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Title of Dissertation: Towards Developing Guidelines for Addressing Situationally Induced Impairments and Disabilities (SIID) and Severely Constraining Situational Impairments (SCSI)

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ABSTRACT

Title of Document: **TOWARDS DEVELOPING GUIDELINES FOR ADDRESSING SITUATIONALLY INDUCED IMPAIRMENTS AND DISABILITIES (SIID) AND SEVERELY CONSTRAINING SITUATIONAL IMPAIRMENTS (SCSI)**

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This research aims for a richer understanding of the variety and complexity of situational impairment events. Mobile users are often placed in less than ideal conditions where environmental variability can negatively affect the completion of an interaction. These interaction issues have been termed “Situationally Induced Impairments and Disabilities (SIID)”. In addition, the omnipresent use of mobile devices seems to have produced a new complexity by-product termed “Severely Constraining Situational Impairments (SCSI)”. Little research to date has attempted to examine SIIDs as events or from a generalizable classification perspective. Nor has much research attempted to explore the by-product of amplified complexity that the increase in usage and functionality offered by mobile technology is engendering. This research represents the culmination of three studies that have resulted in guidelines so

that the design of mobile human-computer interaction can (1) better recognize the new complexity of the diverse facets that present during mobile interaction and (2) effectively account for the presence of SIID and SCSI events in the design of mobile device interaction.

TOWARDS DEVELOPING GUIDELINES FOR ADDRESSING SITUATIONALLY INDUCED IMPAIRMENTS AND DISABILITIES (SIID) AND SEVERELY CONSTRAINING SITUATIONAL IMPAIRMENTS (SCSI)

By

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Chapter 1: Introduction

Background and Research Domain

The introduction of portable information appliances to a mass audience represented a paradigm shift in the way information was consumed. Mobile information device use has contributed to a further information emancipation that began perhaps with two other disruptive technologies: (1) the personal computer, which spawned discretionary computer usage by a wide range of non-programmer/non-expert users, and (2) the World Wide Web, which fundamentally transformed information acquisition, management, and access (Grudin, 2012). The proliferation in the use of mobile technology has theoretically, for the first time in history, provided humankind with the ability to send and consume information whenever and wherever the human-to-machine interaction is desired (Saulynas, 2016).

This newfound ubiquitous access, however, is not without newfound usability issues. When one is sitting in front of a desktop computer, for example, and is focused on a particular task at hand, that task should ideally occupy the whole of the individual's attention. But having a computer task occupy one's whole, undivided attention would certainly be unadvisable, impractical, or even dangerous if one were walking on a crowded sidewalk and about to cross a street or while driving a car (Dourish, 2004).

The onset of the mobile interaction paradigm seems to have brought a recognition from the research community that models for interaction at a stationary desktop might not be adequate when applied in an interactive context that is both moving and variable (Wobbrock, 2006). Context, or information that can characterize the situation of relevant entities to the interaction between a user and an application (Dey, Abowd, & Salber, 2001), has played an increasingly important role in HCI research ever since our ability to interact with electronic devices went mobile. When considering the steps required to complete a mobile I/O transaction, the user must now account for not only the steps required to complete that transaction but also the context in which that transaction is taking place. In the composing and sending of an email message, for example, steps performed while sitting at a desktop computer would most likely differ when comparing that same transaction performed on a smartphone while walking down a busy metropolitan street. In this example, the smaller transaction space of the smartphone, coupled with a moving transaction target area, will affect the speed and accuracy of the transaction and, most likely, the nature of the message itself (i.e., shorter, truncated, or abbreviated/cryptic content). The context of the mobile transaction space requires that the user account for such cognitive factors as how much attention he or she needs to divide between the email task and not running into other humans on the street, a pothole, or the street itself and into oncoming traffic.

In addition, the variable and changing context of the ambient environment itself, even if the user is stationary, can have an effect on mobile I/O transaction completion. For example, if one is attempting to read textual output from a smartphone while outdoors during a sunny day, the context of the environment (i.e. the sun shining on the output screen) might make it difficult or impossible to consume the output offered by the device. The user is, therefore, for the duration of the event, visually impaired for the purposes of resources required to complete that transaction.

Mobile device interaction can be negatively affected by the presence of these situational, contextual, or environmental factors known as “Situationally Induced Impairments and Disabilities (SIID)” (Sears, Jacko, & Xiao, 2003) or, informally, “situational impairments”. If *impairment* can be defined as the loss or abnormality of body structure or function and *disability* defined as the difficulties an individual may have in executing a task or function (World Health Organization Assessment, Classification and Epidemiology Group, 1999), then an SIID, by extension, occurs when the interaction context results in either a temporary impairment or temporary disability (Sears & Young, 2002).

The research presented in this dissertation focuses on the situational impairment problem space. Specifically, it is (1) an investigation into the variety and complexity of situational impairment events (SIE) that are being experienced by users of mobile technology of all abilities, (2) how users attempt to deal with (and wish technology to help with) a situational impairment when it presents, and (3) the guidelines that designers of mobile interaction can follow to help mitigate the effects of situational impairments that users may encounter.

Motivation for the Research: Situational Impairments as "Events"

Both academic and industrial research has examined the existence of SIIDs as well as solutions to various physical and technical mobile interaction issues. For example, research has been conducted to evaluate how mobile technology can be designed to compensate for issues that may exist while walking and attempting text input (Goel, Findlater, & Wobbrock, 2012; Kane, Wobbrock, & Smith, 2008). Researchers in both the practitioner and academic domains have long recognized the limitations of battery life and are constantly developing ways to extend the practical life of batteries used in smartphones (Michigan, 2018; Zhang, et al., 2010). The inability to interact with a touch screen while wearing gloves while in a cold environment has led to the creation of specialized touch-screen gloves (Spencer, 2013). And even with its limitations, Automated Speech Recognition (ASR) provides a means to interact with a device in hands-busy or eyes-busy mobile interaction contexts (Shneiderman, 2000).

All the above areas of research have in common the recognition of a specific mobile interaction issue and the addressing of that specific issue. However, there appears to be a new level of complexity that smartphone usage is adding to our lives which may suggest the collective study of mobile interaction, and in particular the effect of SIIDs on mobile interaction may not be holistically complete.

Complexity is, of course, not a new phenomenon. It can be argued that one of the reasons humans develop and use tools is to help bring order to chaos, or at least a sense of control over one's environmental context. But the usage of tools that may have been designed to address a specific complexity or set of complex issues has often expanded beyond their original intended use. The original purpose of the tool may have been a reduction of chaos, but the subsequent discovery of additional utilities has led to new uses that represented a functionality not previously perceived. This new expanded set of environment-altering functions, at least temporarily, may lead to increased complexity before a better handle of the implications of the by-products of the new technology can be attained.

It appears that we are at such a pivot point in the mobile device interaction problem space. The ability to access information and conduct I/O transactions *on the go* has added tremendous value to our increasingly complex lives. For example, if one was with a group in a crowded location and became separated from the group for some reason, prior to the omnipresence of mobile interaction, this could lead to delays, frustration, and even anxiety, particularly if one of the separated parties was a small child. The existence of mobile technology in this situation affords the ability not only to SMS "Where are you?" but to incorporate multimedia to enhance the information richness of the communication channel (e.g., an SMS response, "I am under this sign" + a digital image of the sign). Such information presented in this format would offer enough cues to help the recipient locate the sender.

The same tool, however, that brings a sense of order and control to a chaotic situation could equally produce greater chaos and disorder. For example, the attempted communication with the group is disrupted by other simultaneous exogenous communications (e.g., text interrupted by a phone call). Also, the inability to access the device to send or receive communication due to unavailable input resources (e.g., hands full), limited device resources (e.g., low battery or weak signal), or other aspects of the environmental context (e.g., too bright to see screen, too loud to send or receive voice, or concern of possible device theft in a crowded and unfamiliar environment) can all conceivably lead, at least temporarily, to a net increase in chaos.

While research to date has certainly recognized that mobile interaction represents a new paradigm, and that the interaction *rules* that represent effective design in a stable desktop environment may not map well to the mobile context (Wobbrock, 2006), little research has attempted to examine the SIID phenomenon as a collection of individual ***events***. Nor has research attempted to create generalizable classifications that could describe the different types of SIID events. Nor has much research attempted to explore the by-product of increased complexity that the increase in usage and functionality offered by mobile technology is engendering.

Many SIID scenarios can be temporarily overcome through user-created workarounds. In the scenario of a user not being able to view his or her mobile device screen because of bright sunlight, for example, the transaction might still be completed by the user finding or creating shade, either by temporarily relocating to a shady position or by shielding the screen from the sunlight by holding his or her free hand over the screen area. Other SIIDs can be effectively neutralized by designing technology to utilize alternative modalities. Instead of finding or creating shade in the above example, perhaps the I/O transaction can be completed by utilizing automated speech recognition to initiate the transaction and audio output to complete the transaction. Also, if the need to complete the transaction is not timely in nature, the user-created workaround might simply be to delay the transaction until the conditions would prove more conducive. In nearly all cases of SIIDs, the execution and/or completion of an I/O transaction may produce a less than ideal user experience, but the transaction can often get completed to the point where some value is transferred to the user.

But what if in the above scenario of bright light masking/occluding content, the user is at a crowded outdoor music festival that is taking place in a vast open space and his or her free hand is occupied with a cup of beer? There is (1) no source for ambient shade, (2) no source for user-created shade without the risk of spilling one's beverage on the ground or, even worse, on another human or his or her mobile device, and (3) due to the ambient noise conditions, no ability to utilize the alternative modality offered by ASR. If a one-handed interaction with the device is even attempted, the user may make more errors as a result of the one-handed interaction, which may lead to more checking of the mobile interface content to ensure that the correct information has been entered or received. Furthermore, what if in the above scenario the need for the transaction is timely? What if the value of the transaction becomes nil if it is not completed within the next 5 minutes? This contextual factor effectively negates the possibility of resolving the issue through the workaround of waiting until the context is more favorable (i.e., the end of the concert).

In addition, some interaction scenarios may present where there is nothing physically preventing the completion of an I/O transaction, but nonetheless, the transaction is not successfully completed. Completion of a transaction using a voice input modality, for example, might be impeded in certain contexts where the user did not wish to disseminate secure information in an environment where that information could easily be obtained by others. Consider the scenario of an individual driving in an automobile to an important meeting. He or she needs to interact with his or her mobile device but is physically prevented from doing so due to the phone being out of reach or because both hands are occupied on the steering wheel. A voice command could be sent to the phone via a Bluetooth device and that same Bluetooth device could return audio output. But what if the screen is locked and cannot be unlocked without authentication? Even if verbal authentication is available, what if there are passengers in the automobile? There is nothing physically preventing transaction completion, but I/O transaction failure may still occur because the user does not wish the passengers to hear the authentication code. Or consider the scenario where a timely transaction is desired while one's hands are not clean, but in a location where the social/cultural context demands quiet. If one cannot (1) locate a means to clean one's hands or (2) extricate oneself from the social/cultural context in sufficient time, the transaction, even if eventually completed, may not have any value.

If one approaches a situational impairment from the perspective of an ***event*** that is occurring as part of a mobile interaction attempt, then it may be the case that not all SIID events are created equally. Some SIIDs, such as those described in the scenarios above, appear to be more severe than others and, therefore, might suggest the need for special or at least different consideration when designing mobile technology. While some SIIDs may be considered an annoyance, if at least the transaction can be completed to the point where value is obtained from the transaction, the user may be willing to accept the need for delay or a workaround in certain contexts in order to arrive at a completed transaction. When an alternative I/O channel or different modality might be utilized, an SIID may be overcome to the point of transaction completion. It is, however, when multiple or all I/O channels are blocked, or the value of a transaction is time dependent, or when the solution to one SIID simply results in the creation of another SIID, that we can no longer view these situational impairment events as simply SIIDs. In addition, experience with mobile device interaction is beginning to reach a level of maturity where many users have amassed a significant interaction history. If that history is replete with frustrating I/O transaction failures, transaction completion may not even be attempted.

When the conditions brought on by the onset of a situational impairment lead to failure to execute and complete the transaction in a timely manner, or where past failure leads to the presumption of failure and therefore abandonment, we must conclude that these conditions must be classified as *severely constraining*. The rapid adoption and omnipresent use of mobile devices seems to have produced a new complexity by-product known as "Severely Constraining Situational Impairments (SCSIs)" or "*an occurrence of a situational impairment and disability where a workaround is not available or easily obtained, or where a technological solution was found that only led to the introduction of a new situational impairment and disability*" (Saulynas, Burgee, & Kuber, 2017). Given the possibility of these severely constraining event scenarios, a reexamination of the SIID phenomenon is needed in order to truly capture the nature of these impairments in the wild. Perhaps there are more scenarios, like the ones described above, being experienced by the average mobile device user. As more scenarios are uncovered, the "severely constraining" situational impairments may garner special or different consideration when designing mobile technology.

The classification of SIID ***events*** for a better generalized understanding of their effects and the addressing of those effects by mobile interaction designers is one of the primary motivations of this research. In addition, the research presented in this dissertation is motivated to discover a better understanding of the complexity that may be occurring as a result of the introduction of smartphone technology and whether this complexity by-product warrants special or different design consideration from that of SIIDs in general.

Research Objectives and Contribution

The objective of this research is to arrive at a richer understanding of how users respond to all situational impairments when they present and discover ways to support mobile human-computer interaction in the presence of SIIDs, particularly in situations where more constraining events are encountered that often lead to transaction failure. While research has examined the accessibility of mobile interactions for users with health-induced disabilities, the study of SIIDs has not garnered a significant enough amount of attention. The overarching objective of this dissertation, therefore, is a contribution towards the establishment of a more positive universal user experience within the mobile interaction problem space. This research will attempt to assist in the reduction of transaction failure or extreme frustration as well as to increase user safety. This will be accomplished by investigating ways to support mobile users facing interaction contexts where multiple channels of communication are restricted, overloaded, unavailable, or simply undesirable by establishing the existence of SCSIs and demonstrating that they are a distinct subset of the SIID problem space. SIIDs, particularly SCSIs, present a real accessibility challenge for true mobile device use *on the go*, and the effects of these challenges can be dangerous. Thus, this research represents both a timely and an important topic.

As part of the exploration toward design solutions for situational impairments, this research will examine possible parallels that may exist with solutions that have been created in design/research supporting users with more permanent and/or omnipresent impairments. Nicolau (2012) has suggested solutions that have been and are currently being explored in domains such as Assistive Technology (AT) and Accessibility may offer value when applied to the SIID problem space. He purports that motor abilities affected by mobility conditions associated with attempting a mobile transaction, may represent the same challenges that are experienced by motor impaired users. This research will seek to explore and expand upon this idea by seeing to what extent existing AT/Accessibility solutions can support solutions for all types of situational impairment events.

The ultimate contribution of this research is the offering of guidelines by which design of mobile human-computer interaction can (1) recognize the new complexity of the diverse facets that present during mobile interaction and (2) properly and effectively account for the presence of SIID and SCSI events in the design of mobile device interaction.

Research Questions

RQ1.1 Can we better understand and classify the various types of situational impairment events that occur when attempting mobile interaction *in the wild* as well as how users of mobile technology are currently accounting for the onset of a situational impairment when attempting to complete a mobile I/O transaction?

RQ1.2 Are there certain types of situational impairment events that are so severely constraining that they increase the need for cognitive resources, leading to mobile I/O transaction failure, abandonment, or danger?

RQ1.3 Can mobile interaction design account for and reduce/eliminate the effects of all situational impairment events for users of all abilities?

RQ1.4 Can new guidance be created and can existing guidance be strengthened to better account for the presence of situational impairments faced by users of mobile technology?

Summary of Original Work

The overarching objective of this work is the heading towards, and development of, generalizable and actionable guidelines. There seems to be a paucity of guidance that has been identified for SIIDs. As a result, it may be confusing for designers to understand how to design for mobile device users and to understand the range and diversity of the challenges that they face. It would be important to have one location for this guidance. Three studies have been conducted in support of this dissertation objective that adopted a structured approach consisting of multiple steps. The first two of these studies are detailed in Chapter 3 but are briefly summarized below. The third study is detailed in Chapters 4 and 5.

As research examining SIID events was limited, an exploratory diary study was conducted to understand better the type of issues faced (Saulynas, Burgee, & Kuber, 2017). The results of the research based on the initial inquiry revealed: (1) that there are at least five generalizable themes that can be used to classify situational impairment events, each with varying implications for mobile device interaction, and (2) a special severely constraining subset of SIIDs, where the multitude and complexity of ambient agents contributing to mobile I/O transaction disruption were found and defied conventional classification. These were dubbed "Severely Constraining Situational Impairments (SCSI)."

The above referenced study was a necessary first step in establishing a problem space by defining and categorizing common events that are occurring during a mobile transaction attempt. However, the results were limited in that only the problem was established. Employing the classification system as the launching point, a second study was conducted in two stages consisting of structured interviews followed by a series of participatory design workshops (Saulynas & Kuber, 2018; Saulynas & Kuber, 2019). The aim of this study was to: (1) obtain a deeper empathy for mobile device users; (2) ideate with users and domain experts regarding implications for mobile interaction design that will help users to perform tasks safely and effectively in common mobile interaction scenarios; and (3) gain critical information regarding situational impairment events that are severe and constraining and whether they warrant different design considerations. The results of the research based on this inquiry revealed:

1. A small corpus of workarounds that users attempt to deploy during the onset of a situational impairment.
2. Users are feeling compelled to complete mobile I/O transactions even if the steps needed to complete the transactions are, at times, putting themselves (and/or others) in potential danger.
3. When asked how they would like technology to address common situational impairment events, users demonstrated clear differences in the design suggestions when expressing issues associated with the onset of SCSIs.

The results of both studies have provided the necessary foundation for the final study that will be presented in Chapters 4 and 5. In addition, the authors of the two previous studies posit that the structured approach that was used might prove helpful for other researchers to adopt. The main contribution of this work, is a set of validated guidance to help researchers and designers of mobile technology better account for the variance and complexity of the SIID phenomena when considering mobile interaction.

Outline of the Dissertation

The following is a brief outline of the chapters contained within this dissertation document.

Chapter 1: Introduction - A background of the problem space is provided, as well as what specific area of the problem space this dissertation will address. Motivations for why the research was conducted and the overarching objective and research questions are also described. Chapter 1 concludes with a brief summary of the research conducted to date in support of the objective and research questions.

Chapter 2: Literature Review - Chapter 2 reviews areas of research pertinent to the problem space described in this research. This includes research and literature specifically addressing situational impairments and SIIDs by name. The chapter also covers related areas such as mobile interaction design, mobile accessibility studies, interfaces to make mobile interactions accessible, and mobile design guidelines for access.

Chapter 3: Investigating, Categorizing, and Designing for Various Types of Situational Impairment Events - Chapter 3 provides detail regarding the two previously published studies that were performed within this dissertation arc. It details the methodology and findings of a diary study conducted to obtain a situational impairment event corpus that was used to develop a generalized set of SIID themes and sub-themes as well as a definition of and characteristics of SCSIs. It also details the methodology and findings of a second, follow-up study that consisted of semi-structured interviews followed by a series of participatory design workshops, resulting in a set of user-led recommendations for the accounting of both SIIDs and SCSIs in common mobile interaction scenarios.

Chapter 4: In Search of Guidelines for the Addressing of Various Types of Situational Impairment Events (Methodology and Results) - Chapter 4 offers a detailed account of methodology and results of the third and final study within this dissertation research arc. The study was conducted in two stages and consists of (1) a systematic literature review and (2) a Delphi method series of iterative online questionnaires. The goal of this final study was to achieve the overarching objective of a set of actionable guidelines to assist developers and researchers of mobile interaction in accounting for the presence of SIIDs and SCSIs.

Chapter 5: In Search of Guidelines for the Addressing of Various Types of Situational Impairment Events (Discussion, Limitations, and Future Research) - Chapter 5 engages in a detailed analysis of the findings of the third and final study, the contributions made, and the implications for the design of mobile interaction. In addition, the limitations of the study will be discussed as well as the directions for possible future research.

Chapter 6: Dissertation Summary and Conclusion - The final chapter will review the findings and contributions of all three studies within this research arc

Chapter 2: Literature Review

Introduction

This chapter examines previous research and work in the addressing of situational impairments. The reviewed research has been grouped into the following categories (each with its own section within the chapter). The next section reviews work examining the importance of “context” to mobile interaction. This is followed with a section outlining studies that have attempted to measure the effects of context in mobile interaction. Next, studies that have attempted to analyze specific environmental factors that might bring on the onset of an SIID are reviewed, followed by a section reviewing works that have attempted to design technology (and prototype tests) that address specific aspects of environmental context. The penultimate section will examine recent works that have begun to look into the possibility of a universal solution to impairment design. Finally, the last section will look at some recent research that has attempted to examine the SIID problem space from a more qualitative perspective. It is hoped that the research reviewed in this chapter will provide the proper foundational structure for the research represented in this dissertation arc.

The Importance of Context in the New Interaction Paradigm

One of the earliest mentions of the term “Situationally Induced Impairments and Disabilities (SIID)” was in the chapter by Sears & Young (2002) noting that the activity a user is engaged in and the environment in which that activity is taking place can play a factor in producing impairments that affect interaction. Sears, Jacko, & Xiao (2003), examined the state of the ubiquitous or pervasive computing problem space and noted how technology is permeating our everyday activities and artifacts. Situational impairments, although temporary, can have the same effect on interaction as that of an actual physical or cognitive disability. They go on to suggest that as technology becomes smaller and more mobile, a better understanding and a broader definition of *context* needs to be explored.

Context, therefore, needs to be at the core of any discussion and indeed a central theme in the analysis of mobile device usage and situational impairments. Dey, Abowd, & Salber (2001) defined context as any information that can be used to characterize the situation of entities considered relevant to the interaction between user and application. Sears, Jacko, & Xiao (2003) suggested that context should be categorized further as consisting of (1) the user, their activities, and the social environment, (2) the environment or location, physical conditions and infrastructure, and (3) the available applications and I/O channels. Research should seek to understand the inter-relationship of user, appliance, and environment, and also the nature of the artifacts created as the result of this mobile induced inter-relationship.

