Evaluating the Disruptiveness of Mobile Interactions: A Mixed-Method Approach

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ABSTRACT
While the proliferation of mobile devices has rendered mobile notifications ubiquitous, researchers are only slowly beginning to understand how these technologies affect everyday social interactions. In particular, the negative social influence of mobile interruptions remains unexplored from a methodological perspective. This paper contributes a mixed-method evaluation procedure for assessing the disruptive impact of mobile interruptions in conversation. The approach combines quantitative eye tracking, qualitative analysis, and a simulated conversation environment to enable fast assessment of disruptiveness. It is intended to be used as a part of an iterative interaction design process. We describe our approach in detail, present an example of its use to study a new call declining technique, and reflect upon the pros and cons of our approach.

ACM Classification Keywords
H.5.m Miscellaneous.

Author Keywords
Research methods; mobile interaction; conversation; social disruptiveness.

INTRODUCTION
Over the last decade, smartphones have become the most ubiquitous computing devices. A recent report stated that there were 4.8 billion unique mobile phone subscribers in 2016, resulting in a subscriber penetration of 65 %[1]. Previous work that investigated where people keep their smartphones shows that users have a close relationship with their phones. Patel et al. [43] found that users' phones were within arm's reach and turned on 50 % of the time. Similarly, Dey et al. [11] showed that users were in the same room as their phones 90 % of the time. Wiese et al. [58] found that users' smartphones were placed horizontally outside of the user's pocket 52 % of the time while at home and 49 % of the time while at work. Similar phenomena were observed in other casual social settings [47, 51].

[1] gsma.com/mobileeconomy/, last accessed: 2017-12-27

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Smartphones have become vehicles for social interactions. Walsh et al. [56] showed that mobile phones can satisfy the users' desire to be connected with other people. Permanent availability, however, also causes negative consequences. A body of work has investigated users' receptiveness to mobile devices (e.g. [45, 46, 49]) and the interruptions these devices cause (e.g. [33, 34, 38]). Mehrotra et al. [38] highlighted the disruptiveness of smartphone notifications. Similarly, Leiva et al. [34] concluded that incoming phone call interruptions add a significantly high overhead.

As a consequence, interactive systems face a non-trivial dilemma. On one hand, users expect ubiquitous connectivity and increased awareness. On the other, they expect to avoid unnecessary distractions. In a world where many recognize that computers have diverted our attention from other humans, fully engaging in human-to-human interactions is key. In our work, we attempt to aid design efforts that reverse the trend where smartphones may negatively affect social engagement and unnecessarily capture the attention of users away from the social environment e.g. through the creation of 'the mobile bubble' [36]. A recent trend in human-computer interaction (HCI) is to build technologies that bring people together and stimulate social interactions [27, 28]. In contrast, we look at eliminating hindrances to socializing that are already caused by technology. In particular, this paper addresses a fundamental challenge in limiting the social disruptiveness of mobile technologies. By understanding how to study which technologies are more disruptive than other solutions, designers can be empowered to build new interaction techniques that place less strain on conversations.

In this work, we contribute a mixed-method evaluation approach for assessing the disruptiveness of mobile interaction techniques. We postulate an approach that uses a conversation task for two participants. We employ eye tracking as a quantitative measure and combine it with qualitative evaluation based on semi-structured final interviews. In traditional coding techniques for face-to-face conversations used in past work [6, 17, 37], hour-long encoding of video and audio material is needed. In contrast, our work offers an alternative approach that highlights how the eye-tracking and interviews can offer complementary yet different insights. Our method is interestingly different from past approaches as it is designed to offer quick answers that result in actionable insight during a design process.

Further, we present an example study where we analyze the disruptiveness of two techniques to dismiss calls, namely the standard Android incoming call dialog and *SurfaceSliding*; a new method which allows the user to slide the phone on the table to decline a call. Using the rapid eye-tacking analysis, we found that users were indeed significantly objectively less distracted by the one dismiss technique. Further, the interviews revealed a set of factors which further help improve the design: (a) the need for empower users to fine-tune their interruption acceptance levels, (b) the impact of the social setting on interruption acceptance (c) the importance of exceptions and emergencies, and (d) the influence of group dynamics. The objective and subjective results together present a holistic perspective on user behavior and reasoning.

The contributions of this paper are three-fold: 1. a new mixed-method approach to study social disruptiveness of technology in conversational settings 2. an example study conducted using the proposed approach 3. an assessment of the suitability, advantages and limitations of our approach

RELATED WORK

This section presents previous research that has inspired our work and sets the setting for our inquiry. First, we highlight the recent trend in designing for collocated interactions and showcase the social goals that recent systems have addressed. Secondly, we look at how past research has evaluated interaction techniques that were to be used during conversations. Lastly, we reflect on previous work addressing the disruptiveness of technologies in a social context.

Collocated interactions

Designing interactions for settings where users are physically co-located and support social interactions through technology has received considerable attention in HCI. Lucéro et al. [35] explored how smartphones can support conversations and enable media sharing to enrich encounters for sitting around a table. They created the technical means to share photos easily during conversations. In a similar vein, Jarusriboonschai et al. [28] designed an application for icebreaking where users sitting in a group were prompted to interact with each other. Researchers have also designed systems to specifically address the content of the conversation. Wang et al. [57] delivered pictures during conversations to stimulate brainstorming. While these past works explored how conversations can be stimulated, we look into how already established conversational setting can be less negatively affected by technology.

Previous work also investigated approaches for delivering messages without causing unnecessary disruptions. Woźniak et al. [59] investigated how amateur runners can communicate with their supporters while participating in a race without losing immersion, using ambient light feedback and vibration. Similarly, Chen and Abouzied [9] explored how strangers could be informed about their shared interests without disrupting the typical interactions during an academic conference. Again, ambient light feedback was used. Alternatively, tools by Goyal et al. [19, 21] devised the notion of "implicit sharing": an automated way to share insights socially between collaborators, requiring minimal effort to share. Our work is inspired by these approaches as we look for ways to minimize disruption in social settings.

Another strain of work has explored how users could become more aware of each other's activities in social settings. Social Displays [29] used an additional display on the back of the device to engage other users. Pearson et al. [44] investigated how the smartwatch screen can be used to display notifications to others close by. Fischer et al. [15] investigated how groups develop strategies to handle notifications while engaged in collaborative activities. Paay and Kjeldskov [42] looked into augmenting public places to better support social activities. Finally, Fjeld et al. [16] proposed a vision where civic environments could be optimized for meaningful discussion. All of these systems call for building extensive technical support for social interactions, but they do not investigate the risk of disruption that technology may generate. We focus on methods for designing future systems that can be less disruptive while still providing useful communication features.

Evaluating in-conversation interactions

To our best knowledge, there is no standard method to measuring engagement in conversations in HCI. However, research in Psychology has built on the understanding of gaze in social interaction for a long time. Kendon [32] showed that gaze gives important visual feedback in conversation, both for the speaker and the listener. Based on this Vertegaal et al. [55] analysed gaze behavior during discussions of three persons. Kendon [32] as well as Vertegaal et al. [55] analyzed conversations of about 8 minutes. Vertegaal et al. [55] showed that listeners look significantly more at the person talking than at others, while the speaker looks at the addressed persons equally. Bednarik et al. [1] proposed using gaze to indicate the engagement in video conferences. Shell et al. [50] proposed observing users' gaze to determine the attention on a system, and thereby cause different actions.

Jokinen et al. [30] show that human behavior in a three-party dialogue can be studied with the help of eye tracking; however when studying behavior of humans in a larger groups videotaping is favored over eye tracking. Chattopadhyay et al. [7] used this technique to study the impact of a collaborative presentation platform on the presenter and the listeners, while Rico et al. [48] used only interviews to evaluate the social acceptability of gestures after performing them in the wild.

