Readability. Out of the total of 180 messages that the participants read, only four were not read out loud correctly. The median readability rating for all messages, as well as for all participants individually, was 5 (the best possible).

We present three examples of the same message in Figure 6. In the upper message, the *M* and *E* are drawn in the same "character". This is due to the user not waiting for the delay to register before drawing the *E*. However, these occurrences were rare, and interestingly, most participants had no trouble reading such messages. Participants practiced with HideWrite before reading the messages from another participant, which might have helped them understand that it is not one scribbled character, but two characters on top of each other.

5.5.3 Subjective Feedback. Participants did not report any noticeable usability issues with the technique. They were consistently positive about their experience and stated that the features were simple to use. However, there were varying opinions about the delay between character input. Half of the participants were satisfied with the existing delay, and the other half reported that it could be shorter. In the future, this parameter could be modifiable, and making the delay shorter would likely increase typing speed.

We also asked participants whether they felt a need to check what they were writing before sending the message, as the evaluated version of HideWrite did not include such a feature. However, most did not think that it was important. This might be because we focused on writing short messages.

5.5.4 Summary and Discussion. Our results suggest that HideWrite is a successful technique in terms of design and usability, and produces highly readable output. When participants started writing with their eyes off the screen, their text entry speed kept increasing. While this can be attributed to the learning effect, we can conclude that taking eyes off the device does not decrease performance. As we expected, with an average speed of 36.9 CPM or 7.37 WPM, HideWrite is slower than most text entry techniques. The majority of techniques situate between 9 and 17 WPM [19, 23, 24, 39, 58, 61], while some reach over 20 WPM [16, 20]. Still, HideWrite is faster than some existing techniques [59]. Because we did not uncover any particular issues with HideWrite and the received feedback was positive, we moved on to Study 3 without changes to the technique.

6 STUDY 3: HIDEWRITE - MEETING SCENARIO

In the third study, we investigated the use of HideWrite in a realistic scenario. Users were tasked with writing messages while aiming to conceal it from another study participant. In this study, we simulated a *meeting*. We did this for three reasons. First, we envision that HideWrite is ideally used in situations where it is not possible to halt the ongoing activity to type a message. Second, meetings are a universal component in work settings and, therefore, represent a typical situation where the need arises to type a message in that exact moment. Third, investigating a scenario different from the HiddenHaptics study (standing discussion task vs. seated meeting task) is likely to provide a more comprehensive understanding of hidden interaction, and how users succeed or fail doing it.

6.1 Recruitment and Participants

We advertised the study as a study focusing on "technology use during meetings", where we did not reveal any details about HideWrite or the related tasks. We advertised through various channels like mailing lists, Slack, and Facebook.

Due to our study design, we needed two participants for each session. Ideally, the pairs would not know each other because of tasks related to HideWrite; otherwise people might realize that the other person is wearing a smartwatch that is brand new or not theirs. Hence, we set up a registration form where prospective participants provided their availability on several dates and time slots, and also provided basic background information such as age and occupation or study program. We used this information to pair people who had matching time slots and who we assumed were unlikely to know each other.

This way, we recruited 22 participants (9 female, 13 male). Their average age was 24.4 (SD = 2.86). Three of the participants were researchers, and the rest were students from various fields such as history, law, medicine and computer science.

6.2 Study Tasks

6.2.1 Meeting Task. Both participants had a *shared meeting task*, which comprised paying attention to and actively participating in the meeting, by answering and asking questions, and providing feedback on the ideas presented by others. Part of the task was to imagine that all three meeting attendees (the two participants and the meeting leader) worked in the same team in the same company.

The meeting was split into *two sessions* with different topics, which lasted around 10-15 minutes each. We used casual meeting topics that were easy to get into for anyone, similar to prior meeting studies [9, 30]. In the first session, the meeting leader wanted to gather opinions about a suitable location for a team summer getaway, and presented four possible locations. The goal was to discuss the strengths and drawbacks of each location and reach a decision on which one to pick. In the second session, the meeting leader suggested ordering customized merchandise with the team logo, to be given to all employees. The team leader presented various options for clothing, hats, and bags. The goal was to reach a decision on the items to pick, as well as the colors and logo positioning.

After each session, the participants completed a brief quiz. The quiz contained four multiple choice questions about the slides and about things that the meeting leader had said, so that only observing the slides was not enough. The quiz questions were the same for both participants, so that their performance could be compared.