As technology started to get smaller and more mobile, the research community quickly began to recognize that user technology may be entering a new interaction paradigm where the interaction rules that represent effective design in a stable desktop environment may not map well to the mobile context (Wobbrock, 2006). A user sitting at a workstation, operating a desktop computer, can have the whole of his or her attention focused on the task presented on that desktop computer. This level of focus, however, would be undesirable and possibly dangerous if the user was not in a stationary work context and/or engaged in a secondary task (e.g. driving a car or walking and crossing a street at a busy intersection (Dourish, 2004).

At the dawn of this new interaction paradigm, Wobbrock (2006) noted four trends in society and technology with direct consequences for mobile HCI: (1) the overall aging of the population; (2) the increasing amount of personal computing done away from the desktop; (3) the increasing capabilities of ever-smaller devices; and, (4) the convergence of computing capabilities onto the mobile phone. With these four trends taken together Wobbrock reached a similar conclusion as was found in Sears, Jacko, & Xiao (2003), that mobile HCI research needs to consider *context* as much as *capability*.

More recently, Marshall & Tennent (2013) noted that while users increasingly carry and use mobile devices while undertaking many ranges of movement and activities, the mobile systems themselves are still primarily designed for active interaction while standing still (and also paying visual and mental attention to the device). For designers of mobile interaction to effectively account for this *truly mobile* interaction need, they identified four challenges of mobile device interaction: (1) cognitive load (limited attention resources); (2) physical constraints (non-mobile activities may place constraints on physical resources); (3) terrain (external environment affects how a user will interact); and (4) other people (movement activities often involve a social element).

Measuring the Effects of Context in Mobile Interaction

With the acknowledgment that context can have an effect during mobile device interaction *in the wild*, researchers have begun to explore ways that these effects might be measured. The effect of individual and joint contextual cues for communication, Web, and media applications on smartphone usage was examined by Do, Blom, & Gatica-Perez (2011) through indirect observation (continuous data collected via automatic recorded logs). Participants were given a smartphone for the data collection period which lasted from October 2009 through June 2010. This data-driven analysis revealed two context-dependent design implications: (1) supporting synchronous communication and (2) context-dependent offering of functionality.

One additional finding in the above study, was that SMS was, by a large margin, the most frequent task (by counting the total number of events) that was deployed by participants. The number of SMS events more than doubled that of the second highest task (voice call). Part of the data collected in the interview section of Study 2 of this dissertation arc (outlined in detail in Chapter 3), corroborates these findings. If SMS has in fact become a more common means of communication than the traditional voice interaction for smartphones, the findings of Lamberg & Muratori (2012) offer some important insight to the effects of context during these mobile interaction events. The researchers were examining the effects of performing a dual-task, such as talking or texting with a cell phone while walking, and whether this may interfere with working memory and result in walking errors. Participants in their study walked, while either talking or texting, toward a target in a controlled environment with their vision occluded. Duration, final location of the heel, linear distance traveled, lateral angular deviation from the start line, and gait velocity were measured. Their results demonstrated walking while using a mobile device impacts executive function and working memory and also influences gait to such a degree that it may compromise safety. In addition, when comparing the two test conditions, texting was found to create a significantly greater interference effect on walking vs. talking.

Implicit (and in some cases explicit) in many of these studies is a recognition of Fitts' Law, or in particular, that I/O transaction performance is a function of (1) the distance from a target and (2) the size of the target (Fitts, 1954). When adding the effects of context to the two Fitts variables, how is the performance of a mobile I/O transaction affected? One example of an explicit Fitts' Law examination was evidenced in the work of Lin, Goldman, Price, Sears, & Jacko (2007). In noting that a mobile I/O transaction is not always the primary task in a variable and moving context, the researchers performed a lab experiment designed to measure how walking affects performance when completing tapping tasks on a PDA (using a stylus) and to see if the tapping task performance differs when on an obstacle course vs. a treadmill. Their results showed that, while attempting data input while walking through an obstacle course, input error rates increased while walking speeds were reduced by 36% when compared to walking on a treadmill.

In attempting to establish a foundation by which the effects of context on mobile interaction can begin to be better understood, Barnard, Yi, Jacko, & Sears (2007) addressed an apparent disconnect between environmental mobile device use and evaluation through varying some contextual conditions and recording changes in behavior. Specifically, the experimenters varied three contextual factors: task type, motion, and lighting level. Participants were placed into two groups and asked to perform a set of tasks on a mobile device while sitting (if in the sitting group) or free walking along a path around a room (if in the walking group). Each group was then asked to perform the tasks in two variant lighting levels. The results of their study revealed more than just movement can affect mobile interaction performance as the varying lighting conditions (whether or not the participant was in motion) had an effect on the performance of each of the separate tasks.

While some of the earlier research, such as is described above, examined the use of a stylus as the means of input to a mobile screen, the current and common use of touchscreens on mobile devices has meant that the direct input device most commonly used has shifted from a stylus to a finger. Recognizing that (1) touching the display with the index finger is a usual way of interacting with mobile devices, (2) the limited space mobile devices have for input often leads to smaller buttons, and (3) mobile device interaction often involves mobile task exogenous user activity, Conradi, Busch, & Alexander (2015) explored what the optimal size of the sensitive areas of touch buttons for mobile devices might be. In a study designed to obtain characteristic values for mobile touch interaction while walking through a distracting environment, participants were asked while on a treadmill (walking condition and standing condition) to perform touchscreen input tasks by holding a device in their left hand and using their right index-finger for input. The results showed significant "time on task" differences between small sized buttons vs. buttons of all other sizes (confirming Fitts' Law) and that walking contributed to a high number of errors for buttons of all sizes, but especially in the case of the smaller buttons. Only one button size (14*14mm) showed low error rates for both walking as well as standing, leading the authors to recommend this button size for designing for mobile input while walking.

More recently, Harvey & Pointon (2017) investigated whether common mobile situations that cause fragmented attention have an impact on user perceptions of the task and their own performance and also if the device type (smartphone vs. tablet) has an effect. The researchers conducted a between-subjects lab study with three context conditions: (1) walking on a treadmill, (2) navigating an obstacle course, and (3) sitting still at a desk. The two device types were independent variables. The result showed that the different conditions had a significant effect on user perceptions, both before and after completing the tasks, that those in the sitting condition were able to generate significantly more accurate and precise queries for a search than those in the other two groups, and participants perceived searching on the smartphone to be harder than that of the tablet, even though the objective performance measures revealed the performances to be identical.

Most recently, Sarsenbayeva, et al (2020), as the result of a two-week in the wild study with 30 participants, found a bidirectional causal relationship between the use of smartphone apps and user emotions. Three themes emerged from their analysis: (1) the content of the apps that were used can affect a user's emotional state; (2) some apps drive user emotions in a certain direction; and (3) the user's emotional state influences both the choice of the application used and the amount of device usage in general (positive emotions reduce total usage and negative emotions increase total usage).

Examining the Effects of Specific Environmental Contexts

Some studies looked at specific environmental/exogenous factors that might bring on the onset of an SIID and analyzed/measured their effects. A cold environment, for example, can hinder an attempt to perform an interaction on a touchscreen. Sarsenbayeva, et al. (2016), investigated how acute cold exposure might affect fine-motor movements as well as user vigilance during mobile interaction. Participants were tested on two mobile applications each custom designed for a specific task. One application tested the user’s ability to tap a specific location on the screen, the second app tested the recall and identification of specific icons. Following a within-subjects design, participants were tested in a warm environment first, then placed in a controlled cold environment. Because modern smartphones have capacitive-sensing touchscreens, they can detect anything that is conductive or has a dielectric differential with air (Tung, Goel, Zinda, & Wobbrock, 2018). Therefore, unless one is wearing specially augmented gloves such as what was designed by Spencer (2013), touchscreen interaction can only be done through direct screen-to-skin contact. For the cold room, they wore outer clothing appropriate for the simulated cold weather environment, but could not wear gloves, nor could they warm their hands in any way during that portion of the experiment. The findings showed that participants took less time and were more precise with the tapping task in the warm room vs. the cold and that movements were skewed in cold conditions. On the recall and identification task participants took significantly longer in the cold room to memorize an icon, but neither time, nor frequency of errors were significantly affected by the cold exposure. The authors noted that one of the limitations of their study was the limited exposure time to the cold environment and that cognitive effects have been demonstrated to have an effect over longer exposure periods.

Another environmental factor that can trigger the onset of an SIID is ambient noise. In a follow-up study to the above, Sarsenbayeva, van Berkel, Velloso, Kostakos, & Goncalves (2018), investigated the effects of ambient sound while engaged in a separate (unrelated) activity (e.g. construction sounds, a fridge humming, background music, or exogenous human conversation) and their potential effects on mobile interaction. Participants were asked to perform three common activities conducted on smartphones: (1) target acquisition, (2) visual search, and (3) text entry. The experiment then measured performance during four ambient noise conditions: (1) music (fast and slow tempo), (2) urban ambient noise (indoor and outdoor), (3) speech (meaningful - English, meaningless - Kazakh), and (4) silence (as a control condition). The results demonstrated that participants (1) were quicker in completing the target acquisition task in music conditions (both fast and slow) compared to the silent condition; (2) were less accurate while listening to slow music; (3) during the visual search took less time to memorize an icon listening to urban noise, but made more errors when finding an icon under urban outdoor noise; and (4) the text entry task was significantly affected by both the urban outdoor noise and meaningful speech conditions. They concluded that effect of ambient noise was more prominent on tasks requiring cognitive skills.

Researchers have begun to examine the effects of SIIDs on users in specific work environments and domains. Distracted driving has shown to be a safety issue when operating a motor vehicle, and that mobile device use is a major contributing factor (National Safety Council, 2015). Many officers employed in local police forces, spend a great deal of time in a car and that mobile computer terminals (MCTs) are the most frequently used in-vehicle technology for police officers. To test the effect of interacting with MCTs, Zahabi & Kaber (2018) ran a study involving twenty police officers in a driving simulator to assess visual behavior, performance, workload, and situational awareness with current and enhanced MCT interface designs. Results demonstrated that MCT decreases visual attention to the roadway, significantly reduces perceived level of driving environment awareness, and increases cognitive workload.

Other studies have examined the effects of mobile interaction in domains where a non-mobile primary task may affect a user's ability to focus. In examining the relationship between human and machine in the automated driving domain Biondi, Alvarez, & Jeong (2019) examined, among other things, some of the unintended consequences that vehicle automation might have on driver's workload, situation awareness, trust, as well as social interactions between driver, vehicle, and other drivers. In examining SIIDs that may present in inhospitable environments that firefighters must conduct their business (e.g. thick smoke, noise from sirens/ventilation fans, etc.) Wolf, Kuber, Pawluk, & Turnage (2017) sought to find ways in which alerts to firefighters can be designed which better resist the impact of SIID and improve upon the overcoming of difficulties in establishing situational awareness in these inhospitable and rapidly-changing settings. Using a combination of contextual interviews and participatory design sessions, the research revealed the need for cues to be quick to interpret, mappings to be simple and intuitive, and improving salience if multiple cues are presented and/or if multiple devices are in use.

Designing Technology to Account for Context and Improve Mobile Interaction Performance

The previous sections reviewed some of the research to date that has attempted to measure the effects that context has on mobile interaction. This section will review a sampling of research being conducted that is attempting to create design solutions to some SIIDs and improve user interaction performance.

For example, Kane, Wobbrock, & Smith (2008) developed a prototype walking user interface (WUI) that changes the screen layout based on user movement. User tests were performed in open public spaces on the WUI prototype, comparing its performance to static interfaces. An initial round of tests revealed, as is shown in (Fitts, 1954), that there was a relationship between target size and movement, suggesting that changes to target size could have a positive effect on performance. The second round of tests deployed the WUI prototype which scaled the target size based on user movement (i.e. when the user is standing still, the targets shrink and when walking, the interface expands). A 3x3x2 within-subjects factorial design was deployed with the following factors and levels: Interface (static-simple, static-complex, adaptive), Difficulty (easy, medium, hard), and Movement (standing, walking). Their results revealed the WUI interface was faster than the static-complex interface (but the static-simple interface was faster than both of the other interfaces). In addition, there was no main effect of Movement on task time, but a significant interaction for Interface*Difficulty and Difficulty*Movement.

"WalkType" is a system developed by Goel, Findlater, & Wobbrock (2012) which takes advantage of the built-in accelerometer of touch screen devices to create an adaptive technique to increase text entry accuracy while walking. The system was tested in a controlled user study that compared "WalkType" to a control interface. Results demonstrated that "WalkType" improved typing performance, that text entry speed was improved, and that the uncorrected error rate was also improved. The improvements were evidenced in both sitting and walking conditions, but were particularly evident for walking. In addition, qualitative data revealed that "WalkType" was highly preferred by participants, who recognized the performance benefits despite there being no visual difference from the control interface.

A study conducted by Lee, Cha, Hwangbo, Mo, & Ji (2018) tested the effect of varying two smartphone form factors (width and bottom bezel) on touch behaviors during one-handed interaction. Tapping tasks were conducted using four different widths (67, 70, 72, and 74 mm) and five bottom bezel levels (2.5, 5, 7.5, 10, and 12.5 mm). Task performance, electromyography (measuring the signals of two thumb muscles), and subjective workload data (using the NASA-TLX method) were collected. The results showed that task performances, subjective workload, and electromyography all deteriorated with increasing width level. The results of analyzing the performance of the bottom bezel devices demonstrated that difficulty increased as the bottom bezel level decreased.

One environmental factor that can negatively affect interacting with a capacitive-sensing touchscreen is attempting to perform that interaction in the rain. “RainCheck”, a prototype to account for a wet touchscreen interaction surface, was developed by Tung, Goel, Zinda, & Wobbrock (2018). It is designed to filter out potential touch points caused by water in order to differentiate fingertips from raindrops/water smears adapting in real-time using the low-level raw sensor data from touchscreen drivers and precise selection techniques. Two studies were conducted in a controlled environment (where water was applied to a touchscreen surface using a spray bottle) to evaluate whether RainCheck would improve (1) touch recognition (gesture performance), and (2) target selection performance. For the gesture test on touch recognition, RainCheck resulted in a 75.7% reduction in errors. For target selection performance, RainCheck was 47.9% more accurate than the unmodified system under wet conditions.

Prasad, Taele, Olubeko, & Hammond (2014) examined how technology might address user mobile interactions while walking in unfamiliar contexts (which require greater awareness of surroundings). They proposed “HaptiGo”, a lightweight vest with vibrotactile sensors giving pedestrians an invisible sensation of being passively guided, thus providing the ability to detect obstacles while maintaining navigational intelligence.

Other studies have examined possibilities using technology that may not be *ready for prime time*. Brain-Computer Interface (BCI), for example, is one technology where the current commercial state of the art has been shown to not be at a performance level that is ready for true everyday use (Saulynas & Kuber, 2017).

However, some exploration such as what was done in Soman, Srivastava, Srivastava, & Rajput (2015) and Campbell, et al. (2010), each of which examined the use of BCI for mobile devices, might suggest avenues for future research.

Assistive Technology/Accessibility Parallels

Some research has begun to address the very nature of what "ability" and "disability" imply and how perceptions of these concepts might influence interaction design. Wobbrock, Kane, Gajos, Harada, & Froehlich (2011), saw a need to perhaps change the focus of current approaches to the design of accessible computing. They suggested that designers should focus on "ability" (as opposed to "disability") when creating systems that can leverage the full range of human potential. As the authors note, "*...people do not have dis-abilities any more than they have dis-money or dis-height*." (Wobbrock, Kane, Gajos, Harada, & Froehlich, 2011).

An SIID event, in effect, simulates a more persistent physical and/or cognitive impairment. Recognizing all users might experience the same (or similar) "disability" issues hampering their "ability" to complete mobile transactions, some research has begun to investigate the possibility of a more universal solution to SIID events by examining what the Assistive Technology and Accessibility domains do to promote the "abilities" of users.

One researcher who began to examine this possibility was Nicolau. He describes in his work (Nicolau, 2012), the possibility of building a relationship between the Assistive Technology and SIID domains that could contribute towards a more inclusive and universal design approach. By focusing on walking conditions and tremor disorder and the situational conditions that may bring about similar issues, and by modeling users with a generalized set of abilities (independently of their impairment), the hope of the research was to see if situational and health induced impairments affect users in similar ways.

Noting that the biopsychosocial model, forming the basis for the International Classification of Functioning, Disability and Health (ICF), suggests a universal perspective on human functioning that encompasses all humans, Jarl & Lundqvist (2018) argue that an artificial separation of Assistive Technology and mainstream technology might represent a barrier towards that universalistic view. The authors put forth an alternative view of Assistive Technology in the form of a concept model that they refer to as the Person–Environment–Tool (PET). With this model, activity and participation are described as a function of factors and does not make distinctions between people of different ability levels, between environmental modifications intended for people of different ability levels, or between different function-enhancing technologies.

The Emergence of SIID Qualitative Studies

The preponderance of research thus far has focused on quantitative and positivist experimental techniques, either to create performance measures or experiment with prototype solutions. Recently, however, some research has attempted to examine SIID phenomena from a more qualitative and phenomenological perspective. In a study to be detailed in Chapter 3, Saulynas, Burgee, & Kuber (2017) deployed a diary study to collect a corpus of situational impairment events. Through theoretical sampling and phenomenological analysis of the data, the research resulted in the development of five themes to describe the types of SIID events that were experienced by the participants in the study.

While people of all abilities can experience an SIID, those who have a more persistent and/or permanent disability (e.g. a visual impairment or an auditory impairment) also may experience SIID events when interacting with a mobile device, in addition to their more persistent disability. One study that examined this issue from a constructivist viewpoint was, Abdolrahmani, Kuber, & Hurst (2016), focusing on SIIDs encountered by individuals who are blind. Through semi-structured interviews (using three scenarios to inspire discussion), the study revealed nine main themes to describe the challenges faced when blind individuals attempt to interact with a mobile device.

Noting the predominantly visual nature of mobile device use, Tigwell, Flatla, & Menzies (2018) ran a study to better understand the effects specifically of Situational Visual Impairments (SVIs) which can include contextual phenomena such as ambient light, moving surroundings, position of device, device accessories, or content design. The results show that mobile users that participated in the study are frequently and broadly experiencing SVIs. In particular, the top three tasks experienced by the participants were: (1) “seeking information”, (2) “text-based communication”, and (3) “creating, consuming, or interacting with media.” Their analysis also revealed that the root causes of SVIs go beyond simply environmental sources. Through phenomenological analysis the study revealed six themes to describe what causes SVIs.

Chapter 2 Summary

This chapter reviewed some of the work that has been done to account for the unique challenges of the new mobile interaction paradigm. The research reviewed included studies that attempted to measure various effects of context on mobile device interaction, different environmental contexts, as well as some prototypes representing potential technological solutions to some specific impairment types. Also, reviewed were some recent attempts to explore the problem space from a universal design perspective, as well as through some qualitative analysis.

While there has been some recent work examining the problem space phenomenologically, most of what is being done is still from a positivist viewpoint. As a result, research to date has done a good job of addressing various specific symptoms. However, little research has attempted to examine the problem space from a holistic and complete perspective. In addition, guidelines, principles, and heuristics, which are an important aspect of evaluating design, are most effective when they can be widely used and are easy to transfer (Nielsen, 1994). Some of the previous work, such as Conradi, Busch, & Alexander (2015) reviewed in this chapter, offer various forms of recommendations based on their specific research questions. However, unlike with general accessibility guidance, there is no one main repository/location for SIID guidance. The studies outlined in the next chapters represent an attempt to address these gaps.

Chapter 3: Investigating, Categorizing, and Designing for Various Types of Situational Impairment Events

Introduction

As was stated in Chapter 1, the research contribution represented in this dissertation is the offering of guidelines to help designers and researchers of mobile human-computer interaction properly and effectively account for the presence of SIID and SCSI phenomena by addressing four overarching research questions:

RQ1.1 Can we better understand and classify the various types of situational impairment events that occur when attempting mobile interaction *in the wild* as well as how users of mobile technology are currently accounting for the onset of a situational impairment when attempting to complete a mobile I/O transaction?

RQ1.2 Are there certain types of situational impairment events that are so severely constraining that they increase the need for cognitive resources, leading to mobile I/O transaction failure, abandonment, or danger?

RQ1.3 Can mobile interaction design account for and reduce/eliminate the effects of all situational impairment events for users of all abilities?

RQ1.4 Can new guidance be created and can existing guidance be strengthened to better account for the presence of situational impairments faced by users of mobile technology?

This chapter provides more detail regarding two published studies representing the initial research performed within this dissertation arc. The first study collected a corpus of mobile device user situational impairment events (SIEs) in order to better understand and define the dissertation problem space and to address the first and second overarching research questions above. The second study applied some of the findings of the first study to obtain a better understanding of mobile device user motivations, task completion preferences, and expectations regarding mobile technology design and utility which offered additional support for the first two overarching research questions as well as address the third.

Each study will be reviewed in the sections that follow. The methodology, results, and implications of the findings of each study will be elucidated along with how these two studies helped provide the launching point for the final study (to be discussed in Chapters 4 and 5) which will address the final of the four overarching research questions.

Related Work for Both Studies

Research has focused on ways to describe the sources of the unique difficulties participants experience when attempting to perform tasks *in the wild*, observing that among other things, *context* (Dey, Abowd, & Salber, 2001) can be central to the examination of mobile device usage. Interaction while in motion can be challenging due to (1) cognitive load (limited attention resources); (2) physical constraints (non-mobile activities may place constraints on physical resources); (3) terrain (external environment affects how a user will interact); and (4) other people (movement activities often involve a social element) (Marshall & Tennent, 2013). Studies such as Goel, et al. (2012) and Kane, et al. (2008) have focused on measuring the effects of SIIDs on task performance or designing mobile technology that might overcome specific types of SIIDs. Some recent research, for example Sarsenbayeva, van Berkel, Luo, Kostakos, & Goncalves (2017), has begun to focus on classification of SIIDs.