Already in 1980 Goodwin [17] presented work using a video coding method to analyze face-to-face conversations. He transcribed the conversation down to phrasal break, false starts, long pauses, and isolated ungrammatical fragments and further they enriched the transcript with the gaze direction of both parties. In recent related work, Brown et al. [6] studied the impact of search results and phones on conversations. Therefore, the authors recorded 24 hours of video material, in which one researcher flagged 205 clips with a length of one to two minutes for further analyses. These 205 videos have been coded and transcribed to understand the influence of phones in a face-to-face conversation. McMillan et al. [37] analysed the effect of smartwatch use. They conducted a study in which they recorded 168 hours of material. They coded clips in which a smartwatch was present and extracted instances to identify effects of using a smartwatch. These studies show the large effort that has been put into studying this space qualitatively. However, researchers like Okamoto et al. [41] has raised questions of the validity of these coding techniques. They identified a influence of the coding person on the results.

Our work offers an alternative approach as we pursue designing a blend of methods that would enable effective and efficient evaluation of how particular interaction techniques disrupt conversation. Further, contrary to past research, we look for a method that can be used within a user-centred interaction design process.

Disruptiveness in CSCW

Borst et al. [4] reviewed how an interruption disputs a task and found that users could be interrupted in a low-problem state and maintain the problem state. On the other hand, Chen and Vertegaal [8] focused on post-reduction of interruptions whenever the user's mental load was excessive. Hudson and Smith [25] discussed the fundamental trade-off between awareness and disruption. In their work, they highlighted that the trade-off is unavoidable and needs to be studied independently for usage scenarios. Tolmie et al. [53] investigated interruptions in game play. Their solution tries to make interruptions visible and available to further prevent them. Our work further explores the nature of interruptions but adopts a more practice-oriented focus, looking for ways to understand disruptiveness in the context of designing new mobile interaction techniques.

Trbovich and Harbluk [54] investigated the impact of cognitive distribution on driving behavior. They observed a change in driver visual behavior when using a speech-based interaction while driving. Bogunovich and Salvucci [3] investigated the direct effect of an interruption on the primary task. They found that the ringing duration in a phone ringing scenario had a significant impact on an email answering task. In contrast, Iqbal and Horvitz [26], in their analysis of a two-week study, found that desktop notifications created awareness but reduced task switching as explicit monitoring was not needed any more. Dabbish and Kraut [10] looked at awareness displays and social motivation for team members and showed that the timing of the interruptions by the awareness displays influences the performance. These works show that managing interruptions may play a crucial role in the success of a technical intervention in a social setting. Similarly in a social setting, Goyal [20] found that mobile interruptions by partners can prove dangerous towards collaborative data analytic challenges. The Author found that using acceleration of psycho-physiological sensors like GSR as a metric can help alleviate disruptions caused by such interruptions. This paper is inspired by the above findings and continues to help identify ways we can design for better interruption management by understanding the disruptiveness of different interaction techniques.

Su and Wang [51] observed phone usage in pubs over three years. They found that phones could help enhance conversations but also cause disruption. This was confirmed in a similar study by Porcheron et al. [47]. Similarly, Ofek et al. [40] investigated on how to effectively deliver information to interlocutors during a conversation. Their study revealed that delivering batches of visual information was the most effective. Newman and Smith [39] adopted a similar approach to study the influence of paper document and laptop usage in conversations. They concluded that providing assistance to keep the time short would help to cut time spent working on the laptop. Boyd et al. [5] developed SayWAT, a device that helped adults with autism to focus on face-to-face conversations. Moreover, Exposito el at. [14] proposed a system to reduce obtrusive note taking while collaborating remotely. They investigated selecting through eye tracking cues combined with foot-based gestures.

While the works cited above show that the CSCW and HCI fields have built an understanding of disruption caused by introducing new technologies, less progress has been made in terms of methods to assess disruptiveness. More importantly for our work, none of the proposed methods offer a flexible and actionable approach that can be used as part of a design process, in smaller-scale experiments and with low-fidelity prototypes.

RESEARCH DESIGN

In this section, we present the considerations and choices involved in creating our evaluation approach to assess the disruptive impact of mobile interruptions in conversation. We discuss the driving research questions and the alternatives that we considered while designing our approach.

Requirements for a new approach

As part of a larger project on designing novel ways to interact with mobile devices in social settings, we encountered a key issue early in our design process. Once we started developing early prototypes, we required ways to rapidly gather feedback from users and decide which ideas needed to be rejected early. However, we found it difficult to determine which of our prototypes were potentially disruptive to conversations. The method we required, needed to:

- allow for work with low-fidelity prototypes and Wizard-of-Oz studies;
- provide clear answers on which interaction techniques are best among a set;
- generate enough qualitative user feedback to play a generative role for later stages of the design process;
- be applicable for casual social environments.

As shown in our review of related work, CSCW and HCI literature did not present any viable solutions. In our search for methods, we later investigated other literature sources for inspiration. Disruption and interruption in conversations is studied in communication science and it is sometimes used to understand interaction between users and interactive artefacts. For example, Karsvall [31] used a dialogical approach to understand the team dynamics of operating theatres. While such an approach is well grounded and offers an in-depth look into the details of the social dynamic involved, the analysis requires an amount of time that is not manageable for an interaction design process. Further, conversation analysis may not yield results that could motivate decisions on which prototypes to choose.

Another field that has a history of studying interruptions is Human Factors and Ergonomics (HFE). Models of disruptions and interruptions are often used in HFE (e.g. Endsley and Jones [12]), so one could expect that suitable methods could be translated from HFE. This is not the case, however, for two reasons. First, most studies of disruptions focus on well-defined controlled tasks. Hodgetts and Jones [24] studied the impact of mobile notifications, which appears to be relevant for our inquiry. However, as appropriate in the HFE tradition, the notifications were studies while performing a highly artificial task (the Tower of London task). This limits the applicability of the methods used in HFE for application in an interaction design process. Secondly, and more fundamentally, the entire field of HFE focuses on non-discretionary use [22], which limits the validity of whatever possibly adaptable method when used in the context of casual social interactions.

Consequently, we opted for re-appropriating some of the methods used in the past in the HCI field and combining them into a new approach. This way, we could ensure a new mixed-method approach would be ecologically valid for social settings and potentially offer input to the design process.

Blending existing approaches

Faced with the challenge of designing a new approach to meet our needs, we decided to adopt a mixed-method approach. This was motivated by the need for a decision of which early prototypes were worth pursuing, and assuring that enough generative user feedback was produced. Our approach consists of a quantitative eye tracking metric, an in-depth semi-structured interview and a generic discussion task designed for strangers.

To qualitatively measure the disruptiveness a given interaction technique produces, we decided to augment the method used by Vertegaal et al. [55]. In this work, the authors show that gaze features are directly coupled to conversational attention. Specifically, they show that looking at one's interlocutor is a significant indicator that one is engaged in a conversation. In our approach, we use this property by investigating the differences in gaze directed towards the interlocutor. Based on the findings of Vertegaal et al. [55] we assume that participants direct a participant- and interlocutor-specific fraction of their gaze time to their interlocutor. Consequently, we investigate how different interaction techniques affect the time spent looking at the potentially disruptive technology and the interlocutor. From a technical perspective, the method requires employing two eye trackers as shown in Figure 1. As continuous timings are measured, data analysis is performed using fast and simple statistical methods such as analysis of variance.

While using quantitative eye tracking metrics can give clear answers about methods affect disruptiveness, the quantitative metrics are unlikely to stimulate further development in a design process. Thus, we decided to employ semi-structured interviews [7, 18], a staple method of interaction design, to assure that enough user feedback can be gathered to not only eliminate possible prototypes, but also stimulate the design of new solutions. In our approach, we use an entry interview to establish the participants' initial attitudes towards disruptions in conversations in technology. This is not only done to generate possible design inspiration, but also to ascertain whether participants find any disruptions acceptable. As shown later

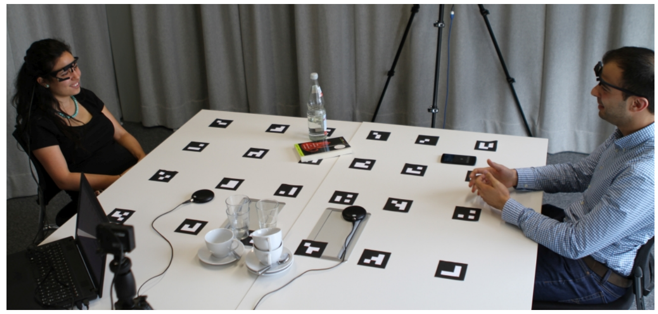


Figure 1. The study setup showing two participants in a conversation wearing mobile eye tracker.

in this paper, some users consider state-of-the-art technology-based disruptions offensive and they differentiate between the disruptiveness levels of different interaction techniques. A final interview is also performed to qualitatively assess the disruptiveness caused by a given technique. This also enables gathering suggestions for prototype improvement. Finally, we employ a simplified version of qualitative coding with affinity diagraming [23] for interview analysis as this offers a rapid way to analyze and understand the feedback provided by interviews. As our approach is not intended to build a structured understanding of disruption, we believe that a more advanced qualitative analysis method is not required.