6.2.2 Writing Task. One participant from each pair was assigned to the role of *User*. Users had a *secret writing task* of writing four messages using HideWrite during the meeting, without the other participant noticing. The messages were split between the two meeting sessions, so the task was to write two messages per session.

6.2.3 Observation Task. The other participant was the *Observer*, who was not initially aware of the other participant's writing task. After the first meeting session, however, they were hinted at the user's secret task and asked to report any activity that they might have already observed. They were then instructed to observe the user in the second session and report their findings afterwards.

6.3 Apparatus

We set up a meeting room with a large table in the middle and chairs around it, and two large displays on one side (Figure 7). The experimenter acted as the meeting leader, who presented slides on one of the large displays and moderated the discussion. The meeting leader stood next to the display, facing the participants. The user was seated directly across from the display, and the observer was seated at a 90-degree angle from the user, so that they had a clear view of the display and other meeting participants.

The user already wore the smartwatch at the beginning of the study. The paired smartphone was held by the meeting leader and it was kept out of sight since it was not needed at any point. A video camera was set up in the far corner so that the entire session as well as the user's interactions with HideWrite could be recorded.

Due to the COVID-19 pandemic, we followed the recommended hygiene standards. All meeting attendees were seated 1.5 meters apart. All furniture and equipment were disinfected before every study session. We used paper for questionnaires to limit the number of devices that would have to be disinfected.

Figure 7: The setup for study 3. The meeting leader positioned himself next to the display on the left, facing the other participants. The user sat across from the display, on the right. The observer sat at the end of the table.

6.4 Procedure

Users were instructed to arrive 20 minutes before the observer. During this period they were briefed about the secret writing task, and they were asked to fill in a consent form regarding the secret task as well as the data that would be collected. Then, they practiced with HideWrite.

Users were instructed to come up with their own message content during the secret task. They were informed that the content of the messages does not matter, but that the messages should be understandable and readable because they will be read by another person later. In typing studies, users are typically told what they should write. We did not do this because we could not instruct users or talk about the secret task mid-study; requiring users to remember what they should write might have presented a confounding variable. We also believe that having participants decide what to write themselves is a more realistic scenario.

Like in the previous study, after the users had sufficiently practiced with HideWrite, they were presented with the messages written by the previous user, and asked to read them out loud and rate their readability on a 1–5 scale.

In the main study part, it was made to look like the user had arrived only just before the observer. They were then both briefed about the upcoming simulated meeting sessions and the meeting task. Participants then signed a consent form regarding the video recording and the data that would be collected during the study.

The meeting leader then started the first meeting session about the team summer getaway locations, asked opinions from participants, and facilitated the discussion so that everyone took an active speaking role. During this time, the user attempted to write two messages. After the meeting session, both participants were presented with multiple-choice questions about the meeting content. Additionally, the observer was hinted at the user's secret task and asked to report any activity that they might have already noticed. This was done using paper, so that the user was not aware of how much the observer knew. The observer was also instructed to pay close attention to the user in the next session.

The meeting leader then ran the second meeting session. Afterwards, a similar quiz was presented, and the observer was again asked how much they saw and what they could make of their observations. Then, the final questionnaires were presented to both participants, each receiving different questions. At this point, the secret task was revealed to the observer. After the questionnaires, the observer could leave and the user stayed for a brief interview. Both participants received 10€ as compensation. Each session lasted for 60 minutes on average (40 minutes for the observer).

6.5 Results

6.5.1 Invisibility of the Interaction. After the first meeting sessions (where observers were not briefed about the user's task), none of the observers detected anything. After the second meeting (for which the observers knew about a secret task and were asked to observe the user), one observer was able to figure out that the other participant was typing on their smartwatch. In this particular occasion, the user had decided to use the watch visibly on the table. The remaining ten observers were unable to detect anything.

6.5.2 User Tactics. Users reported some basic strategies that they incorporated during the meeting to hide their interaction. Eight out of eleven users (8/11) specifically stated that they focused on writing while someone else was speaking. Eight users (8/11) also reported that they paused the writing whenever they received attention, e.g., when someone looked at them, or if a question was asked that they were expected to respond to. They would then wait for a better moment to resume writing.

Nine users (9/11) stated that they attempted to break the line of sight between the other participant and the smartwatch by interacting under the table, which was validated through the video recordings. No one reported any specialized tactics or deceptive behaviors to distract the other participant.

Writing-wise, nine out of eleven users (9/11) wrote all their messages with uppercase letters. One participant wrote half the messages with uppercase and half with lowercase letters, while one participant only used lowercase.