The first study in this chapter attempted to help better classify the SIID problem space. In addition, it sought to identify whether certain events present themselves as so severe and/or complex that simple classification would not be sufficient. In order to accomplish this and to address the two research questions, a study was designed to enable the capture of individual SIEs *in the wild* so that they could be identified, classified, and catalogued. The goal was (1) to discover generalizable themes that might exist from within the corpus of SIEs that were encountered and (2) to determine to what extent some of the SIEs represent situational impairments that are so severely constraining to the mobile user experience that they represent a fundamental thematic difference from other SIIDs.

Study 1 (Diary Study with Follow-up Focus Groups)

Study 1: Background and Research Questions

In that SIIDs are known to pose challenges to mobile device users, a study published in the conference proceedings of the 2017 iConference deployed a diary study to collect a corpus of individual "situational impairment events" (SIEs) (Saulynas, Burgee, & Kuber, 2017). The aim was to discover phenomenological themes that might serve as a basis for the creation of guidelines and principles for addressing SIIDs that could assist in the design of mobile technology. An initial observation/hypothesis that not all SIIDs are created equal led to an initial inquiry with the following research questions:

RQ3a.1: What are the challenges faced by individuals experiencing SIIDs, and are there common themes that can describe them?

RQ3a.2: Do individuals experience some SIIDs that are severely constraining, and are they thematically different from SIIDs?

Study 1: Methodology

Diary Study

Data gathering was principally conducted in the form of a two-week solicited diary study. This methodology was chosen over other forms of qualitative data gathering such as interviews or questionnaires as the format enables participants to provide information about what they experience from a personal perspective versus the interpretation of an observing or analyzing researcher (Symon, 2004). The two-week duration of the study was adopted from the approach taken by Koopman-Boyden & Richardson (2013).

Participants were asked to record and report every occurrence of a “situational impairment event” (SIE), which was defined to the participants as what occurs when any interaction with a mobile appliance was desired, by either inputting information or receiving output, but something about the current situation impacted or prevented them from completing the process to their satisfaction, and that was either unique to or exacerbated by the mobile I/O transaction domain.

Participants were instructed to deliver their SIE reports (minimum of one per day) by email as soon as was possible after the event occurred, but they agreed to do so only if/when interaction conditions were considered safe and appropriate. Electronic recording of diary data was chosen over paper as this modality lessens transcription errors and reduces human labor cost for both participant and researcher (Green, Rafaeli, Bolger, Shrout, & Reis, 2006). Email was chosen over other electronic delivery mediums such as SMS (which may have a per-message character limitation) (Rönkä, Malinen, Kinnunen, Tolvanen, & Lämsä, 2010), thereby making them inappropriate for this study. The researchers were interested in observations as they occurred in the wild. The goal was to allow the collection of data that was as natural and free from observer bias as possible to assure that the participants' minds were open and that they felt as free from experimental pressure as possible (so they could better focus on the context and issues that were creating the SIEs).

A qualitative content analysis was used with a goal of obtaining information that was about something considered to be a misunderstood or at least under-understood phenomenon (Bolger, Davis, & Rafaeli, 2003) and with the intent of discovery through phenomenological analysis. SIID data was gathered by means of a series of four participant cohorts (described in the "Participants and Cohorts" subsection). The data gathered by each subsequent cohort built on the knowledge gleaned from each previous cohort. Through theoretical sampling, concepts and themes were discovered and refined until saturation was reached as the result of no further refinement of existing concepts or the discovery of new concepts. Though four cohorts proved sufficient to achieve data saturation, the researchers were prepared to extend the study to include additional cohort groups if saturation was not reached.

Follow-up Focus Groups

Though the diary data would provide important information regarding what types of events were encountered, such data might be limited in describing the context surrounding the events and the motivation for any actions that were taken to attempt to overcome the SIE. The reports were expected to be brief, which was also desirable. The study was looking for, as immediately as was feasible, a recording of a SIE as it occurred. The aim was to gather as many events into the corpus as possible. Detailed descriptions and analysis of the events were beyond what could be expected if a large and diverse pool of events was the goal. A group brainstorming session and discussion of possible workarounds and other solutions was necessary to provide more granular information and a more complete representation of the experience. Therefore, after the two-week diary portion of the study was complete, each participant from each particular cohort was asked to take part in a 75-minute focus group session to allow follow-up analysis of the observations that they made.

The focus group format, in particular, was chosen over other follow-up formats as in addition to hearing about their interpretations and possible motivations for their actions, the researchers were also very interested in having the groups brainstorm about possible and theoretical technological solutions to the events that they experienced. It was felt that an open discussion environment such as what a focus group offered could better facilitate the generation of ideas.

Participants and Cohorts

A total of 20 mobile smartphone users participated in the study. The number of participants was chosen consistent with Creswell (1998), who recommends a sample size ranging from five to 25 for phenomenological studies. The participants were divided into four staggered cohort groups consisting of five participants for each cohort. Because the aim of the study was to discover phenomenological themes, participants were run in staggered cohorts so that the data analysis could take advantage of the iteration afforded through theoretical sampling and eventual saturation. Each cohort was run independently and the results analyzed before the next cohort was started. The participant details are outlined in Table 1 of Appendix A.

After these two cohorts were finished, the data from both were analyzed and codes were created. The codes were then confirmed by running and subsequently coding a third cohort with a slightly higher age stratification range (39 to 64 years). Finally, after receiving confirmation of existing codes through a set of inter-rater reliability tests, a fourth cohort was run that, like Cohort 1, consisted of university-aged undergraduate students.

Study 1: Results

A total of 425 excerpts were generated from the four cohort groups. This total excludes excerpts that were deemed not to be considered as being the result of, or exacerbated by, the mobile context. For example, the excerpt from Cohort 4 that read…

"*You are using your social media app and the app freezes. You see a notice that says kill the program or wait. I feel this situation is more based on the app itself or an issue with your phone.*"

…was identified as not a SIE as the issue of an application freezing could occur in a non-mobile context and nothing about the scenario described any aspect of the context where the mobile nature of the situation exacerbated the freeze.

Each cohort represented an interactive step in the revealing of the phenomenological themes represented in the data. After completion of the analysis of Cohort 2, the themes that were to be used to describe the various SIE categories were developed. An inter-rater reliability test was performed on 100% of excerpts determined to represent SIEs from Cohort 1 to determine classification consistency. A

Cohen pooled kappa score of 0.78 confirmed good inter-rater reliability of the entire data set. In addition, kappa scores for each individual main theme were calculated, all resulting in scores ranging from 0.62 to 0.90, which indicate good inter-rater reliability within each category as well. An additional inter-rater reliability test was performed after data saturation was achieved following the analysis of the diary data from Cohort 3. In this second test, 54 of the SIE excerpts from Cohorts 2 and 3 were sampled (19.34%). As with the first inter-rater reliability test, a high Cohen pooled kappa score (0.81) confirmed good inter-rater reliability. The sample size, in part, that was chosen for this second test was based on the generally accepted heuristic that suggests sample sizes should consist of at least 30 comparisons (McHugh, 2012).

SIID Themes

At least five generalizable themes that can be used to classify situational impairment events, each with varying implications for mobile device interaction, were gleaned: (1) Technical Issues, (2) Ambient Environmental Issues, (3) Workspace/Location Issues, (4) Complexity Issues, and (5) Social/Cultural Issues. Each of these themes, along with their sub-themes, are defined and detailed in Table 2 of Appendix A.

Severely Constraining Situational Impairments

In addition to the SIIDs, several excerpts (approximately 15%) described events that went beyond a simple solution. The participant descriptions of these events reflected frustration (more so than was the case with other SIEs) and often ended in transaction failure or just abandonment. While still single events, the multitude and complexity of ambient agents that contributed to the mobile I/O transaction disruption, defied conventional classification.

Therefore, these types of events were dubbed "Severely Constraining Situational Impairments (SCSI)" and were formally defined as: "*An occurrence of a situational impairment and disability where a workaround is not available or easily obtained, or where a technological solution was found that only led to the introduction of a new situational impairment and disability*." Based on the variety of descriptions from the diary excerpts, the following characteristics of SCSI events were noted.

- **"Super" Situational Impairment Event**: Multiple impairment events combined in a single transaction (e.g. "Thought of something I wanted to search the web for while I was cutting grass, but couldn't use phone because it was too bright out and couldn't use Siri because it was too noisy.- By the time I reached a shady area, I ended up forgetting what the task was.")
- **Expiration of Transaction "Half-Life"**: The value of a transaction becomes zero before conditions conducive to transaction completion can be achieved. (e.g. A SMS is received (and unattended) while in a store. The text is read upon returning from the store and was a request from the spouse to purchase an item.)
- **Solution to One SIID Produces New SIID**: An existing design solution to an SIID creates a new and different SIID (e.g. voice input can overcome hand encumbrance, but not necessarily if that input contains information that cannot be disseminated in public)
- **Competing Modal Transactions**: Common communication channel needed for competing modal transactions (e.g. "GPS navigation in car interrupted by telephone call.")
- **Pre-Abandonment**: Transaction voluntarily terminated due to [a] concern over the violation of certain contextual social/cultural norms, or [b] past history leads user to not make transaction attempt (e.g. "Operation to get files from a secured 'cloud' service, download them to my phone with an

app, then upload them to a web service is simply too cumbersome to do on the phone... If even possible at all…)

It was clear from reading and analyzing the excerpts identified as SCSIs that these were worthy of different consideration. For example, consider the below excerpt.

> "*Thought of something I wanted to search the web for while I was cutting grass, but couldn't use phone because it was too bright out and couldn't use Siri because it was too noisy—ended up forgetting what it was.*"

One might describe this as perhaps a "Super-SIE" as it seems to be the result of multiple SIEs rolled into a single event. On one hand, the user experienced a situational impairment because he or she wanted information from his or her mobile device but "*couldn't use phone because it was too bright out*" (Ambient Environmental Issues: Meteorological Conditions) and also because he or she was "*cutting grass*"; both hands were occupied, thereby creating another situational impairment (Workspace/Location Issues: Unavailable Resources). Still, both of these SIIDs could be overcome as the result of an existing technological workaround, the automated speech recognition available by *speaking* to Siri. However, that modality was also blocked as the ambient noise of the lawnmower was creating another SIE (Ambient Environmental Issues: Ambient Noise). And all of this is assuming that the mobile device was even in a position to accept audio input. If the user did not have a Bluetooth headset, and the device was in his or her pocket, then he or she was also experiencing the SIE (Workspace/Location Issues: Inaccessible Location). Like a super-strain of the flu, there is no current technology that can *cure* this situation, so the only option is either abandonment or delaying the transaction until the environmental context becomes (or can be adjusted) to a situation that can allow for transaction completion. In this scenario, the user opted to delay the transaction, resulting in a final SIE of him or her forgetting what the original purpose was (Complexity Issues: Cognitive Load).

Or consider this less complex scenario:

"GPS navigation in car interrupted by telephone call."

Here, rather than a complicated series of barriers to transaction completion, there is only one: the fact that both I/O transaction needs require the same single modality (Complexity Issues: Walking Over Tasks). An alternative modality cannot resolve this issue, but theoretically some type of technology (e.g., a "heads up" display) might be designed so that one could at least continue to see the navigation while taking the call. That, however, raises the issue perhaps of too much distraction while driving, which would have to be considered. Also, since the transaction occurred in the car, it was clearly a mobile transaction and is unique to the mobile context as we do not need GPS while sitting at our desks and, even if we did, we would not need active GPS at that moment so would not risk "getting lost" if we had to pause our GPS activity to answer the phone.

But could technology provide simple solutions that would assist the user in the successful completion of the I/O transaction to the user's satisfaction? The answer to that question is largely dependent on the timeliness of both transactions. Consider the following scenarios:

(1) The user was on a highway on a long drive getting directions from an active GPS application. He or she knew they were not going to hit the next weigh point in those directions for a long time. In that situation, they would have no problem temporarily interrupting the GPS to take a call. Therefore, this would be considered a regular SIID, not a SCSI.

(2) Or if the user knew that the call was not of immediate importance, they could effectively ignore the call, and use ASR with Bluetooth to call the person back as soon as it was contextually appropriate to do so. Therefore, as with Scenario 1 above, this would also be considered a regular SIID, not a SCSI.
(3) If, however, the user was at a portion of their journey where many short weigh points were about to be encountered requiring complete concentration on the road and the directions, then even an unimportant interruption could represent a potentially dangerous disruption. The cognitive resources needed to dismiss the call may not be available, or may require too much time to complete, resulting in either missing an important navigation unit or, even worse, risking an accident. Still, this might be interpreted as a SIID, not a SCSI if one made the argument that technology might be developed to be more contextually aware. During this *rapid weigh point section* of the journey, the contextually aware technology would not allow calls to initiate, even perhaps sending an automated message to the caller describing the situation and offering either a time to call back or a delayed alert to the user that a call has occurred.
(4) But now consider the scenario where the user is waiting for an important phone call and the timeliness of their ability to engage in the I/O transaction is important. That call initiates during a *rapid weigh point section* of the journey. If the user (a) cannot afford to miss the call but (b) cannot afford to not pay attention to GPS and (c) is driving in an environment where they cannot easily pull over (e.g., in downtown London or New York City during rush hour), then this could clearly be an example of a SCSI.

In this last scenario, it is not the event itself, but rather the context that makes it a SCSI; in particular, the value of the transaction has an "information half-life" where it only has value to the user if it can be digested and used in a timely manner.

Another scenario from the diary excerpts demonstrates another characteristic of a SCSI:

"Needed to look up my employee ID stored in my phone but was at client bedside gowned up for contact precautions."

In this scenario, the user experienced a failed transaction that could be classified as a SCSI. The issue stemmed first from not being able to access their mobile appliance because it was not in a reachable location (Workspace/Location Issues: Inaccessible Location) and, second, perhaps because gloves were being worn on the hands (Workspace/Location Issues: Unavailable Resources). Perhaps an audio input might have been used had that modality been available and accessible, but even if it was, that would resolve one situational impairment issue and, in the process, create a new one. Audio input or output will most likely create a new SIE that did not exist before the initiation of the I/O transaction (Social/Cultural Issues: Socially Acceptable Behavior and Safety) as it is most likely socially inappropriate to deploy audio I/O due to: (1) the client being disturbed by the noise (if sleeping or if otherwise in need of a quiet environment) and (2) the fact that ID information is not for public consumption. In addition, if the information appears to be timely in nature, then any workaround that results in waiting for the appropriate resources to become available and for the context to be socially/culturally appropriate would be effectively meaningless.

Finally, there are transactions that are needed but not attempted based on the user's perception that the I/O transaction attempt will either fail or not result in a positive user experience. Consider the excerpt:

> *"Operation to get files from a secured 'cloud' service, download them to my phone with an app, then upload them to a web service is simply too cumbersome to do on the phone... If even possible at all…"*

This is an example of a SIE (Complexity Issues: Too Many Steps or perhaps Gulf of Execution/Evaluation if the "cumbersome" aspect involved inappropriate feedback), but there is more going on here. The transaction might very well have been completed, but one will never know for sure. Here the user has most likely amassed a significant interaction history, most of it not positive. As the result of similar transaction attempts in the past, the user here feels that, if the transaction is attempted presently, the result will not be a positive one, so the I/O transaction fails due to *pre-abandonment*.

As with the coding of SIID themes, each occurrence was examined, analyzed, and coded as a SIID or a SCSI and an additional inter-rater reliability test on the binary condition (SCSI v non-SCSI), was conducted. A Cohen pooled kappa score of 0.64 confirmed good inter-rater reliability.

Study 1: Discussion SCSI v SIID Differentiation – More than Simply an Inconvenience

It should be noted that for an event to be classified as a SCSI, it needed to display one or more of the characteristics described above, but not all of them. This being said, this subsection goes into a deeper analysis of how a SCSI can be differentiated from a *regular* SIID.

Implied in the characterization of SCSIs is the realization that, unlike a simple SIID, the conditions are often so overwhelming that the multitude and complexity of the ambient agents lead to transaction failure and, as a result, a design solution to overcome the impairment may not be straightforward. Consider the SIE described by a smartphone user: "*During the day while on the beach, unable to see/view my screen due to sunlight.*" This is clearly a situational impairment that can be classified as an ambient environmental issue resulting from an external meteorological condition. But is it a SCSI? The event certainly results in a transaction inconvenience, but it does not necessarily lead to transaction failure. The user could apply a simple workaround, for example, finding some way to shade their screen or simply postponing transaction completion until the ambient conditions become more favorable (e.g., cloud cover).

Future design solutions to this SIE could also come in the form of, for example, a display screen that accounts and adjusts for the ambient conditions or perhaps utilizes an alternative output modality.

However, some SIIDs are more than simply an inconvenience. Some events result in complete transaction failure where multiple outside contextual agents are collectively contributing to the disruption of the I/O transaction. The SIE that occurred while cutting the lawn (described in the previous section) can be classified as a SCSI for several reasons. First, multiple input modalities are being blocked (*touch* as the result of both hands being occupied plus the possible sweat on the user's hands and *speech* as the result of ambient noise). In addition, multiple output modalities are being blocked (*visual* as the result of the ambient meteorological conditions and *audio* as the result of ambient noise). Finally, whatever value the information might have had to the user was effectively mitigated by a combination of cognitive load and the passage of time (*"…ended up forgetting what it was"*). The resulting transaction failure in this example illustrates one of the ways that SCSIs differentiate themselves from SIIDs in general and, therefore, might carry different design implications. Each sub-element in the above example is in and of itself a SIID. As such, each sub-element might have a potential workaround or design solution. The sum product of these sub-elemental solutions, however, would not be able to solve the "Super-SIE" that is the holistic amalgamation of all event conditions existing simultaneously and within a very acute interval that does not allow for much passage of time before the information value dissipates.

In addition, some SIEs, depending on context, could either be classified as a SIID or a SCSI depending on the information half-life, which can also suggest different implications for design. The value of the information half-life is in the *eye of the beholder* in the sense that actions taken, or forgone, are dependent on each user's subjective perception of the time value of the information. If the implied information half-life was such that postponement of transaction completion was considered an acceptable workaround, the SIE is merely an inconvenience; if not, postponement becomes a transaction failure.

If the information half-life of events dissipates more rapidly, however, we might see users willing to sacrifice cultural norms or even safety. Consider the SIE described in the following user excerpt:

> "*At graduation ceremony and my niece called. She was in the hospital and had just given birth to my second great nephew. I would have not answered the phone if it was anyone else but I decided, despite where I was, to lean down and quietly answer the phone.*"

There is a clear acknowledgment in the above example that attempting transaction completion will be a violation of a perceived cultural norm. However, the present value of receiving the information output was great enough that this user was willing to risk cultural condemnation rather than accept transaction forbearance.

Sometimes, however, the *risk* resulting from a perceived rapidly diminishing information half-life may go beyond that of social embarrassment or reprimand as encountering a SIID in certain contexts could actually place the user and/or others in danger. Consider, for example, distracted driving (a type of inattention where attention is diverted from the driving task to focus on some other activity), which can be classified as either *visual* (requires one to look away from roadway to visually obtain information), *manual* (requires one to take hands off the steering wheel and manipulate a device), or *cognitive* (mental workload associated with a task involves thinking about something other than driving) (National Highway and Traffic Safety Administration, April 2010). The task of attempting to type an SMS or email message while driving would be an illustration of all three types of distraction. Even hands-free interaction (e.g., using Bluetooth to speak or input text) can still be considered a cognitive type of distracted driving (Laubheimer, 2018).

In 2015, an estimated 391,000 injuries in the USA involved distracted drivers (National Center for Statistics and Analysis, 2017). The National Safety Council estimates that cell phone-related crashes (which includes drivers texting, talking on handheld, or hands-free) accounted for approximately 26 percent of all crashes in 2014 (National Safety Council, 2015). Because of the apparent impact that mobile device usage is having on people's daily lives, popular culture is starting to use new terms like nomophobia (discomfort or anxiety caused by being unable to use a smartphone) and smartphone zombie (the looking down at one's phone while walking in public) to describe the by-product behaviors of this apparent impact (Ding & Li, 2017). Not being able to read a message may be annoying. Not being able to conduct business can affect one's bottom line, but are we literally willing to kill ourselves just to read an SMS? Is a distorted perception of information half-life as a result of the increased importance we are placing on timely completion of mobile I/O transactions at least partially to blame?

Study 1: Conclusion and Future Work

The lightning speed to which the mobile interaction paradigm has become commonplace is perhaps without a historical equivalent. This speed has most likely outpaced the design and research communities' ability to address the issues that have developed. As a result, users must overcome transaction completion issues by developing workarounds wherever possible. Research efforts have certainly explored the addressing of SIIDs and continue to do so. The research and analysis presented in this collection are meant to add a piece to this puzzle in a region of the problem space that has yet to be charted.

While SCSIs were identified and defined as "*An occurrence of a situational impairment and disability where a workaround is not available or easily obtained, or where a technological solution was found that only led to the introduction of a new situational impairment and disability*.", thereby addressing RQ3a.2 of the study as well as the second overarching research question of this dissertation arc, the workarounds employed by users, if any, were not fully elucidated, and design ideas for overcoming them were not explored. In addition, the SIID theme identified as "Social/Cultural" was unique relative to the other themes in that transaction impairment was exclusively the result of user volition. Nothing physically is preventing transaction completion, but the transaction is impaired nevertheless because the user voluntarily chose to forgo/postpone the transaction attempt. Based on the responses from the participant diaries, the researchers were able to hypothesize that there were three possible reasons for the user choosing not to complete the transaction attempt: (1) fear of reprisal from an authority; (2) acceptance of social/cultural norms; and (3) concern for safety. The scope of the study, however, produced a limitation in being able to measure motivation accurately. In other words, the study accurately identified user volition as *what* caused the transaction impairment, but not *why* the choice was made to forgo/postpone the transaction.