Our proposed mixed-method approach combines quantitative eye tracking metrics and qualitative interview feedback. The eye tracking data allows determining which technique is less disruptive statistically. However, a better understanding of how the technologies influenced the conversation can only be gained from qualitative interviews. The interviews allow determining further design opportunities and identify drawbacks which lead to future design improvements and better interaction concepts.

Choice of participants and stimulus

As we endeavored to design an approach that would allow for rapid evaluation, we considered flexibility in terms of participant choice as a key feature. Participants are often hard to recruit, especially for studies early in the design process, when rapid feedback is needed. Our approach can be used with a wide variety of participants as it uses a generic conversation stimulus. Participants are grouped in pairs randomly. Further, the experimental design allows for large within-pair variability in eye tracking metrics and thus it does not put any restrictions on the participants' gender, age, race, native language etc. Previous work showed that gaze fixations are an effective way to evaluate two systems [2]. Moreover Okamoto et al. [41] showed eye movements are affected by conversations. Thus, when using eye tracking in conversations, this should be taken into account in the design. As a result measuring the time of eye contract or time spent looking for the conversation partner is not efficient as a disruption measurement. Therefore we propose time spent on the disruption as the measurement. Therefore, a between-groups design for the experiments is necessary as sequence effects are likely to appear when a conversation is prolonged.

We use a generic discussion task in our approach. We decided to use a task designed by language experts specifically for conversations between strangers with a particular focus on paying attention to the other party in the discussions. Consequently, we use the discussion task from the University of Cambridge's English for Speakers of Other Languages Certificate in Advanced English Speaking Test [13]. The task provides a stimulus that is both manageable for advanced non-native speakers and engaging enough for native speakers. The task also includes a shorter introductory segment that can be used as an icebreaker for the discussion. An additional advantage of using a speaking exam task is the fact that analogous tasks exist and can be easily found for other languages and, thus, our approach is not specific to English. Again, using such a task necessitates a between-groups design, as there is no possibility to assure that different discussion topics are equally stimulating to a given randomly assigned pair of participants.

Study plan

The final study procedure in our approach is shown in Figure 2. At the beginning of each study session, the facilitators conduct individual semi-structured interviews (Entry Interview, see Figure 2). The interview serves as a means of collecting demographic data on the participants. Further, it introduces the conversation task. The purpose of the study is not revealed to the participants until the end of the study. Informing the participants about the focus on mobile disruptiveness may cause potential bias due to increased awareness to interruptions. Thus only one participant will be introduced to the additional disruptive task. After the instruction and training phace, the participants are introduced to each other and start wearing the eye trackers. The facilitator then presents the experimental task. First, the participants run through a warm-up phase to get confident with their conversation afterward also the disruption is taking place to observe the participants reactions and potential behavior change. After the discussion is concluded (we recommend a time of 10 minutes, based on language examination experience [13]), individual debriefings (Final Interview, see Figure 2) are performed. All interviews are audio recorded. As a safety precaution, we also recommend video recording the conversation. After the study, eye tracking data is analysed using inferential significance testing and simplified qualitative analysis with affinity diagramming is performed on the interview data.

EXAMPLE STUDY

Next, we present a user study that illustrates a practical application of our approach implementing the proposed study plan. We contribute a standard study description here to showcase how our approach can be used effectively to provide a concise report if required. Our presented mixed-method approach allows analyzing any device or concept, which can potentially disrupt ongoing conversations. Ubiquitous mobile devices such as smartphones or smartwatches have high potential to cause disruption [49], and hence we present a scenario where a mobile phone causes disruption in a face-to-face conversation. In the example study, we compared two techniques to decline incoming calls.

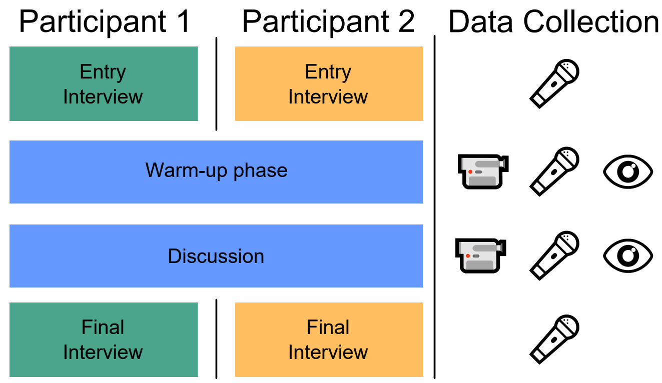


Figure 2. The study procedure in our new mixed-method approach. Data collection methods are: video, audio and eye tracking.

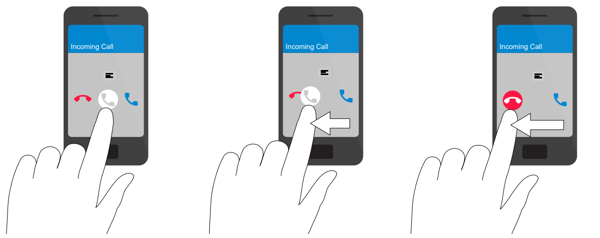
In particular, we investigate *SurfaceSliding*, a new method to decline incoming calls and compare it with the standard technique provided by the Android operating system. The interaction technique is mostly inspired by the work of Wiese et al. [58] who showed that users tend to have their phones lying on a table when at home or in the office. Work by Porcheron et al. [47] and Su and Wang [51] show that phones also play an important role in social settings, and highlights that phones in a pub setting are often positioned visibly on the table. We chose an incoming call scenario as a disruption example inspired by Bogunovich and Salvucci [3]. Declining a call is an action that requires attention, but the attention should be minimal. Thus, this task is a good candidate for designing for limiting disruptions. This has the advantage since all participants were equally familiar with the scenario and most likely have been in a similar scenario before. *SurfaceSliding*, an intermediate prototype in our process for building less disruptive mobile phone interactions, enables the user to decline a call by dragging the phone along the table (instead of dragging their finger over the touch screen).

Study design

The study had a between-groups design with a single independent variable, TECHNIQUE. In the *Touch* condition, the participant with the phone got a standard Android incoming call interface, the interaction is presented in Figure 3. In the *SurfaceSliding* condition, the phone was modified so that the participant could use *SurfaceSliding* to interact with it. The interaction technique is illustrated in Figure 4. Further, as only one participant needed to interact with the phone, we will refer to them as *HasPhone* and *NoPhone*.

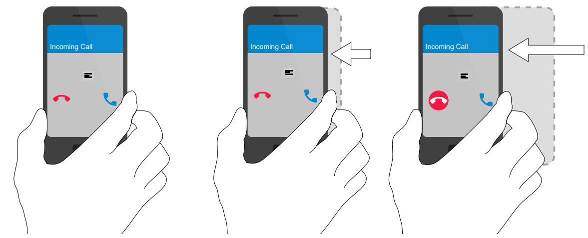
Apparatus

To investigate the effect of using *SurfaceSliding* for declining calls we integrated *SurfaceSliding* in the standard UI of Android v5.0. We implemented *SurfaceSliding* on a Nexus 5, in combination with the incoming call prototype, which had been modified to show an incoming call eight times within 10 *minutes* of discussion. However, the first two minutes of the conversation were left free of disruption to ensure a fluent discussion. After minute two, eight incoming calls were scheduled within every minute. Further, we made sure that two calls



(a) Touch Phase (b) Movement Phase (c) Selection Phase

Figure 3. Declining an incoming call selection phase using the standard touch interface. In the first step (a) the user taps the centre icon and then (b) moves it over to the decline symbol, finally (c) the release of the finger will trigger the highlighted action.