6.5.3 Perceived Success and Workload. Users and observers answered statements on a 7-point scale (Figure 8). The users were very confident that they were able to hide the interaction (Md = 7), while observers reported that noticing the interaction was very difficult (Md = 1). Users stated that the writing task was very difficult while they were speaking (Md = 1), but significantly easier while they were listening to someone else (Md = 6). Observers felt similarly about their task, albeit not as strongly (Md = 3 and 4, respectively). Users were somewhat positive about their ability to focus on the meeting despite their writing task (Md = 5), while observers were slightly more negative (Md = 4). Finally, users felt that they could act naturally despite their writing task (Md = 5).

We tested the participants about the meeting with multiple-choice questions, where only one answer was correct in each question. There were four questions for each session. Out of a maximum score of eight, users scored an average of 7.7 and observers 7.6. An independent samples t-test showed that there was no significant difference between users and observers ($t(22)=0.41$, $p=.888$, $d=0.06$).

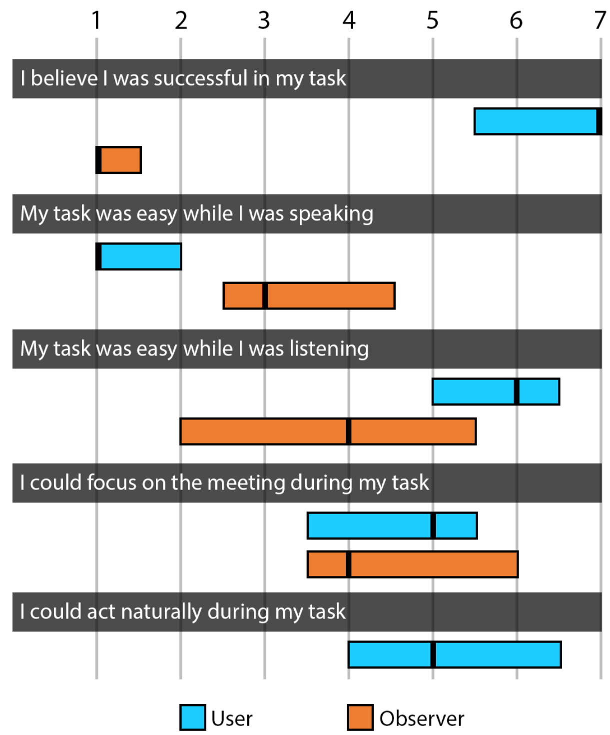

Figure 8: Users' assessment of their writing task, and observers' assessments of their observation task. The black, thick lines represent the medians, and the boxes represent the inner quartiles.

The quiz results therefore suggest that the writing task did not significantly hinder the user's ability to participate in the meeting.

Moreover, similar to study 2, participants did not think that being able to check what they were writing was important. This feature might be deemed more critical when writing longer messages.

6.5.4 Readability. Similar to the HideWrite usability study, users read the messages from the previous participant out loud and rated their readability. All messages, expect for two, were read correctly, and the median readability rating was 4 (on a 1–5 scale). Therefore, we observed only a slight decrease in quality from the usability study, and the readability remained high in a realistic situation.

6.5.5 Summary and Discussion. The results from study 3 suggest that HideWrite is a successful technique for hidden text entry. The writing was very difficult to detect, even when observers where hinted about the task, and the readability of the messages was high. Users were able to participate in the meeting and remember details about it just as well as the observer.

Users sought to interact with HideWrite when the other participant was speaking. Most participants also hid the interaction under the table. Observers, on the other hand, stated that exposing the user was very difficult, and made a point that observing the user was more difficult while speaking. Much like in study 1, users were clearly positive about their experience and task performance, whereas observers were negative about theirs.

7 DISCUSSION

In this section, we draw upon the results from our conducted studies and answer our three primary research questions. It is striking that studies 1 and 3 yielded very similar results, even though they dealt with different scenarios, devices, and interaction techniques.

Finding 1: Users can successfully hide their interaction with hidden interaction techniques. Studies 1 and 3 reveal that observing and exposing hidden interaction techniques is very difficult. With HiddenHaptics, 93.3% of all checking attempts went unnoticed, and with HideWrite, only one out of 11 observers noticed the interaction, and only after being hinted about it.

With HiddenHaptics and HideWrite alike, users were much more confident about their interaction and task success than observers were about their observations. Users also thought that their task was easy, while observers reported their task to have been very difficult. These results suggest that the proposed techniques successfully support hidden interaction and multi-tasking, i.e., users can still sufficiently participate in the ongoing social activity.