Therefore, in order to address more completely the first overarching research question in this dissertation, an additional study was needed to better identify the motivation behind the choices that were made and how design might account for them. In addition, to begin addressing the third overarching research question, when a user is considering how to complete a transaction while impaired and workarounds have been developed to compensate for the lack of a technological solution, do these workarounds suggest what the possible technological solutions should be, and are they different when encountering a SIID vs. a SCSI?

Study 2 (Structured Interviews and Participatory Design Workshops)

Study 2: Background and Research Questions

In Study 1, SIIDs were identified as belonging to one of five generalizable categories. In addition, within and among these categories, certain situational impairment events that were identified as severely constraining were defined and described. While Study 1 was able to catalogue and demonstrate the diversity of the SIID problem space, the steps users might be attempting in order to complete the interaction (i.e., workarounds) were not explored. In addition, further examination was needed to understand user motivations when choosing to delay or forgo interaction completion even when no physical barriers were present. Finally, due to the severity and added complexity of SCSIs, it may be important when designing for mobile interaction to examine if the user approaches the onset of a SCSI vs. a regular SIID differently.

It is clear that the use of mobile devices is common. It is also apparent that in order to maximize a user's experience, mobile design must account for not only SIIDs, but also SCSIs. Not to do so would at best create an annoyance but at worst lead to physical harm. Therefore, a second study was conducted that attempted to add to the understanding of the issues affecting users in this problem space at a greater level of depth and focus and to address the limitations from Study 1 by attempting to answer the following research questions:

RQ3b.1: What are the motivations for mobile device users either attempting or postponing/abandoning a mobile transaction during the onset of a situational impairment?

RQ3b.2: What type of workarounds do mobile device users attempt when encountering a situational impairment, and are they different in the presence of a SIID vs. a SCSI?

RQ3b.3: Can mobile technology design better account for actions attempted and the transactional needs of mobile device users while on the go during the onset of a SCSI?

In addressing the above research questions, this study also attempted to continue the examination of the issues that are represented in the first and second overarching research questions of this dissertation arc as well as addressing the third.

Part of this study was published as a "Late Breaking Work" in the conference proceedings of the 2018 CHI conference (Saulynas & Kuber, 2018). The full study was subsequently published in the Universal Access in the Information Society journal (Saulynas & Kuber, 2019).

Study 2: Methodology

In order to gain a deep understanding of both the user and the context that might influence the ability to interact in the variable and complex mobile problem space, structured interviews with mobile device users were conducted, followed by a series of participatory design workshops. Between these two steps, an interim step occurred that produced a set of rich scenarios that were deployed during the workshops. The study's five steps are outlined in Figure 1 and described below.

The participatory design approach was adapted from a method developed to support individuals with visual disabilities (Kuber, Yu, & McAllister, 2007). Participatory design comes from a research tradition emphasizing that user interaction cannot be seen independently of other conditions that may affect the activity and/or the activity's goal (Bødker, 1989). The participatory design approach also emphasizes iteration for generating ideas and solution creation through interactive evaluation by the intended users (Kuber, Yu, & McAllister, 2007).

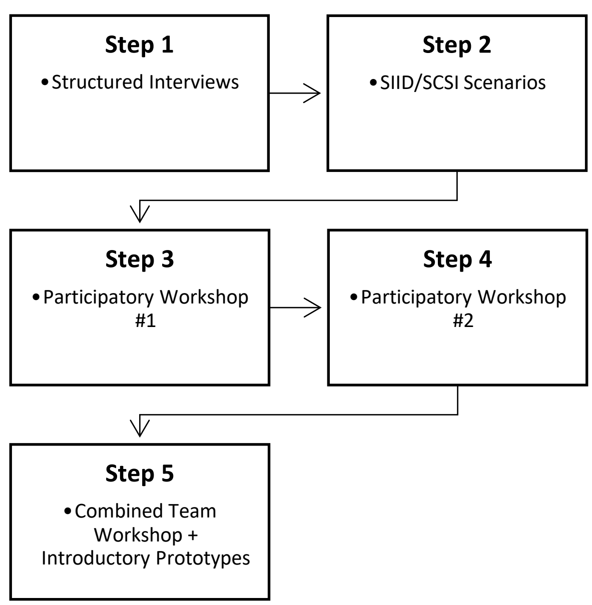

Figure 1: Study 2 Methodology Overview

Step 1: Structured Interviews

Prior to the assembling of the participatory workshops, an understanding of common mobile device tasks and, in particular, those tasks that are most affected by the presence of a situational impairment was needed. Step 1 was designed to obtain this information through a set of structured interviews with a heterogeneous sampling of smartphone users. In addition, the authors desired a sampling of the ways that users react when encountering a situational impairment. For example, if a SIID is encountered while attempting a common mobile task, is a workaround deployed to bypass the technical deficiency, or is the task simply delayed or abandoned? What are the motivations behind the forgoing/abandoning of a task, even if there are little to no physical barriers to transaction completion? Questions probed for common mobile device information activities. Additional questions aimed to shed light upon internal decision-making processes leading to execution of task steps in the presence of a situational impairment. Data collected at this stage was then supplemented with the corpus of situational impairment events collected in Study 1 and inter-rater reliability tests performed on the motivation data that was collected.

Step 2: SIID and SCSI Scenarios

Step 2 utilized data from Step 1 to develop three rich and representative scenarios showing common, meaningful, and identifiable interaction contexts involving typical mobile users encountering the onset of a situational impairment. Each scenario consisted of a SIID as well as a SCSI version to allow for the examination of the unique characteristics of a SCSI. Scenarios formed the basis of discussion for the participatory design workshops assembled as part of Steps 3-5.

Multiple workshops were used so that iteration could not only generate a broader range of possible ideas but also strengthen the ideas suggested in earlier workshops.

Steps 3-5: Participatory Design Workshops

To represent a broad swath of mobile device users, each stage consisted of a heterogeneous sampling of at least one “digital native” (high school/college age at the turn of the century) and one “digital immigrant” (born prior to digital natives) (Prensky, 2001). While use of a heterogeneous population allows non-experienced users to contribute ideas due precisely to their lack of knowledge about marketable technology (Ogonowski, Ley, Hess, Wan, & Wulf, 2013), each team was augmented with at least one domain expert (defined as someone who is an interface designer with experience of developing for SIIDs and other disabilities). The intent of the research was to explore solutions that might apply to a broad spectrum of users while maintaining verisimilitude in regard to present and perhaps near-future technology. It was hoped that the interplay of the two worldviews represented by the user groups combined with the practical and academic knowledge of the domain experts would serve to produce an effective and useful set of holistic design solutions.

The first group was designed to meet multiple times, engaging in brainstorming and discussion with the researcher, who was facilitating and allowing for design suggestions and idea reflection. Each subsequent meeting was designed to serve the refinement of ideas, eventually converging on one or two best solutions to each scenario. This iterative process enables strengthening of ideas, as well as the opportunity to suggest new ones.

In order to evaluate the validity of the first team's solution, and/or to offer further design refinements, a second heterogeneous group was convened. As with the first group, this team was a mixture of digital immigrants, digital natives, and domain experts. It is important that ideas be iterated sufficiently until data saturation is achieved. However, once that moment is obtained from one group, this does not necessarily mean that further refinement or even newer ideas cannot be achieved. Therefore, similar to Kuber, Yu, & McAllister (2007), this new team was asked not only to review the results from Step 3; they were also charged with drilling down into the solutions to obtain very specific design ideas for the various input/output modalities the solution sets call for. (e.g., if a sound is required as output feedback: How loud? How long? Speech or non-speech based?)

Lastly, a third and final participatory design team was assembled, consisting of a mixture of members from both previous teams and maintaining a similar demographic mixture. The team was shown both the current solutions and low-level prototypes representing samples of the input/output modalities for evaluation. (e g., if a sound is required as output feedback: Are the levels of intensity/duration appropriate? Does this match your expectations?) The preset stimuli were presented in these preliminary prototype designs so that design recommendations can be made with specific design characteristics.

<u>Study 2: Results</u>

Step 1: Structured Interviews

A total of 20 participants (7 female/13 male, 16 digital natives, mean age 28.6) partook in the structured interviews, which revealed a deeper understanding of user motivations for workaround and postponement/abandonment. Oft-cited events from the events corpus in Study 1, where a SIID occurred because the user consciously chose not to attempt interaction due to the presence of one of three legally or socially unacceptable contexts (driving, on public transport, or at a public performance/meeting/lecture), were presented. Participants were then asked if they ever wanted to interact with their smartphone using their hands while in each of these three unacceptable contexts, but they chose not to do so. Specifically, for each of these contexts, they were asked: (1) Whether they ever chose not to engage in the interaction; (2) If "yes", could they list the reasons for their transaction forbearance; (3) Have they ever done it anyway; and (4) If "yes", could they list the reasons why they "overrode" the forbearance reasons listed in (2) above. The results were both confirming and at times worrisome.

For (1), all 20 participants indicated that they chose to forgo or abandon the transactions for most or all of the contexts. As suggested by the sub-themes for the Social/Cultural issues defined in Study 1, participant responses for (2) reflected concern for either (a) socially acceptable behavior, (b) safety, or (c) fear of reprisal from an authority. A subset of examples appears in Table 1 of Appendix B. The responses were coded, and none were determined to reside outside of the three sub-themes for Social/Cultural situational impairments defined in Study 1. Each context was analyzed separately for inter-rater reliability, with all calculating to a Cohen's Kappa score above 0.6, indicating good agreement among reviewers. Because the responses helped reveal user motivation, these findings helped confirm the initial findings of Study 1 (that Social/Cultural situational impairments can be classified by one of three sub-themes) as well as substantiate RQ3b.1 (motivations for postponing/abandoning mobile transaction attempt during a situational impairment).

Perhaps the most interesting and potentially significant finding occurred when asked whether they ever overrode their forbearance "rules" and attempted a transaction anyway. For every context that was applicable, ***100% indicated that they have overridden*** their own rules. The same participant, for example, who offered the histrionic "*accident, death…*" response for the driving context referenced in Table 1 of Appendix B, when asked if they did anyway, responded (without hesitation), "*Oh yeah!*" Reasons varied from a sense of urgency for transaction completion to just plain boredom. Some of the reasons offered appear in Table 2 of Appendix B. These results add further depth to the understanding of user motivation as well as highlight the potential importance of discovering ways technology can help mobile transaction completion without putting lives of users (and others) in danger.

Step 2: SIID and SCSI Scenarios

As Study 1 helped define, SCSIs are "a*n occurrence of a situational impairment and disability where a workaround is not available or easily obtained, or where a technological solution was found that only led to the introduction of a new situational impairment and disability*." They were further described as possessing one or more of five characteristics: (1) a "Super" Situational Impairment Event, (2) Expiration of Transaction "Half-Life", (3) Solution to One SIID Produces New SIID, (4) Competing Modal Transactions and (5) Pre-Abandonment.

The interview responses along with the situational impairment corpus created in Study 1 were used to construct three rich situational impairment scenarios (driving, at the movies, and cooking). The scenarios and rationale behind their creation appear in Table 3 of Appendix B. These three scenarios were used by the participatory design workshops in Steps 3-5.

The scenarios represent situational impairment events in contexts that are meaningful to a typical user. By representing some aspects as intensified, this study, through the participatory design sessions, attempted to determine whether users (1) cannot deploy an acceptable workaround that would overcome a SCSI when it presents (RQ3b.2) and (2) confirm the need for special design considerations and recommend design solutions for SCSIs (RQ3b.3).

Step 3: Participatory Design Workshop #1: Sessions Summary

Workshop #1 convened for two separate sessions. Session 01 consisted of five participants (two digital natives, two digital immigrants, and one domain expert, mean age 38.8). Session 02 was without one of the digital immigrants who was unable to attend. In the initial session, each participant brainstormed the ways (modalities) that one can interact with a smartphone, writing ideas down separately to promote free flow of thought without being biased by the ideas/opinions of others in the group. The SIID for each scenario was presented first and the group worked on design solutions, first separately, then by comparing their individual ideas and working towards a consensus for viable solutions. By the end of the session, the group produced a list of ideas for each SIID and SCSI version of the three scenarios. This list was to form the starting point for Session 02.

Session 02 resulted in a convergence on one solution that offered the greatest potential for overcoming the transaction barriers represented by each scenario. The

Session 02 focus was on the refinement and/or revision of the ideas from Session 01. The group was asked/encouraged to consider the best solution to each scenario (even if that solution involved a non-technological workaround or transaction forbearance). What started to emerge from the solution set is a clear distinction between the participants' solutions for the SIID vs. the SCSI versions of the scenarios. In particular, it was apparent that the SIID solutions involved either utilizing an existing technological solution (or with minor enhancements) or simple transaction forbearance.

Driving Scenario

For the SIID, the group systematically eliminated solutions from the previous session where a flaw was noted and concluded that the best course of action would be automatically connecting the smartphone via USB or Bluetooth connection to the console prior to departure and then controlling the GPS app with voice or minimal touch. For the SCSI, the group moved to a solution where calls should go to voicemail while using navigation with (1) an enhanced reminder/notification banner that will allow the user to override if conditions are safe and (2) certain contacts getting a contextual voicemail with additional information (e.g., estimated arrival time, current location). Depending on the phone location, the modality could be touch or voice.

Movie Scenario

For the SIID, after brief discussion, the group concluded that the workaround of simply postponing the transaction reflected the most reasonable solution. Without the confounding factors represented in the SCSI, this transaction could simply wait to be completed. For the SCSI, the group directly took to the idea of custom vibrations for those on a “VIP-priority” list of contacts (similar to the solution to the driving scenario). Vibrations could be delivered to the phone or perhaps a secondary device like a smartwatch. The discussion included suggestions of the types of vibrations that may be used (e.g., varying in intensity based on level of importance) or even a contextually appropriate sequence of sensations (e.g., pulses that simulate a heartbeat from a contact related to an impending birth).

The group seemed to be settling on a solution where, upon recognizing the alert as important, they would then excuse themselves from the theater to complete the transaction. The researcher at this point suggested that this would still not solve the social/cultural issue of having to disturb other theater patrons. The group seemed adamant that, given the circumstance, it would be culturally appropriate to bother people. The researcher then redirected the discussion by suggesting that they might be giving up too easily and perhaps brainstorm a little bit more to see if a solution can be derived where one does not have to settle for second best. This then led to a discussion of contextual awareness. The group saw the advantages of incorporating contextual awareness technology (e.g. a geo-fence), which could allow the user’s mobile appliance to know (1) that they are in a movie theater complex, (2) which theater in that complex they were in, (3) what movie was being shown in that theater, (4) the length of the movie, and (5) how much of the movie has transpired. This information then could be incorporated to provide essential information that could be used to send an appropriate contextual response.

Cooking Scenario

There was only one SIID cooking scenario solution that resulted from the first session, so after briefly considering it and the merits of other simple possibilities, the group stayed with their original solution of using voice as an alternative input modality to record the idea using a Voice Activated Personal Assistant (VAPA) such as Siri or Alexa. For the SCSI, consensus was reached on the use of a secondary device that works in conjunction with other connected devices (e.g., speaking into a Bluetooth headset or having smart kitchen appliances). Having all these elements work in conjunction could support recording the note and could assist by, perhaps, pausing noise or cooking processes to make it easier to get the task done.

Step 4: Workshop #2: Session Summary

Workshop #2 was convened for a single session and consisted of four participants (two digital immigrants, one digital native, and one domain expert, mean age 42.5) and was charged with examining each scenario as well as the solution set from Team 01 to offer any modifications to the existing solutions or to suggest alternative ideas. As was true from the first group, at the conclusion of the session the solutions/modifications offered continued to show a clear distinction between how a SIID and a SCSI are to be resolved. The second group offered some modifications to the first group's solution set as well as specific qualities for the modalities used in the solution.

Driving Scenario

For the SIID, this group after discussion agreed that the Team 01 solution is the best but built on the solution by suggesting that, rather than simply connecting, the user is notified and is asked if they want to connect the device. Also, for safety reasons, it was suggested that the system needs to recognize that the car is in parked gear (to eliminate the possibility of this being attempted while driving or at a stop light). For the SCSI, the group moved to a modification of the Team 01 solution that involved the contextual message being sent as well as getting rid of the phone call, but not automatically. Instead, the group came up with a creative idea whereby the user would employ the steering wheel as a binary, single-touch input device to cancel the call and initiate the voicemail message. The rationale for their idea was based on the logic that the technology could realize that GPS is on but also that a phone call is being initiated. Because both conditions are true, the vehicle could recognize the squeeze as canceling the new input. They also noted that the wheel should immediately vibrate to confirm that the call cancellation took place. The haptic feedback should be intense enough to be felt while driving and quick enough for the brain to know that something was done, but not so long as to add to cognitive load.

Movie Scenario

There was general agreement with the Team 01 solution of ignoring the call for the SIID piece of the scenario. For the SCSI, Team 02 agreed that contextual awareness from the technology available to the user was important. They added a novel suggestion for the use of a secondary device to receive/reply to the message that utilized the cultural affordance associated with the use of a wristwatch. The rationale stemmed from the fact that it is common, even during a public performance like a movie, play, or lecture, to look at one's watch without it representing much of a distraction (if at all). They could then see the message (or the phone number that is calling) and, with minimal touch or using a flick gesture, initiate the contextually aware response with minimal to no social disruption. To reduce the cognitive load of having to interpret multiple haptic sensations, the group stressed that there only be two sensations: (1) a "normal" vibration and (2) a vibration representing "importance". When the researcher prompted for how "importance" should be represented in a haptic response, the consensus solution was that many, rapid staccato pulses would be appropriate. The domain expert and the digital native both noted, however, that haptic engines could be made so that they do not vibrate the chassis of the watch.

Cooking Scenario

For the SIID, Team 02 agreed that the Team 01 solution matched user needs. For the SCSI, the discussion was predominated with the use of some sort of "stylus" that would allow input onto a smart surface of some sort. In addition to such a stylus being a viable alternative if voice was not available, Team 02 noted that sometimes ideas are not represented well with words (e.g., a piece of music or a sketch). The group settled on the use of ordinary utensils (i.e., whatever is currently being used in the cooking process or is readily available) as a stylus for recording the note on some type of smart surface.

Step 5: Combined Group Session Summary and End Solutions

The final team with members from each of the previous groups met to offer a final review of the ideas put forth, to reconcile any differences between the solution sets, and to test some basic prototypes that represented some of the offered design solutions. The final team consisted of the two domain experts from each of the previous sessions as well as a digital native (Workshop #2) and two digital immigrants (Workshop #1). Where the individual teams' solutions differed, the combined team was charged with attempting to reconcile the differences to arrive at one, unified consensus solution for each scenario. In addition, the researcher conducted a preliminary usability test on the effectiveness and usefulness of some of the modalities suggested in the solutions. For the usability test, a crude prototype of the haptic sensations was reproduced using the free Contact Vibrate app (Contact Vibrate). For each of the driving and movie scenarios, a haptic sensation, based on the specifications from the design sessions, was created. For the cooking scenario, a common cooking utensil (spatula) was used to allow the participants to simulate the attempt at using the utensil as an ad hoc stylus during the cooking process. There was very good interaction between the two subgroups as the combined team attempted to reach a reconciliation point between the two solution sets.

End Solution: Driving Scenario

For the SIID, the combined team reached a consensus by agreeing that the solution suggested by Team 01 be accepted as amended by the modifications suggested by Team 02. For the SCSI, after a debate as to how to reconcile the feedback for when a call is canceled in the context of this scenario, it was agreed that using the entire wheel was the best choice. The rationale was simply that it cannot be assumed that the driver has their hands at any specific position on the wheel, or even any specific range of positions. Only with the entire wheel being the input device could the capturing of an input during a period of high and cognitive overload be universally achieved. The group also came to the realization that there is no need to present any additional feedback to confirm that input was received. Since the scenario was of a mobile task overriding another mobile task (phone call interrupting navigation), when the phone call went away and the GPS directions returned, that alone would provide sufficient feedback that the call had been canceled. Since this fact was incorporated into the end solution, the usability test on the haptic feedback was canceled.

End Solution: Movie Scenario

For the SIID, the group reached a consensus on the original Team 01 solution of simply ignoring the call. For the SCSI, the Team 01 solution as amended by Team 02 was accepted. Each user then was asked to test the prototype to assess whether it represented the concept of "importance". The rapid staccato pulse that was specified during the Team 02 session was tested. All participants were satisfied that a rapid, staccato pulse as presented accurately represented the concept of "importance" and thus would be distinct enough to be adequately discerned even when engaged during a movie.

End Solution: Cooking Scenario

For the SIID, all were reconciled that using voice command to activate note application through a phone or a smart speaker represented the best solution, especially as it is a currently available option. For the SCSI, the central point for reconciliation revolved around cognitive load and time sensitivity for both tasks, which of course was the central theme of the scenario. Participants from both subgroups began to question whether they would have time to enter a complete thought, sketch, etc., quickly enough as to not mess up the cooking process (by either forgetting a step or delaying execution of a step). The solution eventually became to create a quick, audible placeholder for the ideas or, if voice was not feasible, then to use the ad hoc appliance to create a quick placeholder note. The participants came to the realization that the key to solving this problem would be to get by that "critical juncture" in the cooking process which most likely would be a few seconds to a minute. Once that passed, the user would then be freer to pause the cooking task and complete the note so that the complete note could be delivered in two or more stages. Participants simulated cooking and then attempted to write a quick note using the ad hoc stylus in their hand for the test. All agreed that this represented the best option, particularly in this scenario, as the input could be achieved quickly, whereas washing hands in order to interact with traditional electric input devices would take too long.

Study 2: Discussion

In reviewing the solution to the three scenarios from the latter portion of this study, as well as the results from the structured interviews, three distinct implications for design emerged.