(a) Grasp Phase (b) Movement Phase (c) Selection Phase

Figure 4. Declining an incoming call using *SurfaceSliding*. In a first step (a) the user grasps the phone. Then the moves the phone in the direction of the decline symbol in respect to the center of the phone (b). After the movement (c) the decline call action is triggered.

were always at least 20 *sec* apart. The study was controlled by a separate laptop where it was possible to start the study or turn the phone into testing mode to show participants the declining methods. The phone was in silent mode the whole time, so ringtone and vibration were turned off. Further, the screen was black by default. The only indicator for an incoming call was the light when the phone displayed the incoming call. After declining a call, the screen turned black again.

We implemented a recognition algorithm which was able to detect moving the device in any direction on the table. For detecting the movement, we used the front facing camera combined with OpenCV's optical flow algorithm. Further, we used the phones' built-in sensors to make sure that the phone was not picked up from the table. The detection algorithm was fully implemented on the phone itself. To trigger the decline action the phone needed to be moved by 5 *cm* to the left.

We used two GoPro Hero 3+ and a Zoom H6 audio recorder with two table microphones to capture the content of the discussion. Further, we placed three coffee mugs, four glasses, one bottle and one book on the table to simulate a realistic discussion environment as would occur in an office or café scenario. A Zoom H1 audio recorder was used to record the second interview. Both conversation partners were equipped with PupilLabs mobile eye trackers to determine how long each participant looked at the phone. To be able to automatically detect where the participants were looking, we used table-mounted QR codes (see Figure 1) for establishing a reference coordinate. For both eye-tracking cameras, we used an IR camera with IR illumination (dark pupil tracking) recording with $640\,px \times 480\,px$ at $30\,fps$. The participant without a phone (*NoPhone*) had a world camera with a field of view (FoV) of 90° recording with $1920\,px \times 1080\,px$ at $30\,fps$. The other participant (*hasPhone*) had a world camera with a FoV of 100° diagonal recording with $1910\,px \times 1080\,px$ at $30\,fps$.

Task

To ensure that one participant did not know about the phone we invited the participants to a study with the title *Stress in Conversations*. We used 5 questions from the CAE speaking test by [13] for the conversation. We played the 5 questions from the exam DVD included with the book to provide the same stimulus for all participant pairs. The questions used were as follows: (1) "Here are some pictures showing different ways in which the computer affects our lives. First, talk to each other about how these pictures show the role of computers nowadays. Then decide which picture best reflects the difference computers have made to our lives." (2) "Some people say that computers are helping to create a generation without social skills. What's your opinion?" (3) "What are advantages and disadvantages of shopping by computer?" (4) "How far do you agree that computer is the greatest invention of modern times?" (5) "A lot of personal information about all of us is now kept on computers. Do you find this worrying?"

Procedure

The participants were guided through the whole study by two researchers. When both participants arrived at our study room, one researcher asked the first participant to enter the room while the second stayed outside to interview the two participants independently. Entry interviews were then performed, during which the participants filled in a consent form and a demographics questionnaire.

The participant who arrived first was always the participant interacting with the phone (*HasPhone*). Therefore *HasPhone* was asked to enter the study room first while the other participant (*NoPhone*) was interviewed in front of the study room. We first interviewed *HasPhone*. We then handed the phone to *HasPhone* and told them that they had to interact with the phone during the study. However, we also told them that the other participant was unaware that a phone would be involved in the study. We then showed how declining a call worked using the test mode of the app. We let them try and familiarize with the interaction techniques until they were comfortable declining calls. After the trial phase, we then set the phone to study mode where the screen turned black and was waiting for simulated incoming calls. After the introduction phase, we invited the *NoPhone* participant into the study room.

Then, we asked them to put on the eye-trackers and started the calibration process; starting all recoding, video, audio, and eye-tracking. Then we played back the discussion instructions from CAE [13]. We used the first instruction as an icebreaker to start the conversation. The first instruction came with images to help the discussion develop. The question was discussed for about 2 minutes, then we presented the second question followed by more questions if needed. When presenting the second question, we removed the images from the table. This was when the data recording that was later analyzed started. Whenever the discussion was less active, the facilitator asked an additional question from the task sheet.

After the discussion phase, participants were interviewed individually. First, we asked them about the overall outcome of the discussion to reflect on the discussion. Followed by questions about their personal discussion behavior. We then inquired whether they noticed the presence of the phone and whether it affected discussion. We then asked whether the declining of the phone call was appropriate. The *HasPhone* participants were asked how they felt on two levels: how it felt to observe the phone and what was the experience of declining the call.

Finally, both participants were asked how they dealt with and where they stored their phone in the following four situations: 1. in a private face-to-face conversation, 2. in a private group conversation 3. face-to-face in a business situation and 4. in a business group setting. We wrapped up the interview with an open question for additional comments

Participants
We recruited 24 participants (17 female) through our university's mailing list. The participants were aged from 19 to 33 years (M = 24.9, SD = 3.9). All of them had either no visual impairment or corrected to normal vision by wearing contact lenses. Three of the pairs had known each other beforehand. We reimbursed the participants with 10 EUR.

EXAMPLE STUDY RESULTS
In this section, we present the results of our example study in which we compared a standard decline a call technique against *SurfaceSliding*. We show how engaging users in a conversation task allowed us to statistically determine which interaction technique was less disruptive and how the interview results allow us identified possible future design improvements.

Eye tracking data
Due to technical problems of the eye tracking software, we excluded two groups from the eye tracking analysis. We first used the built-in QR code plug-in of the eye tracker to recognize where the participants looked. However, in contrast to pre-study results, the eye tracking accuracy was insufficient, most likely due to participant not sitting fully upright. Therefore, we manually labeled the remaining 20 eye tracking videos. For further analysis we treated participants independently from each other by using a new variable *HasPhone* with two levels — either the participant had the phone or not. The results of how long the participants looked on average at the phone is presented in Figure 5. On average, participants spent $M = 22.5\ s$, $SD = 21.8$ with looking at the phone. Participants in the *Touch–Phone* condition looked at the phone for the longest period of time, $M = 48.1\ s$, $SD = 23.7$. Those in the *SurfaceSliding–NoPhone* condition exhibited the shortest time looking at the phone, $M = 8.6\ s$, $SD = 8.6$. A two-way analysis of variance (ANOVA) revealed a statistically significant difference between the *Phone* and the *NoPhone* conditions $F_{1,16} = 10.587$, $p = .005$. We also found a significant difference between the *Touch* and the *SurfaceSliding* conditions $F_{1,16} = 4.623$, $p = .047$. We found no significant interaction effect ($p = .139$).

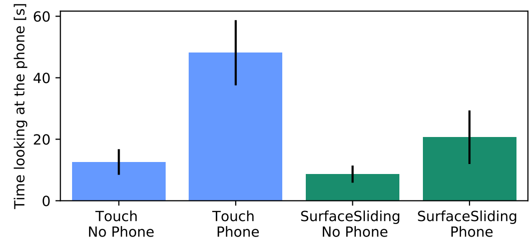


Figure 5. The average values and standard error for TECHNIQUE × PHONE.

Qualitative data
Interview recordings were transcribed for analysis, the total recording time was 4.31 h. We conducted initial filtering with two researchers to only leave data about in-conversation interactions. Next, three researchers coded 15% of the material to establish an initial coding tree. A single researcher coded the rest of the data. Once the initial coding was finished, we used affinity diagramming with printed quotes to establish higher-level themes through constant comparison. We labeled quotes of the participants with group name, the condition, (S) for *SurfaceSlding* or (T) for the *Touch* condition, and a *P* if they had a phone or *NP* if they had no phone. We first present general comments about the technique studied and then discuss the themes of disruption by technology in conversation.