In other studies, successful concealment of an interaction was dependent on special conditions, such as whether observers had prior knowledge of the device [2], or whether the equipment was fully concealed [13]. For the vibro-tactile cues of HiddenHaptics, neither seem to apply, since it is not dependent on hiding the presence or nature of the device. Observers knew exactly how HiddenHaptics works and knew about the user's exact task; even when observers had direct line of sight to the smartphone, their guesses were unsuccessful. For HideWrite, it remains somewhat unclear how much these conditions might affect its successful hiding, but we believe that the effect is small. Our study suggests that people do not typically pay attention to regular devices unless explicitly asked to do so. Moreover, a smartwatch is a natural device and can be hidden momentarily in almost any social situation. For example, users can lean against a wall and type with hands behind their back, or they can hide the interaction behind objects such as tables.

Finding 2: Users interact while someone else is speaking, and try to hide their interaction behind their body or other objects. Observers had an even harder time revealing the interaction when they were speaking, which in turn is the exact time when users preferred to interact. Ofek et al. [38] had the same finding in a study where users received visual and auditory information during a conversation. There seem to be two primary reasons for this preference. First, listening to someone else is less demanding than speaking, and therefore leaves more cognitive resources to be directed elsewhere. Second, there seem to be more ideal opportunities for hidden interaction when someone else is speaking. Speakers tend to be more focused on what they should say, and any additional attendees naturally tend to focus on the speaker, making them less attentive to their surroundings.

The observers' failure and high workload can partly be explained by the continuous nature of their task: observers do not know in advance when the user interacts or intends to interact, and therefore must keep focus on them at all times. The users, on the other hand, have control over this and only need to interact for a small portion of the social situation.

In both studies 1 and 3, most users attempted to prevent the observer from seeing the device altogether, while they interacted with it. In study 1 with HiddenHaptics, users commonly held the smartphone behind their backs or in their pockets. It is notable, though, that the few users who held the smartphone in plain sight were equally successful.

In study 3 with HideWrite, users similarly attempted to interact with the smartwatch by keeping their arms under the table. Two users held the smartwatch in plain sight while they interacted, and one of them got caught. With such a small sample, we cannot determine how big of a role this direct visibility might play at others detecting the interaction with a smartwatch. However, our study does suggest that people do not pay attention to such things unless explicitly asked to do so. Moreover, almost any social situation offers opportunities to hide the device momentarily.

Almost all users settled with these simple principles to hide their interaction. Using deceptive or more specialized strategies to distract the observer was very rare. In study 1, only two participants reported that they adopted some level of deception to hide their interaction (e.g., attempts to direct the observer's focus elsewhere through movement). In study 3, no one reported any such strategies.

Finding 3: Users can sufficiently participate in the ongoing social activity while using hidden interaction techniques. Users were able to attend to the social activity in both studies. In study 1, users were equally active in the discussions and evaluated their ability to participate in the conversation positively (unlike observers). In study 3, users performed in the quiz just as well as the observers, and through our observations participated in the meeting equally to the observers. Again, users rated their ability to participate in the social situation more positively than observers.

In this paper, we focused on addressing two fundamental social activities (casual discussions and meetings), as well as two fundamental interactive tasks (checking the smartphone and writing a short message). It is likely that the interaction would be more difficult to hide, or the main activity would be more difficult to handle well, under more demanding circumstances. Prior research shows that people perform poorly with *continuous* individual tasks (e.g., preparing a presentation) while attending to a social situation (e.g., a meeting) [9, 30]. This suggests that prolonged hidden interaction might be problematic (e.g., writing a long message or exchanging messages continuously). What remains more unclear is how very demanding social situations (e.g., giving a speech) might affect the use of hidden interactions. Studying hidden interaction in such high-stress scenarios could interesting in the future.

7.1 Design Goals for Hidden Interaction

At the outset of our work, we established four design goals that directed the concepts of HiddenHaptics and HideWrite. Both of them were **(1)** eyes-free, **(2)** devoid of visual output, **(3)** naturally deployed, e.g., running on off-the-shelf commodity devices without external hardware, and **(4)** easy to learn and low-effort to use.

Even though the two techniques utilize very different interaction paradigms and they were evaluated in different scenarios and with different devices, both were successful and both were used with similar tactics. Therefore, we believe that these design goals can inform the design of new hidden interaction techniques.