All mobile users will, at times, feel a need to complete transactions "at all costs"

As data from the structured interviews show, mobile device users (whether digital immigrant or digital native) are literally risking their lives to complete mobile I/O transactions. All participants indicated an understanding of certain contexts where interacting with a mobile appliance can be unacceptable or dangerous. This is consistent with recent research such as Moser, et al. (2016), who showed that attitudes towards social/cultural norms could play a factor in the willingness to forgo mobile interaction. However, even though 100% of the participants acknowledged the existence and value/purpose of the *thou shalt not* rules, those same humans, without exception, indicated that they willingly at times ignore these rules just to complete a mobile transaction.

In addition, the results of the interviews indicated that the *thou shalt not* rules that users follow when voluntarily choosing to forgo a transaction in certain contexts fall into one of the three sub-themes for the "Social/Cultural Issues" theme defined in Study 1. This lends further support for the addressing of RQ1.1.

Cognitive load is a significant factor distinguishing a SCSI from a regular SIID

The SCSI solution sets from the workshops illustrate the need to address the diverting of cognitive (or cognitive + physical) resources from another task (i.e., driving or walking) in order to complete a mobile transaction. As described by previous research such as Marshall & Tennent (2013), along with changing environmental conditions, cognitive load represents a compounding, or at least aggravating, factor to task completion that is not present in examining transactions with the desktop paradigm. Sending an email using a desktop computer, for example, requires no added cognitive load or physical task to be accounted for, other than the keyboard/GUI interaction needed to complete the task. In addition, because the interaction is taking place in a private or semi-private space, no environmental situational awareness is required. Finally, because typing and clicking are relatively silent modalities, there is at best only a minimal level of social/cultural consideration that must be accounted for. The mobile user attempting the same task must also account for the variable nature of all the exogenous variables that exist outside of the task and the interface required in completing the task. One's zone of control is changing or moving, thereby requiring the deployment of cognitive resources to maintain the situational awareness required to account for anything or anyone that might come into that zone of control. Current solutions seem to fall short of providing the optimal/safest user experience because they do not adequately recognize the true potential complexity of the mobile transaction space (such as the SCSI scenarios represented in this study) which helps illustrate the importance of differentiating a SCSI event from and SIID event when designing for mobile interaction. This differential in what users indicated they want/need to complete a mobile interaction in the presence of a SCSI as opposed to a "normal" SIID also further supports the addressing of RQ1.2.

Importance of context awareness in designing for SCSIs

Some suggestions developed from the workshops show that non-technological workarounds could be an acceptable response for at least a SIID (perhaps with a notification indicating that an event had happened). However, what also became clear, especially for the SCSI scenarios, was the mobile user's desire for better technological context awareness. This study's workshop teams felt that technology should (1) recognize the context of the situation, (2) assess the best course of action given the environmental context, and (3) execute the steps necessary to complete the best course of action with minimal to no in situ input from the user.

This need to offload information from our working memory is not without analogy in the analog world. When we are temporarily physically or cognitively overloaded, we often turn to a human ally for assistance. A personal valet or office assistant often helps their employer by managing the minutiae of their day which frees the employer to focus on higher order tasks and problem solutions. However, there are limitations to human assistance that are not present in technology. As Holland and Stornetta (1992) once noted, we can design interaction to be as close to emulating human-to-human interaction as possible or we can take advantage of the strengths of the computer to help overcome human limitations and enhance/complement human-computer interaction. One benefit of a non-human assistant is that we do not have to have concern for their feelings, their stress, or their rights. Our only concern is for the limitations of the technologies' capacity and capabilities.

If mobile technology is to continue to be able to support users, it needs to adopt a greater assistive role. The results from the workshops of this study highlight that users need mobile technology to be more context-aware and anticipative in order to begin to solve the problem of "Severely Constraining Situational Impairments" so that users can be not only safe and productive, but also satisfied. This further supports recognizing the design implication differences of a SIID vs. SCSI event for designers of mobile interaction and begins to support the addressing of RQ1.3 as well as offering further support for the addressing of RQ1.2

Chapter 3 Summary

The two studies reviewed in this chapter represent the first two legs of a research arc designed to lead to actionable guidelines for the design of mobile device interaction in the presence of a SIID regardless of type and degree. The first study defined five themes for the categorizing of situational impairment events and revealed the existence of SCSIs (defined as: "*An occurrence of a situational impairment and disability where a workaround is not available or easily obtained, or where a technological solution was found that only led to the introduction of a new situational impairment and disability*") and further described as possessing one or more of five characteristics detailed in the "Study 1: Results" section of this chapter. The defining of five situational impairment themes as well as SCSIs, thereby addressed the first and second overarching research questions of this dissertation arc.

The second study revealed that users are attempting to overcome current design limitations, sometimes at any cost, in order to complete mobile transactions in a timely manner, and that the challenges that are more severely constraining might require different design considerations from those of their nominally constraining siblings. Therefore, Study 2 provided additional support for the first two overarching research questions, as well as beginning to address the third.

These studies produced important implications for design, but not specific actionable design guidelines that can be offered to designers of mobile device interaction. The design implications generated from the research to date are somewhat generalized. They do not offer much in regard to specific insights on how researchers and app developers should consider the design of mobile applications to accommodate SCSIs or SIIDs in general. Therefore, a final study will be conducted, as will be described in the next two chapters.

Chapter 4: In Search of Guidelines for the Addressing of Various Types of Situational Impairment Events (Methodology and Results)

Introduction and Research Questions

The initial study within this research arc (Chapter 3), through indirect observation and follow-up solicitation, discovered what types of SIIDs were affecting users. The second study within this research arc (Chapter 3) helped better understand what users do during an SIID event, and how they would like technology to be designed to address, or at least mitigate, the effects of SIIDs and SCSIs when they occur. Therefore, having determined what is happening to users when attempting a mobile transaction *in the wild* (Study 1), and what is desired by users to address the onset of SIID/SCSI events (Study 2), what next was needed was a set of guidelines for designers of mobile interaction to follow.

The need for guidance in the situational impairment domain is timely as it is believed that little to no guidance for the addressing of various aspects of situational impairments currently exists (Macpherson, Tigwell, Menzie, & Flatla, 2018), (Sarsenbayeva, 2018). After an initial brief literature search, it was determined that there currently indeed exists a paucity of guidance for designers when it comes to developing for interactions that can mitigate or even eliminate the effects of a situational impairment event.

The final study in this research arc, therefore, was designed to at least begin addressing this gap. Nicolau (2012), suggested that there may be a unified set of solutions that, while specifically designed to address health-induced impairments, can be applied to situational-induced impairments as well. Nicolau's work specifically sought to explore issues of motor impairments (e.g. tremors) in relation to similar SIID situations. This present study drew upon materials (best practices) from studies with individuals with other disabilities to see if these hold for all SIID events. Through a series of explorations, this study resulted in the creation of the first dedicated set of mobile interaction design guidelines for addressing SIID and SCSI events. It, therefore, spoke to the final research question within this dissertation research arc: RQ1.4 (Can new guidance be created and can existing guidance be strengthened to better account for the presence of situational impairments faced by users of mobile technology?).

This study approached this issue in two stages. In the first stage, an exhaustive review of interaction literature in parallel and/or related domains was conducted (see the "Stage 1 Methodology" and "Stage 1 Results" sections of this chapter). For example, as was suggested in Nicolau (2012), if there truly is an absence of direct SIID/SCSI guidance, perhaps some solutions can be gleaned from research that has created recommendations towards designing for those experiencing chronic and/or more permanent impairment issues. Consider a scenario where a mobile device user cannot read output from their device due to ambient condition interference (e.g., bright sunlight), that user is in effect visually impaired for the duration of the ambient event in regard to completing their mobile interaction. If guidelines are in existence that address interaction issues for users who are blind or visually impaired, perhaps these guidelines could influence design for interaction scenarios where the visual impairment is situational.

The study then proceeded to the second stage, which refined and validated the preliminary list of SIID/SCSI guidelines derived from the literature review using a novel adaptation of a consensus-seeking process known as the Delphi Method (see the "Stage 2 Methodology" and "Stage 2 Results" sections of this chapter). A panel of experts in both mobile device design and research were asked to evaluate the draft guidelines by mapping and then rating each guideline. This resulted in a final list of guidelines, determined through consensus of the experts. The guidelines mapped to each of the five SIID themes defined in Study 1, as well as SCSI characteristics as these themes represented the breath of possible situational impairment events that could occur based on the Study 1 findings.

The sections that follow will outline the two-stage process that was conducted. The next section outlines the methodology used for the first stage of the study (the systematic literature review) and is followed by the section that reviews the results of that literature review. The two sections that follow then outline the methodology and results for the second stage of this study (Delphi method), the results section of which will culminate in the curated set of validated guidelines for addressing situational impairments (thereby addressing RQ1.4).

Stage 1 Methodology (Systematic Literature Review)

A systematic literature review analyzes existing research using explicit, accountable rigorous research methods involving four key activities: (1) clarifying the question being asked; (2) identifying and describing ("mapping") the relevant research; (3) systematically and critically appraising the materials and bringing together the findings into a coherent statement (synthesis); and (4) establishing what evidence claims can be made from the research (Gough, Oliver, & Thomas, 2017). As opposed to primary studies (designs of methodology to test hypotheses directly and evaluate them under well-established conditions of control), a systematic review is conducted with the intent of producing comparisons, scientifically selected from a set of primary studies, to allow for the creation of generalizations from them (Biolchini, Mian, Natali, Conte, & Travassos, 2007).

One of the purposes suggested by Kitchenham & Charters (2007) for undertaking a systematic literature review is to provide a framework/background in order to position new research activities appropriately. In a similar vein, the systematic literature review conducted in Stage 1 of this study attempted to provide a corpus of both direct and indirect examples of guidelines that might address the issues represented when a situational impairment presents during mobile device interaction. That corpus was then phenomenologically analyzed to determine whether generalizable themes could be gleaned. This resulted in the framework/background that led to the set of draft guidelines that were then presented to a panel of experts in Stage 2.

Process is important for a systematic literature review to be effective and should be undertaken in accordance with a thorough and fair predefined search strategy or it is of little scientific value (Kitchenham & Charters, 2007). With this in mind, the process used in this study was similar to the process used in Groenewald et al. (2016), which was based on existing successful applications in HCI and Software Engineering such as Biolchini, Mian, Natali, Conte, & Travassos (2007), Gough, Oliver, & Thomas (2017), and Kitchenham & Charters (2007). The process that was implemented is outlined in Figure 2 and described in greater detail in the sub-sections below.

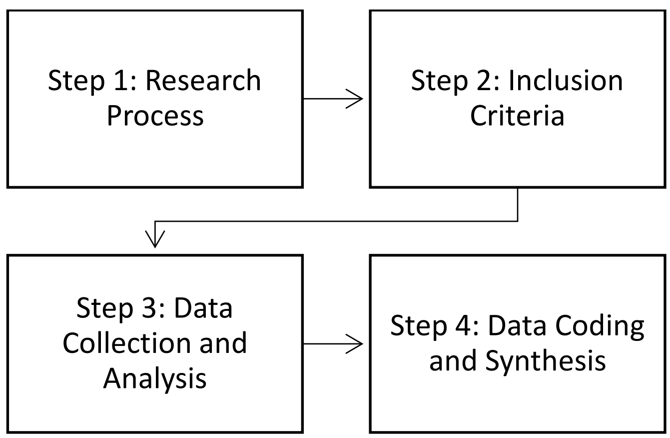

Figure 2: Outline of the Systematic Literature Review Process

Step 1. Research Process

The process utilized two features: (1) databases and (2) keywords. Three primary databases were initially considered: Google Scholar, ACM Digital Library, and IEEE Xplore. Google Scholar was later dropped as it was discovered that the vast majority of hits per search term were not relevant and that many of the relevant hits in Google Scholar search were also appearing in one of the other database searches. This redundancy made the incorporation of Google Scholar searches impractical due to the ratio of hits that were generated to the actual number of unique relative hits that were anticipated.

The keywords used were generated based on a systematic approach similar to what was used in Anthony, Kim, & Findlater (2013). It was imperative that the researchers could first confirm that minimal direct situational impairment guidelines were in existence. Therefore, one set of keywords used situational impairment-related terms (e.g., situational impairments, SIID). Then keywords relating to mobile interaction in general (e.g., mobile interaction, mobile device, smartphone) were used to see if any guidelines existed for mobile device development that might be applied to SIID. To determine whether research in other impairment communities might offer guidance in addressing situational impairments, terms describing assistive technology (e.g., accessibility, assistive technology, disabilities, visual impairment, cognitive impairment) were also used. Other keywords through backward snowballing using references found in hits from the above, as was similarly performed by Groenewald et al. (2016), were added as dictated by the process flow. Finally, keywords were then paired with generalized terms such as “guidelines”, “principles”, or “recommendations”, which resulted in an exhaustive set of search criteria for every relevant combination of terms.

Step 2. Inclusion Criteria

One of the preliminary goals of Stage 1 was the amassing of a corpus of guidelines from relevant domains. As such, the criteria for inclusion utilized sources that offer any reasonable set of guidelines that could either directly or by inference relate to solving one or more of the SIID or SCSI characteristics defined in Study 1.

Some sources may not refer directly to guidelines but nevertheless offer guidance of some form. All sources were peer reviewed and consisted of a variety of research literature including results from empirical testing, as well as suggestions from authors based, perhaps, on their prior experience developing accessible solutions, or based upon their intuition. All were judged on a case-by-case basis and, if deemed to offer content that might be constructed or reconstructed as a set of relevant guidelines, they were added to the corpus. The process was designed to end when data saturation — or the point in the process when additional discovery becomes redundant, reasonably assuring that further data collection would only yield similar results (Faulkner & Trotter, 2017) — was achieved. How, when, and to what degree data saturation was achieved is reported in the final results.

Step 3. Data Collection and Analysis

Papers were extracted, and each was analyzed for adherence to inclusion criteria. If it met the criteria, two actions were performed:

1. A bibliographical entry was created and catalogued to include the relevant domain(s) to which the research applied and relevant keywords.
2. The source content that contained guidelines was then added to a corpus database of guidelines for later coding and analysis.

Step 4. Data Coding and Synthesis

Each extracted guideline was coded using a qualitative content analysis similar to what was used in Study 1. The classified and catalogued set of guidelines was then examined to determine which guidelines are duplications and/or could be consolidated. The process continued until a final set of developed draft guidelines was synthesized and prepared for Stage 2.

Stage 1 Results (Systematic Literature Review)

Step 1 Research Process

Starting with a sampling of papers, a program was run that tallied the frequency of words used. This was used to help comprise a selection of possible search terms to consider. The list of possible search terms fell into one of three generalized domains: (1) Mobile Device Interaction, which included automobile interaction (e.g., “mobile device”, “smartphone”), (2) SIID (e.g., “situational impairments, “SIID”), and (3) Accessibility and Assistive Technology (e.g., “motor disabilities”, “visual impairments”). This resulted in 31 unique search phrases that were then paired with each of five “guideline”-related terms (guidelines, principles, recommendations, frameworks, and heuristics) to form a 31×5 matrix totaling 155 individual search phrases. For example, the impairment category “mobile interaction” was paired with each of the five guideline-related terms to produce the search phrases, “mobile interaction guidelines”, “mobile interaction principles”, etc.

After some initial search runs, and as was similar to what was discovered with the initial use of Google Scholar as a database, much redundancy was revealed in both the domain phrases as well as the guideline-related terms. For example, it was found that when searching more generalized terms such as “accessibility” or “assistive technology”, some of the hits were addressing the general term, but many others also addressed more specific criteria (e.g., hearing impairments, cognitive impairments). In addition, it was discovered early in the search process that some of the “guideline” modifying terms were also resulting in either redundancies or irrelevant hits. For example, it was discovered that the modifier “frameworks” was often generating hits that were more along the lines of technical specifications than of generalizable guidelines. The few that proved relevant were also found in searches using more relevant modifiers such as “guidelines” or “recommendations”. Finally, as the result of backwards snowball sampling, it was determined that the qualifier “requirements” needed to be added to the list of domain modifiers. Also, the key phrase “universal design” was added to the list of key phrases and incorporated into the Accessibility and Assistive Technology generalized domain.

As a result, a final total of 18 unique search phrases were used within a revised 6×3 matrix, as shown in Table 1 below.

	Guidelines	**Recommendations**	**Requirements**
SIID	SIID Guidelines	SIID Recommendations	SIID Requirements
Situational Impairment	Situational Impairment Guidelines	Situational Impairment Recommendations	Situational Impairment Requirements
Mobile Interaction	Mobile Interaction Guidelines	Mobile Interaction Recommendations	Mobile Interaction Requirements
Accessibility	Accessibility Guidelines	Accessibility Recommendations	Accessibility Requirements
Assistive Technology	Assistive Technology Guidelines	Assistive Technology Recommendations	Assistive Technology Requirements
Universal Design	Universal Design Guidelines	Universal Design Recommendations	Universal Design Requirements

Table 1: Complete list of search terms used for the systematic literature review

<u>Steps 2 and 3: Inclusion/Exclusion Criteria and Data Collection</u>

A total of 56 searches were conducted. Using each of the 18 search phrases from the table above on each of the two databases (ACM and IEEE) resulted in 36 of the 56 total searches. The results from an additional 20 searches are included as they were conducted using “principles”, “frameworks”, and “heuristics” as modifiers for

"SIID", "Situational Impairments", and "Assistive Technology", respectively, yielding 18 (3×3×2) result sets, as well as "principles" + "Accessibility", which yielded an additional two. These additional hits represent results before the researchers determined that the use of these modifiers was not yielding truly unique and pertinent results. Nevertheless, since data was collected, as it may have represented data that would have resulted from other searches conducted later, it was decided to include these results in the total.

A total number of 348,926 raw hits resulted from the 56 searches. The studies found/used were almost exclusively classified as either conference proceedings or peer-reviewed journal articles. Where there was an exception to this rule, it was a piece taken from a periodical ACM or IEEE publication (e.g., Wobbrock, et al, 2011 which came from the *ACM Transactions on Accessible Computing*). As is shown in Table 2 below, nearly two-thirds of raw hits (65.40%) came from the Accessibility/Assistive Technology generalized search domain.

	Total	**% of Total**
Accessibility/Assistive Tech	228,190	65.40%
Mobile Interaction	119,491	34.25%
SIID/Situation Impairments	1,245	0.36%
Total Search Results	*348,926*	

Table 2: Breakdown of raw search results by generalized domain

Also, as was hypothesized, of the nearly 350,000 raw search results generated, search phrases that incorporated "SIID" or "situational impairments" only accounted for 0.36% of the total. Table 3 below shows the raw hits for each search phrase used also broken down by database.

Search Phrase	Raw Hits (ACM)	Raw Hits (IEEE)
Accessibility Guidelines	1,021	7,893
Accessibility Principles	3,762	16,377
Accessibility Recommendations	1,346	7,628
Accessibility Requirements	11,102	30,161
Assistive Technology Frameworks	1,039	4,304
Assistive Technology Guidelines	311	1,555
Assistive Technology Heuristics	86	313
Assistive Technology Principles	386	3,399
Assistive Technology Recommendations	415	1,236
Assistive Technology Requirements	1,667	5,407
Mobile Interaction Guidelines	480	15,089
Mobile Interaction Recommendations	865	17,266
Mobile Interaction Requirements	2,987	82,804
SIID Frameworks	0	35
SIID Guidelines	0	5
SIID Heuristics	0	4
SIID Principles	0	54
SIID Recommendations	0	11
SIID Requirements	1	65
Situational Impairment Frameworks	16	259
Situational Impairment Guidelines	7	133
Situational Impairment Heuristics	0	26
Situational Impairment Principles	8	168
Situational Impairment Recommendations	8	108
Situational Impairment Requirements	32	305
Universal Design Guidelines	2,433	12,639
Universal Design Recommendations	3,342	12,316
Universal Design Requirements	23,477	78,337

Table 3: Breakdown of search results by search phrase and by database

In cases where the total number of raw hits was relatively low (e.g., ACM hits for "Situational Impairment Recommendations" or IEEE hits for "SIID Requirements"), no filtering of the data set was applied as the result set was small enough to access. For the result sets that had a larger number of hits, various filter conditions were applied to reduce the consideration of irrelevant results. For example, searches were filtered to include only work published in the 21st century. In addition, various filter words/phrases were added to exclude clearly irrelevant topics (e.g., robot, computer-aided instruction, security of data, government data processing, educational courses, and groupware). Also, searches that resulted in hits that represented books, standards, and courses were filtered from consideration.

Of the remaining hits (which were sorted by relevance by each database), each title in order of relevance was considered. Titles that reflected obvious non-sequitur subjects were not considered. Titles that required payment or subscription to gain access were also excluded from consideration.

Finally, even after applying filtering criteria, the volume of some of the search results was still somewhat large. For example, for the search phrase "Mobile Interaction Requirements", the IEEE database returned 82,804 raw results (see Table 3 above). After applying filtering criteria, the result was 15,220. Because the results were sorted in each database by relevance, meaning that the amount of useful hits was top heavy, some searches were terminated after the first 200-500 results if it became apparent that few, if any, relevant hits were being discovered beyond a certain point.

Papers where the title suggested there might exist some set of guidelines or related content that was pertinent to one of the four domains being analyzed were afforded additional consideration. Abstracts that explicitly noted the piece included a set of guidelines, requirements, and/or recommendations were read and any relevant data was extracted to a guidelines database for later coding. If no explicit references to guidelines/requirements/recommendations were found in the abstracts, the paper was still scanned and, if found to contain anything that constituted a set of guidelines/requirements/recommendations or perhaps simply some “implications for design”, the relevant data was extracted to a guidelines database for later coding.

The final number of papers from which guidelines were extracted was 285 (169 from the ACM database and 116 from the IEEE database). The breakdown of papers used by generalized domain appears in Table 4 below.

	Total	% of Total
Accessibility/Assistive Tech	213	74.74%
Mobile Interaction	43	15.09%
SIID/Situation Impairments	29	10.18%
Total Search Results	285	

Table 4: Papers used by generalized categories

As was the case with the total raw search results, the vast majority of the papers used (74.74%) were obtained from Accessibility/Assistive Technology domain-related searches. The number used per search term deployment appears in Table 5 below.