General feedback
As our participants were unaware that we were interested in studying phone interactions, we asked how their conversation was influenced by the incoming calls. Independent of TECHNIQUE, none of the participants without a phone realized that the phone was part of the study. Two participants did not acknowledge the presence of a device on the table until we asked them explicitly (*5–S–NP* and *12–T–NP*). One participant believed that the other person was checking the time on the phone *(1–T–NP)*. All others expressed their awareness of the interruption quite vividly:

'(My discussion partner) has repeatedly interrupted (the conversation). (2–S–NP)'

Most of the negative statements concerned the lack of familiarity with the method:

'I'd rather not use (SurfaceSliding), but this may be entirely due to my current habits. (12–T–P)'

On the other hand, users reflected that the method was easy to use, even without attributing visual attention to the phone:

'(With SurfaceSliding) rejecting calls was easy, also without looking [at the phone]. (5–S–P)'

Another user noted that *SurfaceSliding* did not have a negative influence on the conversation:

'(SurfaceSliding) is clearly unobtrusive. (11–S–P)'

Four participants provided additional suggestions on how to improve declining incoming calls. Users suggested that one should always slide away from the body to decline calls, irrespective of the location of the phone or the hand used. A left-handed participant suggested:

'(The system) should account for right- and left-handed people. (3–S–P)'

Further, by analyzing the recorded videos, we can conclude that none of the participants tried to pick up the phone from the table; even those who had the *Touch* condition and had not been instructed to keep the phone on the table. It is notable that all calls were successfully declined.

Levels of phone acceptance in conversation

When asked about the role that smartphones may play in conversations, the participants reported many different stances. Our analysis showed two equally large groups of users. The first group was strict about eliminating any phone interaction from the conversation. They believed a smartphone was only an unnecessary distractor. One participant remarked:

'Irrespective of the situation, if one wants to participate in a discussion, the phone belongs in the pocket. (8–T–NP)'

The second group expressed that the acceptance of a smartphone in a conversation was highly dependent on the context of the interaction. These participants mentioned that the topic and the people present highly affected what was acceptable. They also believed that the acceptability depended on how the interactions were handled:

'It's only okay when the calls are rejected and the influence on the conversation is as small as possible. (9–S–P)'

We observed that some of the participants were happy to accept a phone placed on the table during conversation, especially in more casual settings. The position of the phone on the table also appeared to be important

'In a meeting, (it's okay to put it) on the table, but a bit on the side. (7–S–P)'

Private and professional settings

Most users expressed that different acceptance levels were valid for professional and casual settings. Many recommended ways where suggested to handle incoming calls specifically in a business environment. Participants expressed that while users are often expected to be aware of the state of their smartphone, they should not interact with it during meetings:

'In business meetings, the phone can lay on the table, but it should not be used. (8–T–NP)'

In contrast, users showed more flexible attitudes when interacting with groups of friends or family members. Attitudes ranged from simply being more lenient towards interruptions to not perceiving the presence of a phone as a factor influencing the conversation:

'(When talking to) friends, the phone is always on the table, but not in the case of family. (7–S–P)'

'[...] with friends, the phone can always be in your hand. (11–S–P)'

Notably, participants were stricter in home environments where they saw no need to pay attention to their phone when having family conversations.

Handling interruptions, exceptions and emergencies

Users commented extensively on situations where exceptions are possible and smartphone use during conversation may be acceptable. They suggested a number of cultural codes that could be used in special circumstances, including placing the phone on the table as an indicator that one is expecting a call:

'When you have company, [put the phone] on mute in your pocket. On the table is acceptable when expecting extremely important calls. (3–S–P)'

Interrupting conversation was perceived as highly problematic, even in exceptional situations:

'When one picks up, one should apologize immediately. (12–T–NP)'

Moreover, participants indicated that one should verify if the call is important for a possible interruption to be acceptable.

'There are things that are important and need to be dealt with immediately... work, family stuff. (9–S–P)'

Influence on group dynamics

Our participants reported that the composition of the conversation group and its size highly influenced the handling of possible interruptions. Conversations involving only two participants, as the one explored in our study, were considered most sensitive to interruptions and prompted immediate reactions:

'It was very impolite when the conversation partner looked at the phone. I wanted to say something. (5–S–P)'

Larger groups seemed to offer more leeway in interacting with a phone. One participant commented on how a bigger group enabled a limited amount of interruption:

'It's also not okay in a group, but a bit more okay (than in a one-to-one conversation). (9–S–NP)'

Finally, users saw putting one's phone away as a sign of appreciating the other parties in the conversation and deeming the social activity interesting:

'If one's having a good conversation, the phone should be put away entirely. (9–S–P)'

LESSONS LEARNT FROM THE EXAMPLE STUDY

We investigated whether *SurfaceSliding* was less intrusive and how can the design improved in the future. The presented findings will help to improve *SurfaceSliding* as well as designers to build less disruptive ubiquitous systems. As we discuss the quantitative eye-tracking data showed a reduced disruption when using *SurfaceSliding*. The qualitative results discussed highlights for further improvements. Furthermore, the lessons learned to rise the discussion about the social acceptability of disruptions through technologies, in general.

Around device interaction

The eye tracking data indicates that users paid significantly more attention to their interlocutors when using *SurfaceSliding*. Therefore, we can conclude that our technique provides an effective and non-interrupting way to decline calls in-conversation. In the light of the analysis by Vertegaal et al. [55], it can be inferred that users in the *SurfaceSliding* condition were more engaged in the conversations than the users using the current default method. This fact suggests that design space for creating new non-disruptive techniques for managing attention should be explored further. *SurfaceSliding* provides a working example of how in-conversation interruptions can be effectively reduced. The fact that none of the users grabbed the phone in their hand during the study suggests that they were comfortable with interacting with the device while it was lying on table. This confirms previous work on spatial interaction pattern for on-surface mobile devices [59]. While past work has shown that sliding mobile devices on surfaces can be effective for complex task and long interaction periods, *SurfaceSliding* illustrates that moving along a horizontal surface can also be effective for short, atomic tasks.

Addressing complete designs

As it surfaced in the interviews, the users expected they would be able to choose the direction of the sliding. We recognize that this improvement may render our technique more effective. However, this require extensive sensing of the user's body position or an explicit set-up phase before using *SurfaceSliding*. Further, users may confuse directions, which increase error rates. These facts showcase that a more explorative approach not limited to two techniques may have generated more feedback. However, that providing the participants with an experience of declining the call, irrespective of the details of the technique, triggered valuable on-the-spot feedback.

Strict users

We observed that there is a user group strictly opposed to phones entering conversations. These users find placing the phone on the table unacceptable and answering calls during conversation is offensive to them. We believe that future systems should offer more support for this user group. For instance, a user should conveniently be able to inform other participants in the conversation that they do not wish that phone to be part of the experience. This could be achieved by a setting in the user's device that is communicated to other devices. Furthermore, that specific user group requires an easy means to deactivate phone output during a conversation. If future mobile devices are able to sense conversations, this user group would require all disturbing features to be deactivated. Overall, future mobile devices should provide users with effective means to both deactivate disturbing features in their phones and inform other users that they do not wish to be disturbed. However, as the strict users only represent part of the user base future systems will also need to provide opportunities to negotiate behaviors, especially in intercultural settings. Our approach, however, is not suited to designing with and for those users.

Emergency cases

Nearly all of the participants in our study reflected that, despite their wish to limit interruptions, designs should account for emergency cases. Users noted that there were exceptions where interruptions were acceptable. If future systems are to offer better management of in-conversation interruptions, they must incorporate the means to prioritize emergency. While current systems do include some means to deal with emergencies (e.g. in iOS, the do not disturb mode can be deactivated when the users receive repeated calls), more extensive features are required. Again, our study participants reflected that determining what constituted an emergency was highly dependent on the context. For instance, while on holiday, calls from work are likely to be emergencies, and a mid-day call from the school may require the immediate attention of the parent. Designers of future mobile devices should help users define possible emergencies and use context sensing efficiently to ensure interruptions are efficient exceptional circumstances.