7.2 A Word on Ethics

We acknowledge that hidden interaction techniques could be perceived as deceptive from the bystander's perspective. Prior research notes that deceptive technology use can also be well-meaning [1], and that users will interact with their devices no matter what, and that it is better to allow some interactions to go unnoticed so that observers can remain un-offended [2]. Visible technology use can also lead to ill-informed conclusions [2]. For example, checking the smartphone during a conversation might make the observer think that the user is bored, even if they are not. We emphasize that hidden interaction techniques are not intended to offend or harm others, but to protect the user from privacy threats and judgment, and to introduce flexibility to the use of mobile devices. We also envision numerous other benefits; for example, hidden interaction techniques could be used in dangerous situations to call for help or provide details about the situation. Still, it is possible that hidden interaction techniques could be used maliciously, and, therefore, their social acceptance should be studied at large.

7.3 Limitations and Future Work

We identify some direction for future research. First, with HiddenHaptics in study 1, we focused on transmitting simple haptic patterns, because our focus on the hidden aspects of the interaction, rather than the transmitted information. In the future, advanced haptic patterns could be explored in this context, which could convey more complex information (e.g., messages). Prior research suggests that users can learn complex vibro-tactile cues through practice [7, 14, 26], but it is currently unclear how well this would work in the context of hidden interaction.

In this work we focused on two-person scenarios. We believe they serve as the best baseline for studying hidden interaction, as observers can focus clearly on the user, making it less favorable for the interaction. In larger groups, people tend to shift their attention based on who speaks. We already saw this in study 3; when the meeting leader spoke, observers typically focused on them and users took this opportunity to type unnoticed. However, studies with larger groups could still generate more insights, in particular if the user has to interact in parallel to shifting their attention from person to person.

We believe that our results overall would translate well between smartphones and smartwatches. In the HiddenHaptics study, we used a smartphone because it was less clear how hiding would work with a device that needs to be held. A smartwatch, on the other hand, is already attached to the skin, making receiving haptic information more subtle. HideWrite, in turn, could function on smartphones as-is. However, since the smartphone needs to be held, it is not clear whether this would be advantageous or disadvantageous for hidden interaction. On one hand, holding a smartphone and drawing on the screen might seem out of place. On the other hand, since the smartphone is not attached, there are diverse opportunities for placing it while typing, for example, leaving it on the table and disguising the interaction as "idle fidgeting" [2]. More research would be warranted to evaluate the exact extent of device interchangeability, and to uncover any subtle differences in interaction between devices.

Finally, hidden interaction techniques are also of interest to other application areas. For example, authentication schemes based on behavioral biometrics can benefit in that hidden interactions make it more difficult to observe human behavior and, hence, minimize the risk for so-called mimicry attacks [31]. In particular, behavioral biometrics schemes could consider behavior during hidden interactions as input.

8 CONCLUSION

In this paper, we introduced and evaluated the concept of *hidden interaction techniques*. We evaluated two techniques: **HiddenHaptics** allows users to receive information through vibrotacticle cues on a smartphone. We envision that subtle haptic feedback can be used to extract simple information, like information on active notifications. **HideWrite** allows users to write text messages by drawing on a dimmed smartwatch screen. We especially envision HideWrite to be useful for writing short messages in situations where the ongoing activity is difficult or not ideal to halt (e.g., a meeting at work). The shared major design goals for both techniques were that **(1)** users do not need to look at the device during interaction, **(2)** they do not provide any visual output, **(3)** they function on off-the-shelf devices without external hardware, and **(4)** they are easy-to-learn, low-effort techniques.

We conducted three user studies to better understand hidden interaction in situations where other people are present. We focused on how well users are able to hide the interaction from observers, what tactics they utilize to succeed, and how well they can attend to the ongoing social situation while interacting.

We found that **(1)** Users can effectively hide their interaction using hidden interaction techniques. All interactions with HiddenHaptics were successful 93.3% of the time, despite the observer knowing about the technique and being instructed to observe any interactions. With HideWrite, only one out of 11 observers noticed the interaction, but only after being asked to pay special attention to the user. **(2)** Users interact when another person is speaking, as speakers tend to focus more on what they should say, and other nearby people tend to focus on the speaker. Users also tend to conceal the device by holding it behind their backs, keeping it in their pocket, or by using objects like tables, although concealment does not seem to be entirely necessary. **(3)** Despite their interaction, users can sufficiently commit to the ongoing social activity, like a conversation or a meeting.

Through this work we have gained broad, empirical knowledge on hidden interaction; how successful such techniques are and how they are used. We have furthermore presented four design goals that form a basis for designing new hidden interaction techniques. Finally, we presented the design of HideWrite, a novel text entry technique for smartwatches.

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