Search Phrase	Used Hits (ACM)	Used Hits (IEEE)
Accessibility Guidelines	30	6
Accessibility Principles	5	10
Accessibility Recommendations	15	1

Accessibility Requirements	11	12
Assistive Technology Frameworks	9	6
Assistive Technology Guidelines	12	9
Assistive Technology Heuristics	3	6
Assistive Technology Principles	6	3
Assistive Technology Recommendations	3	6
Assistive Technology Requirements	19	8
Mobile interaction Guidelines	16	14
Mobile interaction Recommendations	5	2
Mobile interaction Requirements	4	2
SIID Frameworks	0	0
SIID Guidelines	0	1
SIID Heuristics	0	0
SIID Principles	0	0
SIID Recommendations	0	0
SIID Requirements	0	0
Situational Impairment Frameworks	2	5
Situational Impairment Guidelines	5	4
Situational Impairment Heuristics	0	0
Situational Impairment Principles	1	3
Situational Impairment Recommendations	1	3
Situational Impairment Requirements	3	1
Universal Design Guidelines	16	3
Universal Design Recommendations	1	4
Universal Design Requirements	6	3

Table 5: Breakdown of papers used by search phrase and database

Step 4: Analysis, Data Coding, and Draft Guidelines

Corpus Extraction Statistics and Classifications

The goal of the extraction task was to create a corpus of items that would eventually become the draft guidelines to be presented to experts in Stage 2. This extraction was to be performed by identifying data from the 285 pieces of literature gathered in Steps 1-3 of Stage 1 that might represent a potential guideline towards the addressing of a SIID and/or a SCSI. In looking for existing guidelines/requirements/recommendations from domains related to the greater SIID problem space, the research pursued the goal of discovering parallel solutions that may be applied or adapted to solving the issues that were outlined in the five SIID themes and SCSI characteristics defined in Study 1.

The process was similar to brainstorming, where the goal is the accumulation of divergent ideas and concepts for later convergence during coding and analysis. Once a source with potential legitimate additions to the guidelines corpus was identified, it was important to extract the potential corpus items with as little to no bias or filtering as was humanly possible. For example, when the guideline "*The system should provide voice feedback to the user*" was found, there was almost complete certainty from the researcher that this particular guideline was already extracted from an earlier examined source. This item was, nevertheless, added to the raw corpus list with the understanding that duplicates will be removed as part of the convergent thinking process to take place later.

This resulted in 3,080 extracted pieces of data from the 285 sources that were mined, of which, nearly 60% (59.49%) came from AT/Accessibility domain articles (1,832 extractions). Only 40 extractions (1.30%) were guidelines that related at all to SIID. The breakdown by generalized domain is detailed in Table 6 below:

	Total	**% of Total**
Accessibility/Assistive Tech	1,832	59.49%
Mobile Interaction	1,208	39.22%

SIID/Situational Impairments	40	1.30%
Total Search Results	3,080	

Table 6: Raw corpus extractions by generalized domain

Coding and Analysis

Once extraction was complete, the process of converging the 3,080 items on the raw guidelines' corpus began. The list was first sorted alphabetically so that obvious duplicates might be quickly identified. Next, the researcher went through each item in the extraction corpus by applying the following criteria:

1. Does it offer a suggestion that can be utilized to directly solve any of the themes/categories of SIIDs and/or SCSIs?
2. Does it offer a suggestion that can be utilized to indirectly solve any of the themes/categories of SIIDs and/or SCSIs? (e.g., does a guideline that addressed a visual impairment or a motor impairment offer an analogous solution to a situational impairment)
3. If duplicate, does it say the same thing as another guideline or does it approach the problem space from a different or unique angle?

Once items that did not meet the criteria above were removed from consideration, the corpus was refined down from 3,080 to 583. At this point it was decided that any remaining duplicates (those not recognized during the initial sort) need not be removed as the next step of the process (described in the next sub-section) will effectively assimilate and incorporate *like* items into more general themes.

Developing coding themes

Even if all 583 records represented a valuable guide for design, not all 583 necessarily represented a truly *unique* guide for design. Therefore, with the remaining records still sorted alphabetically, the researcher next examined the data for generalized common themes present in multiple records. By coding and developing themes, the remaining records could be grouped in common buckets, which would assist in the process of assimilation.

For example, many of the data points referred directly to the need for "context awareness". The need for mobile interaction technology to be more context aware was one of the insights gleaned from Study 2. In addition, these solutions map well to the "Complexity" theme from Study 1 as well as to the characteristics of a SCSI. A few examples appear below:

> "*Adapt to changing context. Caption color and background should automatically change based on lighting conditions*." (Jain et al, 2018)
>
> "*Time services based on context. Time when to act or interrupt based on the user's current task and environment*." (Amershi et al, 2019)

This resulted in an initial set of ten coding themes which are displayed in Table 7 below (ordered by % of total). It should be noted that the 11th theme "Other" contained only eight items, none of which were used in the final set of data.

Code	% of total
Context Aware	24.7%
Complexity	14.8%
Personal Assistant	12.9%
Limited Physical Resources	8.4%
Salience	8.1%
Multimodal	7.7%
Limited Tech Resources	7.6%
Limited Cognitive Resources	7.0%
Socially Acceptable	4.8%
Locus of Control	2.6%
Other	1.4%

Table 7: Initial Coding Themes

Developing Draft Guidelines from the coded themes

Having narrowed down the general themes to 10 categories, the process of extracting guidelines from each category commenced. Guidelines were obtained one of three ways:

1. Direct extraction from the source (unmodified)
2. Edited/modified version of the extraction
3. Editing and/or combining several extracted source items

An example of each of the above is provided here from the "Limited Technical Resources" category. One of the 44 items in the corpus coded with this theme that was extracted directly and unmodified was "*It should be easy to recharge via a cradle rather than a plug.*" (Van Biljon & Renaud, 2016)

An example of the process of obtaining an edited/modified version on an extraction appears below:

- **Original Text from source**: "*Additionally, an often-expressed issue is that people do not want to be concerned with another device to charge. Long battery life and ease of handling, storing and charging is critical. We propose to employ a simple plug mechanism to connect and draw power from the phone, (e.g., implemented in the phone bags [sic.] or a pocket (we saw that more than 60% of the participants kept it in a trouser pocket)*." (Holleis et al, 2008)
- **Modified Draft Guideline**: Employ a simple plug mechanism to connect and draw power from the phone (e.g., implemented in phone bag or a pocket).

The third method for creating a guideline resulted from the combining of two or more extractions. An example of this process appears below:

- **Original 1**: "*Client-side image maps to be used instead of server-side image maps except where the regions cannot be defined with an available geometric shape*." (Sierkowski, 2002)

- **Original 2**: "*Locate Functionality with High Complexity on Server side. Running functionality with high complexity tends to consume high resources of CPU and Memory. Allocate such functionality in S.Control*." (La, Lee, & Kim, 2011)
- **Original 3**: "*Locate Functionality with a large amount of data manipulation on server side. Mobile devices have a limited secondary memory space, and computing with data on secondary memory is inefficient*." (La, Lee, & Kim, 2011)
- **Edited/Combined Draft Guideline**: Locate Functionality with high complexity or a large amount of data manipulation on server side.

It should be noted as well that some extractions represented the same guideline. In these cases, the first instance in the database was used and all others were removed.

<u>Mapping Guidelines/Coding Themes to SIID Themes/SCSI Characteristics from Study 1</u>

The coding themes were consolidated from ten to five, as shown in Table 8 below. Also shown in the table were the number of records from the eventual draft guidelines list that were coded with each theme. Guidelines covered the gamut of disability issues including physical (e.g. vision, hearing, motor) and cognitive challenges (e.g. memory). In addition, a decent portion of the literature addressed designing technology for older adults, a population that can experience vision, hearing, motor, and memory challenges as the result of the aging process. Various interaction environments including desktop, Web, and mobile (both walking and in a car) were examined. A detailed discussion of each and how they might map to the five SIID themes appears in the paragraphs that follow.

Code	Consolidated from First Pass Themes	# of Guidelines
Context Aware	Context Aware + Personal Assistant	14

Limited Cognitive Resources	Limited Cognitive Resources + Complexity + Salience	11
Limited Physical Resources	Limited Physical Resources + Multi-modal + Locus of Control	13
Limited Tech Resources	N/A	7
Socially Acceptable	N/A	4
	Total	***49***

Table 8: Consolidated Coding Themes and mapped guidelines

Context Aware

Records extracted that were coded as "Context Aware" focused on designing solutions where technology adjusts input and output conditions based on the changing ambient conditions of the mobile interaction space. The need for technology to adapt to changing context was a major requirement determined by the participants of Study 2, especially when solving for the SCSI version of the situational impairment scenarios.

Accuracy, adaptation, and being able to make the adjustments in real time were prominent in the guidelines offered. Sehic et al (2014), in a paper about creating a context-aware programming model, noted, "*Context-aware applications have to be developed using dedicated programming abstractions that provide an environment-agnostic interface.*" Papers specifically addressing the Assistive Technology and Accessibility domains also noted the need for technology to be adaptable to the user and to context. In a paper on designing accessible TV remote controls Costa et al (2012) noted, among other things, that buttons should be configurable for sensitivity so that users regardless of dexterity and strength will be able to interact effectively. Other papers note that considerations should be made including adaptive keyboards/text-entry, ambient brightness and meteorological conditions, and notification alerts.

Some records that were originally coded as "Personal Assistant" were consolidated to this theme. While in general belonging to the "Context Aware" theme, technology solutions suggested by some sources refer specifically to the need for the technology to act much as a human personal assistant might do. The technology needs to get to know and continuously learn about what the user wants and needs, and produce results that reflect an almost human-like empathy. Because the technology "knows" the user, it can adapt not just to the ambient context but also to the user-specific situational context. These types of adjustments can include determining the best time to interrupt (or not disturb), what needs user attention, and what can wait, or even be handled by the system in the background without any need for direct user intervention.

Inostroza & Rusu (2014), for example, in their paper about mapping usability heuristics note, "*Like a good personal assistant, [the system should] shield people from unimportant minutiae. People want to stay focused, and unless it's critical and time-sensitive, an interruption can be taxing and frustrating.*" This human-like technological empathic need also expressed itself often in papers offering recommendations addressing in-vehicle user interaction. Papers in the AT and Accessibility domains also point to this need as well. Sulaiman et al (2010) perhaps summarized this need best when noting that an intelligent system for blind users should ultimately be able to "*...read the right thing, at the right time, and at the right pace.*"

Limited Cognitive Resources

Issues relating to cognitive load were termed “Limited Cognitive Resources” and refer to the unavailability of the user’s intrinsic resources to complete a mobile I/O transaction effectively. Anything that tests the limits of human working memory that is either unique to or exacerbated by the mobile interaction space was coded to this theme and mapped well to the sub-themes: “Cognitive Load”, “Number of Steps”, and “Gulf of Execution/Evaluation” of the “Complexity Issues” theme. Issues of limited available cognitive resources were also noted as a principal differentiator of a SIID vs. a SCSI during the participatory design workshops of Study 2.

A reduction of situational awareness as the result of the primary task, mobile task, and/or any other task, all competing for the same limited working memory and perceptive resources, is one example of an issue that is exacerbated by the mobile interaction context (Rauch, Gradenegger, & Krüger, 2008). Since mobile devices may demand attention that can distract users from more important tasks, Gong & Tarasewich (2004) suggest that mobile device interface needs to be designed to require as little attention as possible. Okoshi et al (2017) suggest the discovering of “Breakpoints”, or the “*boundary between two adjacent units of user activities*”, as timing potential distractions (such as perceiving and responding to notifications) to lower the impact on users’ cognitive load.

Research on the AT/accessibility designed to assist users with sustained cognitive impairments also offer suggestions that may serve as guidelines for the addressing of situational impairments. For example, when designing for older adults the content layout and information should be concentrated mainly in the center, and the layout of the screen as well as navigation should be simple, clear, and consistent, according to Zaphiris et al (2005). In addition, in a paper about mobile usability of impaired users, Siebra et al (2015) indicate the importance of being able to start a mobile device from any portion or place on a touch screen. A few AT-related papers noted that because assistive technology users often need to have separate dedicated devices for their specific physical or cognitive needs, the burden of having to deal with/carry additional items in and of itself creates an additional layer of complexity. For example, Quinones, Greene, & Yang (2011) note that visually impaired users "*...desire to carry around as few tools as possible. An open concern is how to design a technology such that it poses little burden while also being able to give the appropriate amount of information and being affordable*." The need for this type of burden reduction could have parallels in the able-bodied domain. The forgetting of a needed mobile accessory (e.g., headset, charger) was among the issues that appeared in the Situational Impairment Events corpus from Study 1, suggesting, at least in part, that the added capability/functionality and usage of mobile devices in users' everyday routine are adding some level of complexity to that daily routine.

Some excerpts referred to the need for the means of mobile input and output to be salient to the end user. The concept of salience in design is not unique to mobile interaction contexts. The need to make certain aspects of the design space that require user attention and/or focus is a common guideline in both UI/UX design and presentation theory (Kosslyn, 2007). However, in the mobile transaction space, because attention is often fragmented due to other tasks and the need to complete a transaction as quickly as possible is of greater importance in varying ambient contexts, the need for mobile design to get the user attending as quickly and efficiently as possible is exacerbated. While this does not map directly to any SIID theme or SCSI characteristic from Study 1, it does support the need to perceive both input and output content that can be hindered as the result of events that fall into the "Ambient Environmental Issues" theme from Study 1. In addition, proper salience of content may be an important factor in resolving issues of "transaction half-life" which is one of the characteristics of a SCSI event as the sooner content can be perceived, the sooner it can be interpreted and acted upon.

Limited Physical Resources

The Stage 1 theme termed "Limited Physical Resources" refers to issues that users have accessing or applying the necessary physical resources that are needed to complete a mobile I/O transaction. For example, if one's hands are occupied (e.g., holding grocery bags), one cannot complete a touch-screen transaction. If one's mouth was full, one could not input information using a vocal channel. An important differentiator for this category is that this refers specifically to "physical" resources being affected. This theme primarily supports the "Workspace/Location Issues" theme from Study 1 but also secondarily the "Ambient Environmental Issues" theme.

Solutions focused primarily on things that could overcome various common physical limitations that occur during mobile events, such as accounting for limited/restricted workspace (Economou, Gavalas, Kenteris, & Tsekouras, 2008), or providing support for body and clothing-specific affordances as alternative input spaces (Lyons & Profita, 2014). AT and accessible solutions also centered around overcoming limitations but for those users whose physical limitations are more omnipresent. Examples include promoting single-handed interaction (Pantonial & Cornelio, 2017 and Veloso & Costa, 2016) as well as support for both left- and right-hand use and various hand sizes and grips (Kascak, Rébola, & Sanford, 2014). Wu, Marshall, Yu, & Cheng (2007) suggested that for visually impaired indoor navigation, design should avoid anything that blocks sensory input (e.g., need to use headphones/headsets).

Also offered were guidelines that look to alternative modalities to the normal primary modality of a mobile task. The ability to use an alternative input and/or output modality represents a viable solution to the "Workspace/Location Issue" theme from Study 1, particularly the sub-theme "Unavailable Resources". In addition, alternative modalities can address the sub-theme "Walking Over Tasks" from the "Complexity Issues" theme as well as when the primary modality is blocked during an "Ambient Environmental Issue". Also, the SCSI characteristic of having a solution to one SIID create a new SIID can be addressed with an abundance of alternative modalities. Schulze & Woerndl (2011), for example, note that alternative ways of input must be considered, as keyboard-based input on mobile devices is laborious at best and infeasible at worst, and suggest that "clever interfaces" need to avoid manual text input wherever possible.

A small but meaty set of records discuss the importance of the user maintaining some sense of control over their mobile transaction space. Locus of control is a design principle offered by Ben Shneiderman as part of his "Eight Golden Rules of Interface Design" and so is commonly known to be an important consideration in designing interactive technology. However, as with other considerations regarding mobile interaction and situational impairments in particular, the unique and varying contexts in which one attempts mobile interaction can make the loss of control not only frustrating but also potentially dangerous.

Limited Technical Resources

Items from the corpus coded as "Limited Technical Resources", unlike the "Limited Physical Resources" and "Limited Cognitive Resources" themes discussed above, refer to solutions to issues that are exogenous of the user and focused on the technical limitations that mobile technology places on successful completion of mobile I/O transactions. The most common of these issues and indeed the majority of suggested solutions in the corpus were battery life and Internet connection, which map directly to the two major sub-themes of the "Technical Issues" theme from Study 1.

Suggestions included placing data and data sets for mobile applications on the server side to reduce the need to use battery-hogging phone resources (La, Lee, & Kim, 2011). Oliver & Keshav (2008) recommended the explicit distinguishing of connection and disconnection periods and then using the disconnection periods to (1) refresh the metadata cache, (2) compress/decompress data bundles, (3) pre-compute forwarding strategies, and (4) perform "explicit garbage collection". Even though few records were extracted from AT/accessibility papers, a few did offer guidance. For example, in focusing on mobile use by the elderly in developing countries, Van Biljon & Renaud (2016) offered the need to show a clear indication of battery charge remaining, as well as the ability to easily recharge via a cradle rather than a plug.

Socially Acceptable

There were some recommendations and suggestions that focused on addressing issues of social acceptance when attempting transactions in the wild. These mapped directly to the “Social/Cultural Issues” theme from Study 1. The preponderance of these guidelines came from AT/accessibility research focusing on how one might design technology for an impaired population for use without a feeling of self-consciousness or helplessness (e.g., a blind person attempting a transaction in the wild without knowing who else might be in or near their transaction space).

Most of the recommendations, therefore, focused on being able to interact while impaired without appearing obvious that technology is being used to overcome a transaction issue that is the result of an impairment. Coventry & Bright (2013), for example, examined design requirements for assistive technology to meet the psychological and socio-emotional needs of older adults. They noted the importance of technology being “covert” in order to minimize perception interactions being of an assistive nature. In evaluating gesture interaction requirements of mobile applications for deaf users, Chuan et al (2017), suggested that mobile interaction avoid offensive gestures during gesture interaction. Amershi et al (2019) offered guidelines for Human-AI interaction and suggested that AI avoid language/behaviors that may reinforce stereotypes and biases. Oh & Findlater (2014) observed that visually impaired participants prioritized social acceptability over ease of use, physical comfort, and preferred input locations that were discreet.

Privacy is also a concern as was noted in Piccolo, Menezes, & Campos Buccolo (2011). The authors suggest that being able to know that one's information input or output is secure is important for a blind user as they may not be aware of the presence of others in the environment. This can be seen as also applying to any user who might be experiencing reduced situational awareness.

Draft Guidelines

This process ultimately resulted in the creation of the set of 49 draft guidelines that were deployed in Stage 2 of this study. Tables 9-13 below represent the draft list organized by theme. In each case, the guideline representation is coupled with the type of paper from which the record(s) was/were extracted ("AT" for a paper on Assistive Technology, "Acc" for a paper in accessibility, "Mobile" for papers relating to situational impairments or mobile interaction in general, and "Car" for any paper that specifically examined human-car interaction). In some cases, the developed guideline was combined from sources representing different domains (e.g., AT and Mobile). There were also instances where the source was offering guidance across multiple domains (e.g. mobile interaction for visually impaired users). In these instances, the Article Category is represented as mixed (e.g., AT/Mobile).

It is important to note the sub-domains that were the source of these guidelines were varied. In the Assistive Technology domain, for example, sources which were selected covered issues of visual, hearing, motor, and cognitive impairments, as well as areas such as designing technology to support an aging population. For example, the guideline, "A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae…" was partially sourced from research in designing technology for individuals with cognitive impairments. The guideline, "Access guaranteed by different input methods…with attention to particular users' needs and strengths" was partially sourced from research in designing technology for individuals with visual impairments as well as a paper on the application of WCAG guidelines in the Korean market. There was no particular sub-domain that was detected that held dominance when it came to the production of this draft list.

Limited Technical Resource Guidelines

Article Category	Guideline
Mobile	Connect with different communications and data networks to ensure high availability of services.
Mobile	Employ a simple and universal external mechanism to provide power for the phone (e.g. implemented in a carry bag or in a coat pocket) making it accessible
Mobile	Explicitly distinguish between periods of active use and passive use, then use the passive periods to conduct power and data intensive operations
Acc	Device should be easy to recharge via a cradle rather than a plug.
Mobile	Locate functionality requiring a large amount of data manipulation or complexity on the web server (as opposed to the device).
Mobile	Low energy consuming localization methods should be used as substitute for power hungry localization techniques (e.g., GPS).
Mobile/Acc **Mobile**	Connectivity and power issues should be transparent for the end-user. Use automatic logging as an efficient way to obtain continuous battery information and highlight/educate the user regarding their battery life limitations and performance improvements

Table 9: Draft Guidelines Coded as Limited Technical Resource

Context Aware Guidelines

Article Category	Guideline
Mobile/AT	Any function designed for the adaptation to the variable contexts and environments must function in real-time and as a background task without altering the normal operation and use
Mobile	In unfamiliar/new environments, automatic discovery of device/data services should distinguish between services that interact with applications and those that interact with users.

Acc	Design buttons with configurable sensitivity to adapt to the user's own dexterity and strength
Mobile	Define in advance the semantic locations (e.g. park, car, street or office) where the user will likely interact with the application then conduct context analysis of the environment factors influencing each location.
Acc	Design features to reduce contextual stress. (e.g. facilitate the ease of safety check-ins, users locating one another, and compensate for lack of communication synchronicity).
Mobile	Push notifications after phone calls and text messages rather than random times
Mobile	Passively identify potential situational impairment events so that the device can react independently of users' direct feedback.
AT	When in motion, user can query the system using voice, when not in motion, users can interact with the system using tabs and gestures
AT/Mobile/ Mobile/AT	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)
Mobile	Detect breakpoints (when the user is not actively manipulating the device) using additional sensors, such as GPS, accelerometer, proximity and light sensors
Mobile	Sensing the user's attention state must be performed all day long as long as the user's notification system is available.
Mobile	Notification settings should leverage users' existing contact info metadata in order to select when, where and how to be notified by certain people.
Acc	Assign task weights through either micro or macro factors: Micro factors refer to the application or condition of use (e.g., sit, walk); whereas macro factors refer to the most-used input method for each individual user and different personal touchscreen behavior.
Car	In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.