Accounting for changing context

We noticed that our participants often remarked that the decision on whether attending to an event or information was worth interrupting a conversation depended on many factors. In a way, deciding whether to answer a call or message during a conversation is an economic decision. There is a certain social cost associated with answering the call, which is dependent on the context of the conversation. There is also the social cost of possibly ignoring an important call or missing a social interaction. Each time the user decides to accept or decline, they make a conscious decision, yet current mobile devices only offer the identity of the caller as a potential aid in making an informed choice. Further, participants reported that they not only consider who is calling them when deciding whether to answer the call; they also considered the context of the conversation and the possible purpose of the incoming call. There is an emergent need for mobile devices to adapt to the richer context. Our approach uses static measures that require stationary equipment and thus it is not particularly suited for studying how disruptiveness is affected by change of usage context. We recognise that the majority of the participants in our study expressed that their acceptance of interruptions varied depending on the context of usage. The composition of the conversational group or the purpose of the conversation affected the level of interruption that was deemed acceptable. While our approach allows the experimenter to freely introduce a context, the static setting of the discussion task renders switching social contexts difficult.

ADVANTAGES OF THE MIXED-METHOD APPROACH

Participants interpreted the phone as an unnecessary distraction to the conversation, showing the dilemma of notifications caused by technologies in general. However, today's smart device users rely on notifications. Conducting the example study enables us to reflect on the properties of our mixed-method approach. In the following, we discuss the applicability of our mixed-method approach for new technologies and new interaction techniques. We further discuss how eye tracking enables a rapid decision on which technology is less disruptive while the interviews complement the choice of technology and point out further improvements.

Rapid answers

Our example study showed a clear result in terms of which studied interaction technique was superior. The eye tracking data showed a significant effect which strongly indicated that *SurfaceSliding* causes less disruption than the baseline technique. This shows that our approach is well suited to fit in a design process. The fast quantitative analysis can be used for quick A/B testing during design sprints for rapid evaluation of interaction techniques. This is in contrast to past approaches such as conversation analysis. Once a superior technique is determined, designers can use the qualitative feedback to stimulate further refinements to the interaction technique. A study that offers meaningful feedback can be conducted and analyzed within a day for a number of participants.

Focused, on-the-spot feedback

The conducted example study showed that our approach managed to trigger extensive reactions in the participants. We believe that contextualizing the interview questions enabled the participants to reflect extensively on the disruptiveness caused by interruption techniques. The discussion task served as a kind of priming before the final interviews. We theorize that the extensive material we obtained was partly provoked by the direct experience of being engaged in a discussion. We believe that the fact that participants are interviewed directly after a discussion facilitates focusing specifically on the disruption caused by the technology and imagine how the discussion could be shaped had the technology been different. As only one of each pair of participants is tasked with using the phone, designers are able to obtain a first-hand account of how one attempts to limit the disruption caused to the interlocutor while using a particular interaction technique. This contributes to building the ecological validity of our method.

Designing with the social context in mind

It is worth noting that some users in our study were willing to sacrifice some degree of their social engagement for better awareness of the events communicated through their phone. For instance, more interruptions can be acceptable in a personal conversation when one intends to be informed about the current score in an important football match. Such situations produce opportunities for designers to intervene and create tools for personalized interruption rules, which could act like the mobile version of an email filter. While we used a neutral discussion task without any distractions, our approach easily enables modifying the context of the disruption. One can alter the pre-study briefings provided to the user or introduce additional distractors in the study room. Further, we recognize that while we suggest a quick qualitative analysis and subsequent iteration, our approach can potentially offer deeper insights if more detailed analysis is performed.

Potential for a generative role

As the users in our study are engaged directly in a discussion, the reactions triggered by the prototypes studied can be reflected upon immediately. In the final interview, participants can directly reflect on particular disruption caused by particular actions. In later stages of the design process, such accounts enable designers to understand the details of the disruptiveness caused by the prototype and stimulate users to provide generative feedback. As the participants can easily recall the discussion task, our approach facilitates discussing alternative techniques or usage contexts. Further, for techniques that require bodily movements (such as the one in our example study) the direct engagement with the mobile device makes users more likely to imagine real-life scenarios. Past work has shown that direct physical engagement with low-fidelity prototypes in social contexts can be particularly beneficial in a design process [52]. Thus, we believe our method can be applied to a variety of design contexts and constitute a rapid and versatile formative evaluation tool.

LIMITATIONS OF THE MIXED-METHOD APPROACH

We also recognize that the new technologies which are studied by the researchers may effect the participant's behavior. In our example study, modifying the user's smartphones would have rendered the study technically unfeasible. Furthermore, as our study investigates a new interaction technique, using multiple smartphone models may play a role in the social acceptance in interactions. However, using one model guaranteed consistency between the studied groups. Furthermore, the required measurement infrastructure in the study setup itself might influence the participant's behavior. In future work, the influence of wearing an eye tracker and the surrounding infrastructure should be analyzed.

The proposed mixed-method approach is designed to evaluate the distinctiveness in social settings. In detail, we focus on two-people, face-to-face discussions. We believe that the proposed method is also applicable for social settings involving more persons. However, applying our mixed-method approach to a setting with more people needs to be investigated first.

CONCLUSION

This paper contributes a new mixed-method approach to measuring the disruptiveness of technology. Our new approach uses eye tracking and semi-structured interviews in a generic conversation task to offer rapid, actionable insights for designing interaction techniques that may be used in conversations.

We presented an example study where we investigated techniques for declining calls in a face-to-face conversation. We were able to revisit the conversation and draw conclusions from the participants' behavior using video and audio recordings. Using our approach enabled us to understand the impact of a new interaction technique on disruptiveness. Eye tracking revealed a significant drop in time spent looking on the phone when using the new technique. Interviews provided evidence for underlining social mechanics that affect disruptions.

Designing techniques beyond existing ones to study the influence of different interaction mechanisms on conversational engagement remains an important challenge. We are eager to see how future designs will explore the design space that we merely begin to understand.

As we recognize that our study is constrained by the fact that it was conducted in a lab setting, we hope that using our approach will be complemented by other studies that use alternative methods such as in-the-wild deployments of new interaction techniques. We also believe that an ethnographic study of the social acceptability of smartphone interruptions in public settings such as cafés or libraries will produce interesting insights for design. We hope that our work will inspire further developments and the creation of enhanced evaluation methods for future interaction techniques.

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REFERENCES

1. Roman Bednarik, Shahram Eivazi, and Michal Hradis. 2012. Gaze and Conversational Engagement in Multiparty Video Conversation: An Annotation Scheme and Classification of High and Low Levels of Engagement. In *Proceedings of the 4th Workshop on Eye Gaze in Intelligent Human Machine Interaction (Gaze-In '12)*. ACM, New York, NY, USA, Article 10, 6 pages. DOI:http://dx.doi.org/10.1145/2401836.2401846

2. Sven Bertel, Thomas Dressel, Tom Kohlberg, and Vanessa von Jan. 2017. Spatial Knowledge Acquired from Pedestrian Urban Navigation Systems. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '17)*. ACM, New York, NY, USA, Article 32, 6 pages. DOI: http://dx.doi.org/10.1145/3098279.3098543

3. Peter Bogunovich and Dario Salvucci. 2011. The Effects of Time Constraints on User Behavior for Deferrable Interruptions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. ACM, New York, NY, USA, 3123–3126. DOI: http://dx.doi.org/10.1145/1978942.1979404

4. Jelmer P. Borst, Niels A. Taatgen, and Hedderik van Rijn. 2015. What Makes Interruptions Disruptive?: A Process-Model Account of the Effects of the Problem State Bottleneck on Task Interruption and Resumption. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 2971–2980. DOI: http://dx.doi.org/10.1145/2702123.2702156

5. LouAnne E. Boyd, Alejandro Rangel, Helen Tomimbang, Andrea Conejo-Toledo, Kanika Patel, Monica Tentori, and Gillian R. Hayes. 2016. SayWAT: Augmenting Face-to-Face Conversations for Adults with Autism. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 4872–4883. DOI: http://dx.doi.org/10.1145/2858036.2858215

6. Barry Brown, Moira McGregor, and Donald McMillan. 2015. Searchable Objects: Search in Everyday Conversation. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing (CSCW '15)*. ACM, New York, NY, USA, 508–517. DOI: http://dx.doi.org/10.1145/2675133.2675206