Table 10: Draft Guidelines Coded as Context Aware

Limited Cognitive Resources Guidelines

Article Category	**Guideline**
AT	Design technology such that it poses little burden/encumbrance (i.e. reducing the need for resources such as hands or storage areas like a coat pocket)
Acc/AT/ Mobile/ Mobile	Minimize the number of steps and consider simple movement (e.g. clicking) over complex movements (e.g. dragging, drawing certain shapes). Also, interaction based on tap length (invoking different functionality on long tap) should be avoided
AT	Use horizontal navigation structures as they are more easily understood than vertical navigational structures when no assistance is provided.
Mobile	Associate pitch and amplitude of output to the severity of the situation (e.g. unsafe

	temperatures, presence of a hazard) rather than a continual increase in intensity which may be ignored after a period of time.
Mobile/Acc **AT**	Implement hard keys for often used tasks and an easily discernible tactile "home" that ensures one key on any tactile control pad can be used to orientate users within the interface. Provide tactile exploration with a haptic groove or gentle directed motion towards the target element.
Acc	Phone must have an obvious top and bottom.
AT/Acc **Mobile/Acc**	Users should be able to identify the exact position of the input device (e.g. finger, stylus) and start devices in any position on the touch screen; and the user should be able to "snap back" to the start position or any other known location. Features should be in the same location to help the user's sense of orientation.
Car	Account for the fact that users may engage in distracting activities because they may not realize that their performance is degraded or overconfident in their ability to deal with distractions while engaged in the primary activity.
Acc	Avoid distractions (i.e. blinking images) and discourage unconscious action in tasks that require vigilance.
Acc	Information should be concentrated mainly in the center
Acc	Design flexible limits for task completion and warnings/feedback should stay in the screen as long as the user does not respond to them

Table 11: Draft Guidelines Coded as Limited Cognitive Resources

Limited Physical Resources Guidelines

Article Category	**Guideline**
Acc/AT	Accommodate one-handed and right or left-handed access as well as use and variations in hand and grip size.
AT	Avoid gestures needing precision, large areas to perform, or cause physical pain after prolonged use
Acc	Avoid pull down menus and scroll bars
Acc	Avoid touch input that is too sensitive (prevent accidental presses) and tackle the fear of accidentally initiated commands
Acc	Avoid two-handed, multiple-finger interaction
Mobile	Consider clothing-specific affordances for wearable placement or attachment (e.g. a clip that can attach to different clothing straps, folds, or loops).
AT	Minimize the necessity to look down on the display
Car/AT	No part of the system should obstruct user's ability to perceive the external environment.
Mobile	Stability is important for both users experiencing shakes or quivers as well as on-the-go users experiencing vibration.
Mobile	Under certain ambient conditions (e.g. extreme cold) account for reduced accuracy (e.g. offset skew) in target acquisition, particularly in one-handed interaction.

Acc/AT	Access guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.
Mobile	For any given task the design should specify which modalities are appropriate for each context and offer additional value to users that are not directly interacting with the screen
AT	When visually impaired, support body input.

Table 12: Draft Guidelines Coded as Limited Physical Resources

Socially Acceptable Guidelines

Article Category	Guideline
AT	Provide subtle feedback, such as vibration from within a pocket, or personal audio, in situations where individuals are hesitant to carry their devices in public.
AT	Covert technological capability to minimize perception of use. Designers should consider how their device design would impact how the user is perceived in public
AT	Make sure that gesture interactions do not involve offensive or culturally inappropriate action from the user
Mobile	Ensure the AI system's language and behaviors do not reinforce undesirable and unfair stereotypes and biases.

Table 13: Draft Guidelines Coded as Socially Acceptable

While source domain(s) for each draft guideline has been referenced, it should be noted that it is somewhat problematic to actually cite specific sources for each guideline represented. The domain references were often a function of that source being *the last man standing*, or what remained after several duplicate sources were removed during the processes that took a corpus of 3,080 items and paired it down to 583 and then eventually the 49 listed below (described in Stage 1 Results - Step 4: Analysis, Data Coding, and Draft Guidelines). As previously noted, in addition to cases were the same conceptional guideline may have been referenced in several discrete sources, many guidelines have been created/curated as the result of combining and/or assimilating aspects of several pieces into a new, single guideline. Even in cases where the guideline was mostly or completely extracted for use, there is no way to determine if that source was the first or only source to note that particular idea.

For example, the 7th draft guideline in the "Limited Physical Resources" table above ("*Access guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths*.") was at least partially derived from a paper discussing W3C standards and another paper discussing designing for individuals with cognitive issues. Papers referring to the W3C standards, not just the one that was a part of this constructed piece, were common in the corpus. The reason a particular standard was used in their work may have been unique, but not the standard or the concept itself. It is the concept that was extracted in the corpus, not the unique purpose for including or discussing that concept. It would be impractical to attempt to source all the papers with items extracted to the corpus that in essence offered the same recommendation.

This was true even with items that were more discrete in terms of source. For example, the 1st draft guideline in the "Social-Cultural" table above ("*Provide subtle feedback, such as vibration from within a pocket, or personal audio, in situations where individuals are hesitant to carry their devices in public*.") was derived from an AT paper regarding visually impaired users. Providing vibration feedback however, was not the unique contribution of the piece. Subtle vibration feedback, after all, was one of the design recommendations from the Study 2 participatory design workshops.

A complete list of all 285 original sources used appears in a separate bibliography in Appendix C. However, for the reasons listed above, no direct reference to any sources appears in the above tables.

Once the structured literature review was completed and a draft set of guidelines were curated, the second and final stage of the study was ready to commence. The next part of this chapter describes how the above set of guidelines was validated by a panel of experts using the Delphi method and offers the results of that validation process.

Stage 2 Methodology (Delphi)

Through the analysis of a structured sampling of what has been, and what is currently being, suggested as guidelines for the greater SIID problem space, Stage 1 of this study culminated in 49 potential guidelines for the addressing of situational impairments. The draft guidelines were fashioned through an exhaustive process that in part used phenomenological coding to map content to the SIID themes from Study 1. Validation, however, is required to determine whether any or all of these items on this draft list can be offered as guidance for designers and researchers of mobile interaction. Stage 2 of this study was designed to provide that validation in a novel way.

The set of draft guidelines was presented to a population of experts to see how well they can map to what is wanted/needed by users and possible/feasible from designers. Feedback from designers/researchers was important as their expertise and concept model of the problem space will offer an important perspective and a deeper level of understanding than that of the general public. This was achieved using the Delphi method.

Introduction to the Delphi method

The Delphi method is a way of structuring group communication to obtain the most reliable consensus of an assembly of experts (Linstone, Turoff, & others, 1975). It uses a series of controlled feedback exercises, which has the advantage of avoiding direct confrontation of the experts and affords a more conducive way to promote independent thought (Okoli & Pawlowski, 2004).

Originally employed intermittently by the RAND Corporation to obtain a consensus of expert opinions on military-related problems (Dalkey & Helmer, 1963), it has over the years expanded to other business and technology domains. Some examples include identifying software project risks (Keil, Cule, Lyytinen, & Schmidt, 1998), knowledge management (Holsapple & Joshi, 2002), or, more recently, the assistive technology and wearables design space (Wentzel, Velleman, & van der Geest, 2016).

This method lent itself well to the goals of this research for several reasons. When approaching a problem in which there are no correct answers, the Delphi method can be an effective way to deal with uncertainty in an area of imperfect knowledge (Paliwoda, 1983). Also, as to be described in detail later in this section, participants offered responses asynchronously via email and independent of the other panelists. Anonymity helped avoid counterproductive tangential discussions as well as problems arising from powerful personalities, group pressures, and the effects of status that could arise in more conventional meetings (Thangaratinam & Redman, 2005), such as focus groups. Finally, as is to be later elucidated, participants were still able to benefit from the input of others as the result of the iterative nature of the controlled feedback exercises.

Many variants of the Delphi method are currently in use. For example, the "rating-type" variant is used to arrive at a group consensus regarding the relative importance of issues (Okoli & Pawlowski, 2004) and often falls within a three-phase framework of data collection: (1) the discovery of issues, (2) determination of the most important issues, and (3) rating of the issues (Schmidt, 1997). "Concept-framework", on the other hand, is a variant that typically involves the identification and/or elaboration of a set of concepts followed by classification and/or taxonomy development (Okoli & Pawlowski, 2004). For this variant, some modifications to the three-phase structure are practiced; in particular, the "discovery of issues" phase is often the result of "pre-Delphi" research. The discovery of issues component, in this study for example, consisted of the information gleaned from the Systematic Literature Review from Stage 1.

For Stage 2, this study deployed a unique mixture of the "rating-type" and "concept-framework" variants of the Delphi method. It incorporated elements similar to Wentzel, Velleman, & van der Geest (2016); Okoli & Pawlowski (2004); and Holsapple & Joshi (2002), but also substituted a 5-point Likert Scale where participants rated the value of each guideline on its separate merits as opposed to rating each guideline relative to the others. This method was successfully utilized in a recent study by Chen (2019), who used this in a Delphi study that evaluated design guidelines that might be applied in gamification projects.

In order to assure that the broadest swath of stakeholder interests was being accounted for, the Delphi panel was assembled as a single group of designers of mobile technology and researchers of mobile interaction. All sessions were conducted asynchronously and online. The target for participation was 10-18 members as suggested in Paliwoda (1983) and Okoli & Pawlowski (2004). Because Delphi studies usually require multiple sessions and can be highly demanding, one potential issue with a Delphi study is participant attrition. To help reduce the potential for attrition, in addition to being conducted via email, the question sessions were designed to be as brief as possible (Okoli & Pawlowski, 2004). Turnaround time for each set was to be one or two weeks. The process implemented is outlined in Figure 3 and described in greater detail below.

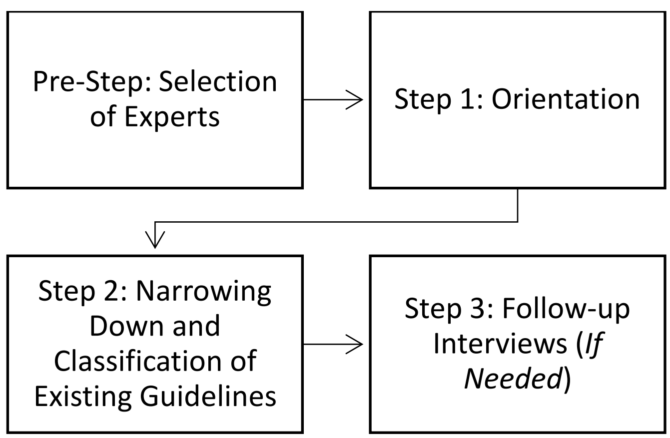

Figure 3: The Delphi Process Outlined

Pre-Step: Selection of Experts

Since a Delphi study is a group decision mechanism that requires qualified experts with a deep understanding of the domain and problem space, the process of selecting the right participants to populate the panels is an important step that needs to be rigorously fashioned (Okoli & Pawlowski, 2004). Therefore, the selection process in this study was similar to what was done in Okoli & Pawlowski (2004) using the detailed guidelines briefly outlined below:

1. **Prepare a Knowledge Resource Nomination Worksheet (KRNW)** to help categorize/classify the experts before identifying them.
2. **Populate the KRNW with names** through use of a personal network of contacts and snowball sampling.
3. **Inviting experts to the study**. The participants were asked to commit to completing up to four questionnaires and returning them within one (or two) week(s) of receipt. The questionnaires will be designed carefully following principles established by Dillman (2011), to maintain high levels of participation by establishing trust and the perception of increased rewards while reducing the social costs of participation.

Step 1: Orientation

Due to the volume of concepts that need to be understood and considered, participants were introduced to the problem space through orientation material that introduced/defined each theme and sub-theme. An example of each was also provided, and participants were encouraged to ask questions or seek clarification.

The objective of this step was training/orientation. The domain represented in this study (situational impairments in mobile device interaction) was most likely recognizable and understood by the study participants. However, the concepts and themes used, while already vetted through peer review, may only have been familiar to those exposed to the vetted material in which the concepts were introduced. This step helped ensure that all participants were *on the same page* before beginning actual data collection.

Step 2a: Narrowing Down and Classification of Existing Guidelines

A minimum of two rounds is required for the Delphi method and most studies only use two or three rounds to avoid fatigue and participant attrition (Thangaratinam

& Redman, 2005). This step necessarily involved a minimum of two rounds. For the first round, as in Wentzel, Velleman, & van der Geest (2016), the expert panel was presented the draft guidelines produced in Stage 1 via email-delivered online questionnaire modules.

Specifically, the participants were sent six separate email modules. Each module represented one of the five SIID themes from Study 1, with the sixth module representing SCSI. The list was presented in groups of 10, with each group of 10 residing on a separate page. Each page had the theme definition and links to the sub-theme definition on display for review. For each module, the participants were asked to consider each item on the list. If it mapped to the situational impairment theme currently represented in the module, they were to drag and drop that guideline in the space provided. A screen capture of the first page of the "Complexity" module appears in Figure 4 below. For each item selected, they were then asked to justify their choice using textboxes that appear at the bottom of each screen (see Figure 5 below). A final screen was offered at the end of the module to allow any comments or to suggest additional guidelines.

The modules were sent as a series of links in a single email. The order in which the links appeared within the email was determined by Latin Square for each participant to reduce order bias. The guidelines were presented in alphabetical order to reduce order bias. Each module presented the same set of guidelines. The results were then analyzed and the summarized answers commuted to the participants in Round 2.

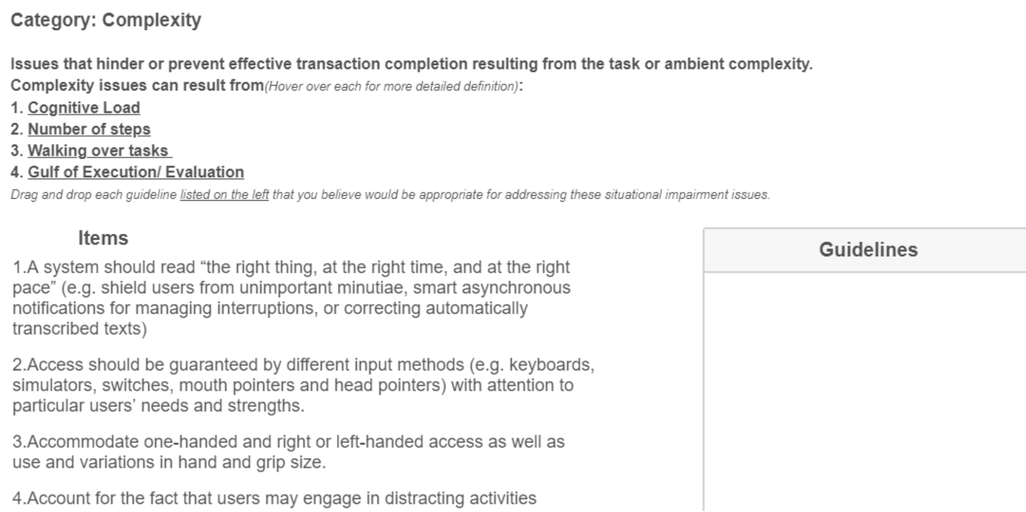

Figure 4:Sample Initial Round Screen

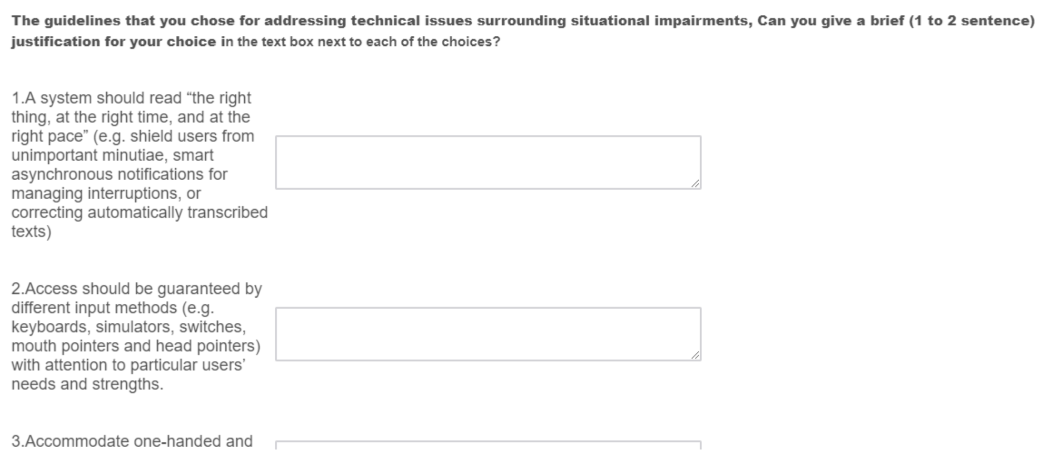

Figure 5: Sample Choice Justification Screen

<u>Step 2b: Rating Rounds</u>

The objective of this step was the paring down and refining of the list so that meaningful analysis could be achieved (Schmidt, 1997). Another important outcome of this step was not only a paired list but one that was bound statistically, rather than arbitrarily (Schmidt, 1997). The iterative process in this step was a function of relative consensus within the group where each participant's mapping was compared with the mappings of the other participants. After the first round, one additional round was run, which provided each participant a chance to change his or her response based on the metadata represented in the statistics, as well as comments made by other participants. This process represents one of the strongest aspects of the Delphi method. Each participant is a member of a "group" but — as the result of the asynchronous and non-co-located nature of the process — remains anonymous. The possibility of bias and/or the issue of unbalanced group participation (i.e., one member dominating a meeting or one member not contributing at all due to reluctance) is tremendously reduced (Thangaratinam & Redman, 2005). Decisions are affected by the collective responses of the group but not by those of any specific individual(s).

Rating Round 1

Similar to the format adopted by Wentzel, Velleman, & van der Geest (2016), guidelines were presented, grouped by theme, to the participants. For the first rating round, the guidelines chosen were ones that were selected by over 50% of the participants to reduce the lists to a more manageable size (Okoli & Pawlowski, 2004). Within each theme group, the guidelines were listed alphabetically to reduce the effect of order bias.

Specifically, the participants were asked to rate each guideline on a 5-point Likert Scale, as was done in Thangaratinam & Redman (2005) and Chen (2019). Each participant was sent an MS Excel workbook, with each worksheet representing one of the six situational impairment themes. Each sheet contained: (1) a listing of all the guidelines chosen by 50% or more participants for that particular situational impairment as suggested by Okoli & Pawlowski (2004), (2) the definition of that theme and sub-themes, (3) a place to enter their rating, and (4) an area to provide a brief written justification for their rating. The 5-point Likert Scale values were defined as follows:

5 = Essential guideline for this type of situational impairment

4 = Important guideline for this type of situational impairment

3 = Could have some value, but not essential for this type of situational impairment

2 = May have some minimal value for this type of situational impairment if rewritten or rethought in some way

1 = Offers no value for the addressing of this type of situational impairment and should be removed from the list

As an example, in the initial round, five guidelines were chosen by 50% or more of the participants to address SIID that were categorized as "Ambient Environmental Issues". The first worksheet of the workbook was shown to participants, as is displayed in Figure 6 below.

Ambient Environmental Issues: Anything about the environmental context of the transaction space that is hindering or preventing effective transaction completion.

Ambient-Environmental issues can result from:

Meteorological Conditions: Some aspect of the weather (i.e. sun, rain, heat, or cold) that is hindering or preventing effective transaction

Ambient "Noise" Conditions: Some non-meteorologically ambient condition is creating "noise" in the communication channel hindering or preventing effective transaction. The "noise" can be any non-meteorological input that is negatively affecting the signal-to-noise ratio of the transaction signal (not necessarily just audible noise) including another human.

Below are the guidelines selected by 50% or more of you to address Ambient-Environmental issues. Rate each issue (on a scale of 1 to 5) based on the following criteria:

5 = Essential guideline for this type of situational impairment

4 = Important guideline for this type of situational impairment

3 = Could have some value, but not essential for this type of situational impairment

2 = May have some minimal value for this type of situational impairment if rewritten or rethought in some way

1 = Offers no value for the addressing of this type of situational impairment and should be removed from the list

Guideline	Rate	Can you offer a brief justification for your choice?
Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.		
Avoid touch input that is too sensitive (prevent accidental presses) and tackle the fear of accidentally initiated commands		
For any given task the design should specify which modalities are appropriate for each context and offer additional value to users that are not directly interacting with the screen		
Passively identify potential situational impairment events so that the device can react independently of users' direct feedback.		
Under certain ambient conditions (e.g. extreme cold) account for reduced accuracy (e.g. offset skew) in target acquisition, particularly in one-handed interaction		

Figure 6: Sample Rating Round 1 Worksheet

The results in this round were then analyzed and measured for consensus agreement as to the appropriateness of each selected guideline. Similar to the approach used by York & Ertmer (2011), a guideline reached consensus in this round if either of the following two conditions was met:

1. Interquartile Range (IQR)[1] <= to 1 **AND** >=75% agreement on a rating of 4 and 5
   or
2. A >92% frequency rating in the 3, 4, 5 categories (>92% indicated all but 1 participant).

Rating Round 2

Any guideline that did not meet the consensus criteria listed above was then offered back to participants in one final round. Participants were sent a second MS Excel workbook, again with six worksheets (one for each theme). Specifically, on each sheet the participant was shown the theme definition and then a list of each guideline that did not achieve consensus. They were also shown: (1) the percentage of participants who rated that guideline a 4 or 5, (2) the percentage of participants who rated it a 3, 4, or 5, (3) the mean rating, (4) their rating, and (5) sample comments from participants. Incorporation of a sampling of the comments representing rationale of choices helps facilitate a quicker arrival at consensus (Rohrbaugh,1979 as referenced in Okoli and Pawlowski, 2004). The participant was then asked to consider all the metadata and was then given the opportunity to revise and/or comment.