7. Debaleena Chattopadhyay, Kenton O'Hara, Sean Rintel, and Roman Rädle. 2016. Office Social: Presentation Interactivity for Nearby Devices. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 2487–2491. DOI: http://dx.doi.org/10.1145/2858036.2858337

8. Daniel Chen and Roel Vertegaal. 2004. Using Mental Load for Managing Interruptions in Physiologically Attentive User Interfaces. In *CHI '04 Extended Abstracts on Human Factors in Computing Systems (CHI EA '04)*. ACM, New York, NY, USA, 1513–1516. DOI: http://dx.doi.org/10.1145/985921.986103

9. Jay Chen and Azza Abouzied. 2016. One LED is Enough: Catalyzing Face-to-face Interactions at Conferences with a Gentle Nudge. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing (CSCW '16)*. ACM, New York, NY, USA, 172–183. DOI: http://dx.doi.org/10.1145/2818048.2819969

10. Laura Dabbish and Robert E. Kraut. 2004. Controlling Interruptions: Awareness Displays and Social Motivation for Coordination. In *Proceedings of the 2004 ACM Conference on Computer Supported Cooperative Work (CSCW '04)*. ACM, New York, NY, USA, 182–191. DOI: http://dx.doi.org/10.1145/1031607.1031638

11. Anind K. Dey, Katarzyna Wac, Denzil Ferreira, Kevin Tassini, Jin-Hyuk Hong, and Julian Ramos. 2011. Getting Closer: An Empirical Investigation of the Proximity of User to Their Smart Phones. In *Proceedings of the 13th International Conference on Ubiquitous Computing (UbiComp '11)*. ACM, New York, NY, USA, 163–172. DOI:http://dx.doi.org/10.1145/2030112.2030135

12. Mica R. Endsley and Debra G. Jones. 2001. Disruptions, Interruptions and Information Attack: Impact on Situation Awareness and Decision Making. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 45, 2 (2001), 63–67. DOI: http://dx.doi.org/10.1177/154193120104500214

13. Cambridge ESOL. 2008. *Speaking Test Preparation Pack for CAE Paperback with DVD*. Cambridge University Press.

14. Marc Exposito, Vicky Zeamer, and Pattie Maes. 2017. Unobtrusive Note Taking: Enriching Digital Interpersonal Interactions Using Gestures. In *Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing (CSCW '17 Companion)*. ACM, New York, NY, USA, 167–170. DOI:http://dx.doi.org/10.1145/3022198.3026319

15. Joel E. Fischer, Stuart Reeves, Stuart Moran, Chris Greenhalgh, Steve Benford, and Stefan Rennick-Egglestone. 2013. Understanding Mobile Notification Management in Collocated Groups. In *Proceedings of the 13th European Conference on Computer Supported Cooperative Work (ECSCW 2013)*. Springer London, London, 21–44. DOI: http://dx.doi.org/10.1007/978-1-4471-5346-7_2

16. Morten Fjeld, Paweł Woźniak, Josh Cowls, and Bonnie Nardi. 2015. Ad hoc encounters with big data: Engaging citizens in conversations around tabletops. *First Monday* 20, 2 (2015). DOI: http://dx.doi.org/10.5210/fm.v20i2.5611

17. Charles Goodwin. 1980. Restarts, Pauses, and the Achievement of a State of Mutual Gaze at Turn-Beginning. *Sociological Inquiry* 50, 3-4 (1980),

272–302. DOI:**http://dx.doi.org/10.1111/j.1475-682X.1980.tb00023.x**

18. Nanna Gorm and Irina Shklovski. 2017. Participant Driven Photo Elicitation for Understanding Activity Tracking: Benefits and Limitations. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing (CSCW '17)*. ACM, New York, NY, USA, 1350–1361. DOI: **http://dx.doi.org/10.1145/2998181.2998214**

19. Nitesh Goyal and Susan R. Fussell. 2016. Effects of Sensemaking Translucence on Distributed Collaborative Analysis. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing (CSCW '16)*. ACM, New York, NY, USA, 288–302. DOI: **http://dx.doi.org/10.1145/2818048.2820071**

20. Nitesh Goyal and Susan R. Fussell. 2017. Intelligent Interruption Management using Galvanic Skin Response based Physiological Sensor for Collaborative Sensemaking. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 1, 3 (Sept. 2017).

21. Nitesh Goyal, Gilly Leshed, Dan Cosley, and Susan R. Fussell. 2014. Effects of Implicit Sharing in Collaborative Analysis. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 129–138. DOI: **http://dx.doi.org/10.1145/2556288.2557229**

22. Jonathan Grudin. 2017. From Tool to Partner: The Evolution of Human-Computer Interaction. *Synthesis Lectures on Human-Centered Interaction* 10, 1 (2017), i–183. DOI:**http://dx.doi.org/10.2200/S00745ED1V01Y201612HCI035**

23. Gunnar Harboe and Elaine M. Huang. 2015. Real-World Affinity Diagramming Practices: Bridging the Paper-Digital Gap. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 95–104. DOI:**http://dx.doi.org/10.1145/2702123.2702561**

24. Helen M. Hodgetts and Dylan M. Jones. 2003. Interruptions in the Tower of London Task: Can Preparation Minimise Disruption? *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 47, 8 (2003), 1000–1004. DOI: **http://dx.doi.org/10.1177/154193120304700810**

25. Scott E. Hudson and Ian Smith. 1996. Techniques for Addressing Fundamental Privacy and Disruption Tradeoffs in Awareness Support Systems. In *Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work (CSCW '96)*. ACM, New York, NY, USA, 248–257. DOI: **http://dx.doi.org/10.1145/240080.240295**

26. Shamsi T. Iqbal and Eric Horvitz. 2010. Notifications and Awareness: A Field Study of Alert Usage and Preferences. In *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work (CSCW '10)*. ACM, New York, NY, USA, 27–30. DOI: **http://dx.doi.org/10.1145/1718918.1718926**

27. Pradthana Jarusriboonchai, Sus Lundgren, Thomas Olsson, Joel Fischer, Nemanja Memarovic, Stuart Reeves, PawełWoźniak, and Olof Torgersson. 2014. Personal or Social?: Designing Mobile Interactions for Co-located Interaction. In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational (NordiCHI '14)*. ACM, New York, NY, USA, 829–832. DOI: **http://dx.doi.org/10.1145/2639189.2654840**

28. Pradthana Jarusriboonchai, Aris Malapaschas, and Thomas Olsson. 2016a. Design and Evaluation of a Multi-Player Mobile Game for Icebreaking Activity. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 4366–4377. DOI: **http://dx.doi.org/10.1145/2858036.2858298**

29. Pradthana Jarusriboonchai, Aris Malapaschas, Thomas Olsson, and Kaisa Väänänen. 2016b. Increasing Collocated People's Awareness of the Mobile User's Activities: A Field Trial of Social Displays. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing (CSCW '16)*. ACM, New York, NY, USA, 1691–1702. DOI: **http://dx.doi.org/10.1145/2818048.2819990**

30. Kristiina Jokinen, Hirohisa Furukawa, Masafumi Nishida, and Seiichi Yamamoto. 2013. Gaze and Turn-taking Behavior in Casual Conversational Interactions. *ACM Trans. Interact. Intell. Syst.* 3, 2, Article 12 (Aug. 2013), 30 pages. DOI: **http://dx.doi.org/10.1145/2499474.2499481**

31. Arvid Karsvall. 2011. *Intercreativity in Surgical Practice : A Dialogical Approach to Interaction & Technology*. Ph.D. Dissertation. Linköping University, The Tema Institute, Faculty of Arts and Sciences.

32. Adam Kendon. 1967. Some functions of gaze-direction in social interaction. *Acta Psychologica* 26 (1967), 22–63. DOI: **http://dx.doi.org/10.1016/0001-6918(67)90005-4**

33. Kostadin Kushlev, Jason Proulx, and Elizabeth W. Dunn. 2016. "Silence Your Phones": Smartphone Notifications Increase Inattention and Hyperactivity Symptoms. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 1011–1020. DOI: **http://dx.doi.org/10.1145/2858036.2858359**

34. Luis Leiva, Matthias Böhmer, Sven Gehring, and Antonio Krüger. 2012. Back to the App: The Costs of Mobile Application Interruptions. In *Proceedings of the 14th International Conference on Human-computer Interaction with Mobile Devices and Services (MobileHCI '12)*. ACM, New York, NY, USA, 291–294. DOI:**http://dx.doi.org/10.1145/2371574.2371617**

35. Andrés Lucero, Jussi Holopainen, and Tero Jokela. 2011. Pass-them-around: Collaborative Use of Mobile Phones for Photo Sharing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. ACM, New York, NY, USA, 1787–1796. DOI: http://dx.doi.org/10.1145/1978942.1979201

36. Sus Lundgren and Olof Torgersson. 2013. Bursting the Mobile Bubble. In *First International Workshop on Designing Mobile Face-to-Face Group Interactions, European Conference on Computer Supported Cooperative Work, ECSCW*.

37. Donald McMillan, Barry Brown, Airi Lampinen, Moira McGregor, Eve Hoggan, and Stefania Pizza. 2017. Situating Wearables: Smartwatch Use in Context. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*. ACM, New York, NY, USA, 3582–3594. DOI: http://dx.doi.org/10.1145/3025453.3025993

38. Abhinav Mehrotra, Veljko Pejovic, Jo Vermeulen, Robert Hendley, and Mirco Musolesi. 2016. My Phone and Me: Understanding People's Receptivity to Mobile Notifications. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 1021–1032. DOI: http://dx.doi.org/10.1145/2858036.2858566

39. William Newman and Ethan L. Smith. 2006. Disruption of Meetings by Laptop Use: Is There a 10-second Solution?. In *CHI '06 Extended Abstracts on Human Factors in Computing Systems (CHI EA '06)*. ACM, New York, NY, USA, 1145–1150. DOI: http://dx.doi.org/10.1145/1125451.1125667

40. Eyal Ofek, Shamsi T. Iqbal, and Karin Strauss. 2013. Reducing Disruption from Subtle Information Delivery During a Conversation: Mode and Bandwidth Investigation. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)*. ACM, New York, NY, USA, 3111–3120. DOI: http://dx.doi.org/10.1145/2470654.2466425

41. Dina G Okamoto, Lisa Slattery Rashotte, and Lynn Smith-Lovin. 2002. Measuring interruption: Syntactic and contextual methods of coding conversation. *Social Psychology Quarterly* 65, 1 (2002), 38–55.

42. Jeni Paay and Jesper Kjeldskov. 2008. Understanding Situated Social Interactions: A Case Study of Public Places in the City. *Computer Supported Cooperative Work* 17, 2 (2008), 275–290. DOI: http://dx.doi.org/10.1007/s10606-007-9072-1

43. Shwetak N. Patel, Julie A. Kientz, Gillian R. Hayes, Sooraj Bhat, and Gregory D. Abowd. 2006. *Farther Than You May Think: An Empirical Investigation of the Proximity of Users to Their Mobile Phones*. Springer Berlin Heidelberg, Berlin, Heidelberg, 123–140. DOI: http://dx.doi.org/10.1007/11853565_8

44. Jennifer Pearson, Simon Robinson, and Matt Jones. 2015. It's About Time: Smartwatches As Public Displays. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 1257–1266. DOI: http://dx.doi.org/10.1145/2702123.2702247

45. Martin Pielot. 2014. Large-scale Evaluation of Call-availability Prediction. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '14)*. ACM, New York, NY, USA, 933–937. DOI: http://dx.doi.org/10.1145/2632048.2632060

46. Martin Pielot, Karen Church, and Rodrigo de Oliveira. 2014. An In-situ Study of Mobile Phone Notifications. In *Proceedings of the 16th International Conference on Human-computer Interaction with Mobile Devices & Services (MobileHCI '14)*. ACM, New York, NY, USA, 233–242. DOI: http://dx.doi.org/10.1145/2628363.2628364

47. Martin Porcheron, Joel E. Fischer, and Sarah Sharples. 2016. Using Mobile Phones in Pub Talk. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing (CSCW '16)*. ACM, New York, NY, USA, 1649–1661. DOI: http://dx.doi.org/10.1145/2818048.2820014

48. Julie Rico and Stephen Brewster. 2010. Usable Gestures for Mobile Interfaces: Evaluating Social Acceptability. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10)*. ACM, New York, NY, USA, 887–896. DOI: http://dx.doi.org/10.1145/1753326.1753458

49. Alireza Sahami Shirazi, Niels Henze, Tilman Dingler, Martin Pielot, Dominik Weber, and Albrecht Schmidt. 2014. Large-scale Assessment of Mobile Notifications. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 3055–3064. DOI: http://dx.doi.org/10.1145/2556288.2557189

50. Jeffrey S. Shell, Roel Vertegaal, and Alexander W. Skaburskis. 2003. EyePliances: Attention-seeking Devices That Respond to Visual Attention. In *CHI '03 Extended Abstracts on Human Factors in Computing Systems (CHI EA '03)*. ACM, New York, NY, USA, 770–771. DOI: http://dx.doi.org/10.1145/765891.765981

51. Norman Makoto Su and Lulu Wang. 2015. From Third to Surveilled Place: The Mobile in Irish Pubs. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 1659–1668. DOI: http://dx.doi.org/10.1145/2702123.2702574

52. Dag Svanaes and Gry Seland. 2004. Putting the Users Center Stage: Role Playing and Low-fi Prototyping Enable End Users to Design Mobile Systems. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '04)*. ACM, New York, NY, USA, 479–486. DOI: http://dx.doi.org/10.1145/985692.985753

53. Peter Tolmie, Andy Crabtree, Tom Rodden, and Steve Benford. 2008. "Are You Watching This Film or What?": Interruption and the Juggling of Cohorts. In *Proceedings of the 2008 ACM Conference on Computer Supported Cooperative Work (CSCW '08)*. ACM, New York, NY, USA, 257–266. DOI: **http://dx.doi.org/10.1145/1460563.1460605**

54. Patricia Trbovich and Joanne L. Harbluk. 2003. Cell Phone Communication and Driver Visual Behavior: The Impact of Cognitive Distraction. In *CHI '03 Extended Abstracts on Human Factors in Computing Systems (CHI EA '03)*. ACM, New York, NY, USA, 728–729. DOI: **http://dx.doi.org/10.1145/765891.765954**

55. Roel Vertegaal, Robert Slagter, Gerrit van der Veer, and Anton Nijholt. 2001. Eye Gaze Patterns in Conversations: There is More to Conversational Agents Than Meets the Eyes. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '01)*. ACM, New York, NY, USA, 301–308. DOI: **http://dx.doi.org/10.1145/365024.365119**

56. Shari P. Walsh, Katherine M. White, and Ross McD. Young. 2009. The phone connection: A qualitative exploration of how belongingness and social identification relate to mobile phone use amongst Australian youth. *Journal of Community & Applied Social Psychology* 19, 3 (2009), 225–240. DOI: **http://dx.doi.org/10.1002/casp.983**

57. Hao-Chuan Wang, Dan Cosley, and Susan R. Fussell. 2010. Idea Expander: Supporting Group Brainstorming with Conversationally Triggered Visual Thinking Stimuli. In *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work (CSCW '10)*. ACM, New York, NY, USA, 103–106. DOI: **http://dx.doi.org/10.1145/1718918.1718938**

58. Jason Wiese, T. Scott Saponas, and A.J. Bernheim Brush. 2013. Phoneprioception: Enabling Mobile Phones to Infer Where They Are Kept. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)*. ACM, New York, NY, USA, 2157–2166. DOI: **http://dx.doi.org/10.1145/2470654.2481296**

59. Paweł Woźniak, Kristina Knaving, Staffan Björk, and Morten Fjeld. 2015. RUFUS: Remote Supporter Feedback for Long-Distance Runners. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '15)*. ACM, New York, NY, USA, 115–124. DOI: **http://dx.doi.org/10.1145/2785830.2785893**