[1] The IQR is an alternative measure of variance that is the result of the subtraction of the 3rd quartile from the 1st quartile value. This measure has been used by some Delphi studies like Chen (2019) that employed Likert Scale rating as an alternative measure of variance to standard deviation. IQR has an advantage over standard deviation in that it is unaffected by extreme outliers. It is for this reason that the researchers chose this measure of variance for the present study.

As an example, in the initial round, two of the five guidelines presented to the participant in the previous rating round to address SIID that were categorized as "Ambient Environmental Issues" did not meet the criteria for consensus. The results in this round were then analyzed using the same criteria and measure for consensus as were done in the previous round. The first worksheet of the workbook was shown to participants, as is displayed in Figure 7 below.

Ambient Environmental Issues: Anything about the environmental context of the transaction space that is hindering or preventing effective transaction completion.							
Guideline	% Rated 4 or 5	% Rating 3,4, of 5	Avg Rating		Your Rnd 1 Rating	Your New Rating	If you changed your rating, what led you that decision?
Avoid touch input that is too sensitive (prevent accidental presses) and tackle the fear of accidentally initiated commands	69%	85%	3.7				
Passively identify potential situational impairment events so that the device can react independently of users' direct feedback.	69%	77%	3.7				
Sample comments (Guideline 11)	**Rating**						
"...the environmental situation is tough by itself and the user is already involved in something that they do not like."//"Workers are in fast paced conditions at times. Too sensitive means having to go back to correct or change how you normally operate..thus slowing you down. Not feasible in jobs that pertain to inspections. (Oil, water, waste)."	4 or 5						
"It is unrealted to this category."//"Sounds like modifying the interaction for *just* ambient enviro conditions, which could produce confusing inconstistencies in system behavior."	1 or 2						
Sample comments (Guideline 39)	**Rating**						
"If the situational impairment is bad it might limit the person's ability to overcome the problem and so this guidelines is crucial."//"This would be great if the device reacts correctly to the users specifications. Sometimes user may not be able to provide feedback."//"This could be helpful depending on what the user is doing – passively identifying impairments could be valauable when driving, for example, but not needed in other situations."	4 or 5						
"It is unrealted to this category."//"Independent changes could be confusing, I would assume its better to instead detect problems and then *ask the user* if they want accomodations."	1 or 2						

Figure 7: Rating Round 2 Example Worksheet

Step 3: Follow-up Interviews (If needed)

If they had been deemed necessary (e.g. if consensus had not been reached on many of the draft guidelines), follow-up interviews would have been conducted with some of the participants to ensure that the commentary and findings truly represented the positions and opinions of the participants and perhaps to help describe some of the more critical themes.

Stage 2 Results (Delphi)

Selection of Experts and Orientation

The qualifying criteria for participation were based primarily on having at least one year of experience in the design or research of mobile interaction and being at least 18 years of age. In addition, requirement #3 stated that the recruited experts needed to want to participate without any expectation of monetary compensation. This may have been a factor that helped reduce participant attrition (discussed later in this section) as prior to agreeing to participate, the expert needed to be motivated by intrinsic factors alone. The complete Knowledge Resource Nomination Worksheet (KRNW) is displayed in Figure 8 below:

Knowledge Resource Nomination Worksheet (KRNW)

1. The participant must be either
   a. A researcher (academic or other) that has examined some aspect of mobile device interaction (e.g. developing prototypes, user testing, or theory development) or
   b. A designer or developer of mobile interaction applications or devices
2. The participant must have a minimum of one year experience in either sub-domain listed in #1 above.
3. There will be no monetary compensation. The participant must be willing to participate because of a genuine interest in the subject and scope of the research, perhaps with the understanding of being able to incorporate knowledge gleaned from their participation towards their continued work in the domain of mobile device interaction.
4. The participant must be at least 18 years of age
5. The participant must have access to on-line software capable of using an application that has direct manipulation (drag and drop) capabilities.
6. The participant must be willing to devote 30 minutes every other week (bi-weekly), for anywhere from 3 to 5 iterations, to fill out and return an online questionnaire.
7. After the 5 bi-weekly iterations listed above are complete, the participant must be willing (if necessary) to participate in a 30 minute on-line, one-to-one interview with the researcher

Figure 8: KNRW

After completing the research consent form, 20 experts (5 females/15 males) agreed to participate (mean age: 40.7, mean experience: 6.2 years). A demographic breakdown appears in Table 14 below.

ID	Age	Sex	Exp(yr)	Occupation
R1	45	m	10	Usable security researcher/freelance UX developer
R2	54	m	4	Professor
R3	42	m	5	PhD Student
R4	29	m	4	Assistant Professor
R5	32	f	6	Doctoral Researcher
R6	41	m	15	Associate Professor
R7	25	f	2	Student
R9	67	m	10	Professor
R10	28	m	2	PhD Student
P1	53	m	18	Software Engineer
P2	21	m	2.5	Student
P4	38	m	3	Software Engineer
P6	48	m	10	System Developer
P7	54	m	1	IT Project Manager
P10	49	f	3	Software Engineer
R8	*36*	*f*	*1*	*Graduate Assistant*
P11	*61*	*m*	*7*	*CTO*
P8	*25*	*f*	*10*	*Student*
P3	*28*	*m*	*4*	*Software Engineer*
P5	*38*	*m*	*7*	*Lead Developer*

Table 14: Participant Demographics

Over half of the participants (60%) came from the researchers' professional network or were *snowballed* from that network. The complete breakdown appears in Table 15 below. Each participant was provided with a link to a brief orientation video[2] defining the SIID themes and SCSI, along with a pdf file containing the

[2] Link to the orientation video: https://youtu.be/t-iByKVzfo4

definitions from the video and a pdf file with the list of 49 draft guidelines in alphabetical order.

Recruitment Source	Total	%
Researcher Professional Network	7	35%
Snowball (Professional Network)	5	25%
Facebook	3	15%
CHI Conference SIID Workshop	2	10%
Snowball (Facebook)	1	5%
LinkedIn	1	5%
UX Meetup Event	1	5%
Total Initial Participants	*20*	

Table 15: Initial Recruitment by Source

Narrowing Down and Classification Round

After orientation, participants were sent an email containing the links to six Qualtrics web-based survey modules (one for each SIID theme and one for SCSI)[3]. The order in which the links appeared in the email was different for each recipient and was determined via Latin Square to reduce order bias, and participants were asked to complete the modules in the order in which they were presented. Since this was the longest of the rounds, participants were given two weeks to complete all six modules. For each module, participants chose as many of the 49 draft guidelines as they believed represented a potential guideline for the addressing of that module's situational impairment theme. The results were tallied, and any guideline that was selected by 50% or more of the panel was then advanced to the next round (Okoli &

[3] An example of one of the modules ("Complexity") can be found at: https://umbc.co1.qualtrics.com/jfe/form/SV_39rcvoVasNk7ZZP

Pawlowski, 2004). Of the 20 who started the process, 13 completed all three modules, and an additional two participants completed some, but not all.

Of those 49 guidelines, 29 unique guidelines met the criteria for carryover into the rating round. This represented a total of 43 guidelines to rank over the six themes as there were several guidelines that were represented in multiple tables. The breakdown of the draft guidelines that were carried over by theme are detailed in Tables 16-21 below. The second column of each table (Score) represents the number of experts that chose that guideline and the third column represents the percentage of total participants that chose that guideline (which was based on either a total of 14 or 15 participants due to partial completions).

Ambient Environmental		
Guideline	**Score**	**% (15 tot)**
Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	9	60.0%
Avoid touch input that is too sensitive (prevent accidental presses) and tackle the fear of accidentally initiated commands	8	53.3%
For any given task the design should specify which modalities are appropriate for each context and offer additional value to users that are not directly interacting with the screen	8	53.3%
Passively identify potential situational impairment events so that the device can react independently of users' direct feedback.	8	53.3%
Under certain ambient conditions (e.g. extreme cold) account for reduced accuracy (e.g. offset skew) in target acquisition, particularly in one-handed interaction	12	80.0%

Table 16: Narrowing Down and Classification Round – Ambient-Environmental Guidelines

Complexity		
Guideline	**Score**	**% (14 tot)**
A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	13	92.9%
Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	12	85.7%
In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	12	85.7%
Account for the fact that users may engage in distracting activities because they may not realize that their performance is degraded or overconfident in their ability to deal with distractions while engaged in the primary activity.	11	78.6%
Minimize the number of steps and consider simple movement (e.g. clicking) over complex movements (e.g. dragging, drawing certain shapes). Also, interaction based on tap length (invoking different functionality on long tap) should be avoided	10	71.4%
Avoid distractions (i.e. blinking images) and discourage unconscious action in tasks that require vigilance.	9	64.3%
Design features to reduce contextual stress. (e.g. facilitate the ease of safety check-ins, users locating one another, and compensate for lack of communication synchronicity).	7	50.0%
Detect breakpoints (when the user is not actively manipulating the device) using additional sensors, such as GPS, accelerometer, proximity and light sensors	7	50.0%

Table 17: Narrowing Down and Classification Round – Complexity Guidelines

Social Cultural		
Guideline	**Score**	**% (14 tot)**
Make sure that gesture interactions do not involve offensive or culturally inappropriate action from the user	10	71.4%
Provide subtle feedback, such as vibration from within a pocket, or personal audio, in situations where individuals are hesitant to carry their devices in public.	10	71.4%

A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	9	64.3%
In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	8	57.1%
Minimize the necessity to look down on the display	8	57.1%
Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	7	50.0%
Ensure the AI system's language and behaviors do not reinforce undesirable and unfair stereotypes and biases.	7	50.0%
When in motion, user can query the system using voice, when not in motion, users can interact with the system using tabs and gestures	7	50.0%

Table 18: Narrowing Down and Classification Round – Social-Cultural Guidelines

Technical		
Guideline	**Score**	**% (14 tot)**
Connect with different communications and data networks to ensure high availability of services.	12	85.7%
Connectivity and power issues should be transparent for the end-user. Use automatic logging as an efficient way to obtain continuous battery information and highlight/educate the user regarding their battery life limitations and performance improvements	12	85.7%
Low energy consuming localization methods should be used as substitute for power hungry localization techniques (e.g., GPS).	12	85.7%
Explicitly distinguish between periods of active use and passive use, then use the passive periods to conduct power and data intensive operations	10	71.4%
Device should be easy to recharge via a cradle rather than a plug.	9	64.3%
Employ a simple and universal external mechanism to provide power for phone (e.g. implemented in a carry bag or in a coat pocket) making it accessible	9	64.3%

Table 19: Narrowing Down and Classification Round – Technical Guidelines

Workspace Location		
Guideline	**Score**	**% (15 tot)**
Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	9	60.0%
Avoid two-handed, multiple-finger interaction	9	60.0%
Design technology such that it poses little burden/encumbrance (i.e. reducing the need for resources such as hands or storage areas like a coat pocket)	9	60.0%
Avoid gestures needing precision, large areas to perform, or cause physical pain after prolonged use	8	53.3%
Minimize the number of steps and consider simple movement (e.g. clicking) over complex movements (e.g. dragging, drawing certain shapes). Also, interaction based on tap length (invoking different functionality on long tap) should be avoided	8	53.3%
When in motion, user can query the system using voice, when not in motion, users can interact with the system using tabs and gestures	8	53.3%

Table 20: Narrowing Down and Classification Round – Workspace-Location Guidelines

SCSI		
Guideline	**Score**	**% (14 tot)**
In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	11	78.6%
Design features to reduce contextual stress. (e.g. facilitate the ease of safety check-ins, users locating one another, and compensate for lack of communication synchronicity).	9	64.3%
Notification settings should leverage users' existing contact info metadata in order to select when, where and how to be notified by certain people.	9	64.3%
Passively identify potential situational impairment events so that the device can react independently of users' direct feedback.	9	64.3%
A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	7	50.0%

Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	7	50.0%
Any function designed for the adaptation to the variable contexts and environments must function in real-time and as a background task without altering the normal operation and use	7	50.0%
Avoid two-handed, multiple-finger interaction	7	50.0%
Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	7	50.0%
For any given task the design should specify which modalities are appropriate for each context and offer additional value to users that are not directly interacting with the screen	7	50.0%

Table 21: Narrowing Down and Classification Round – SCSI Guidelines

Rating Round 1

The previous round identified what draft guidelines were considered worthy of consideration by a majority of a panel of mobile interaction experts. However, the strength of each expert's opinion was not measured. In these first of two rating rounds, the participants rated how important each presented guideline was towards addressing each situational impairment theme. Any guideline where there was consensus from the panel as either being "important" or "essential" was then included in the final list of recommendations. All 13 participants who completed the initial round also completed this round.

A guideline was considered "in consensus" if it met one of the two following criteria (York & Ertmer, 2011):

1. IQR <= to 1 **AND** >=75% agreement on a rating of 4 and 5
   or
2. A >92% frequency rating in the 3, 4, 5 categories (>92% indicated all but 1 participant).

Based on the criteria for consensus listed above, 23 of the 43 items (53.5%) reached a consensus as to being either important or essential. Of the remaining 20 items that did not meet consensus, 16 were selected to be carried over to the second and final rating round. The four items that did not make consensus but were not considered for Round 2 were under 50% agreement on a rating of 4 and 5. Since the goal is guidelines that experts agree should be considered, the researchers chose to eliminate from consideration any guideline where less than half of the experts ranked it as important or essential, which is consistent with the 50% agreement used to advance a guideline into this round. The summary breakdown by theme appears in Table 22 below. A complete breakdown appears in the Appendix section.

Theme	**Ranked**	**Reached consensus**	**Removed due to <50% 4/5 rating**	**Carry to next round**
Ambient-Environmental	5	3	0	2
Complexity	8	6	1	1
Social-Cultural	8	3	1	4
Technical	6	5	0	1
Workspace-Location	6	3	0	3
SCSI	10	3	2	5
Totals	*43*	*23*	*4*	*16*

Table 22: Rating Round 1 - Guideline Consensus Summary

Rating Round 2

As previously noted, unlike a focus group, one of the **advantages** of the Delphi method is that because the responses are given asynchronously and anonymously, there is little chance for personalities to dominate discussion; nor can individuals *hide* and not contribute their *fair share* due to a general lack of participation. Unlike a focus group, however, one of the **limitations** of the Delphi method is the lack of idea refinement through feedback. This is at least partially addressed by having iterative rounds where participants can observe the results of the group as a whole along with examining the unstructured feedback of the other participants.

To see whether a consensus could still be obtained for any of the guidelines where consensus was not achieved, a second round of rating was conducted. For each guideline that did not reach consensus, participants were shown their rating compared with summarized metadata for the group. In addition, participants were presented with a sampling of the comments representing rationale of choices made from Round 1 for that guideline. Then, based on this data, participants were asked either to hold to their original rating or, based on the metadata presented, to consider reassessment. If they chose to reassess their original rating, they were asked to offer a brief justification.

As a result of the opportunity to reconsider based on the external data and comments presented, more of the draft guidelines were able to meet the criteria for consensus. The criteria for consensus (IQR consensus ratings, percentages, and acceptance criteria) stayed as strict as was the case in Rating Round 1. Similar studies such as Chen (2019) relax their criteria in subsequent rounds, primarily over concerns for participant attrition should the study extend too long. It was clear that participant attrition was beginning to show as only 12 of the 13 who participated in the first rating round completed this final round. The researchers were prepared to offer eased criteria for consensus, but the results of this round showed no need to do so. As Table

23 below shows, of the 16 guidelines that were reassessed, only 5 remained without achieving consensus. This resulted in a total consensus percentage of 79.1%, which exceeded the consensus percentage in Chen (2019) even with relaxed criteria.

Therefore, with only 5 of the original 43 criteria not in consensus, as was similarly done in Chen (2019), the study terminated in this round with no need for any follow-up interviews.

Theme	No consensus during Rating Rnd 1	No consensus during Rating Rnd 2	Net add to Master List
Ambient-Environmental	2	1	1
Complexity	1	0	1
Social-Cultural	4	3	1
Technical	1	0	1
Workspace-Location	3	0	3
SCSI	5	1	4
Totals	*16*	*5*	*11*

Table 23: Rating Round 2 - Guideline Consensus Summary

Guideline #20 ("Design flexible limits for task completion…") was an example of a guideline for the SCSI theme that did not reach consensus from participants in Round 1, but did in Round 2. After Round 1, it had a mean rating of 3.5, 54% rated it a "4" or a "5", 85% rated it a "3", "4", or "5", and it had an IQR value of "1". Therefore, even though it had an acceptable IQR value, it failed on both of the criteria for consensus, namely 75% or more rating it a "4" or "5" (with an IQR of 1 or less) or 92% or higher rating it a “3”, “4”, or “5”. One participant who rated it a “2” in Round 1 noted that they were, “*...not sure how this could help with SCSIs.*”

In Round 2, however, the average rating rose to 3.8. While the IQR value was unchanged, the percentage rating it a “4” or “5” increased to 69%. This still was not enough for the guideline to be considered in consensus, but the percentage that rated it a “3”, “4”, or “5” also increased to 100%, qualifying it as being in consensus. The participant referenced in the paragraph above that rated it a “2”, changed their rating to a “4” indicating, *“I guess this recommendation is quite important, giving it a second thought was useful.*” Comments from participants that rated it a “4” or “5” in Round 1 that were available for consideration included:

> “*Reduce the undue stress that may be posed due to the fear of missing something important.*"
>
> "*Sounds like this could reduce some of the time-based constraints of severe impairment scenarios.*"

The final breakdown for each guideline along with the data used for consensus is displayed in the Tables 24-29 below. Each table represents a single theme from Study 1.

Ambient-Environmental						
G#		IQR	4 + 5%		3+4+5%	Consensus
2	Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	1.0	77%	or	92.3%	x
11	Avoid touch input that is too sensitive (prevent accidental presses) and tackle the fear of accidentally initiated commands	1.0	69%		92.3%	x
27	For any given task the design should specify which modalities are appropriate for each context and offer additional value to users that are not directly interacting with the screen	1.0	54%		92.3%	x
39	Passively identify potential situational impairment events so that the device can react independently of users' direct feedback.	1.0	69%		84.6%	
45	Under certain ambient conditions (e.g. extreme cold) account for reduced accuracy (e.g. offset skew) in target acquisition, particularly in one-handed interaction	1.0	85%		92.3%	x

Table 24: Final Consensus Calculation Breakdown – Ambient-Environmental

Complexity						
G#		**IQR**	**4 + 5%**		**3+4+5%**	**Consensus**
1	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	0.0	92%	or	92.3%	x
4	Account for the fact that users may engage in distracting activities because they may not realize that their performance is degraded or overconfident in their ability to deal with distractions while engaged in the primary activity.	0.0	77%		92.3%	x
8	Avoid distractions (i.e. blinking images) and discourage unconscious action in tasks that require vigilance.	1.0	85%		92.3%	x
19	Design features to reduce contextual stress. (e.g. facilitate the ease of safety check-ins, users locating one another, and compensate for lack of communication synchronicity).	1.0	38%		76.9%	
20	Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	2.0	69%		92.3%	x
22	Detect breakpoints(when the user is not actively manipulating the device) using additional sensors, such as GPS, accelerometer, proximity and light sensors	1.0	62%		92.3%	x
29	In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	1.0	77%		100.0%	x
36	Minimize the number of steps and consider simple movement (e.g. clicking) over complex movements (e.g. dragging, drawing certain shapes). Also, interaction based on tap length (invoking different functionality on long tap) should be avoided	1.0	77%		100.0%	x

Table 25: Final Consensus Calculation Breakdown – Complexity

Social-Cultural						
G#		IQR	4 + 5%		3+4+5%	Consensus
1	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	1.0	85%	or	84.6%	x
20	Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	0.0	77%		92.3%	x
25	Ensure the AI system's language and behaviors do not reinforce undesirable and unfair stereotypes and biases.	1.0	92%		92.3%	x
29	In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	2.0	46%		76.9%	
34	Make sure that gesture interactions do not involve offensive or culturally inappropriate action from the user	3.0	62%		69.2%	
35	Minimize the necessity to look down on the display	1.0	69%		84.6%	
41	Provide subtle feedback, such as vibration from within a pocket, or personal audio, in situations where individuals are hesitant to carry their devices in public.	1.0	85%		92.3%	x
48	When in motion, user can query the system using voice, when not in motion, users can interact with the system using tabs and gestures	2.0	62%		76.9%	

Table 26: Final Consensus Calculation Breakdown – Social-Cultural

Technical						
G#		IQR	4 + 5%		3+4+5%	Consensus
13	Connect with different communications and data networks to ensure high availability of services.	0.0	100%	or	100.0%	x
14	Connectivity and power issues should be transparent for the end-user. Use automatic logging as an efficient way to obtain continuous battery information and highlight/educate the user regarding their battery life limitations and performance improvements	0.0	85%		100.0%	x
23	Device should be easy to recharge via a cradle rather than a plug.	1.0	62%		92.3%	x
24	Employ a simple and universal external mechanism to provide power for phone (e.g. implemented in a carry bag or in a coat pocket) making it accessible	2.0	54%		92.3%	x
26	Explicitly distinguish between periods of active use and passive use, then use the passive periods to conduct power and data intensive operations	1.0	85%		100.0%	x
33	Low energy consuming localization methods should be used as substitute for power hungry localization techniques (e.g., GPS).	1.0	69%		100.0%	x

Table 27: Final Consensus Calculation Breakdown – Technical

Workspace-Location						
G#		IQR	4 + 5%		3+4+5%	Consensus
2	Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	0.0	85%	or	92.3%	x
9	Avoid gestures needing precision, large areas to perform, or cause physical pain after prolonged use	1.0	85%		100.0%	x
12	Avoid two-handed, multiple-finger interaction	1.0	77%		92.3%	x
21	Design technology such that it poses little burden/encumbrance (i.e. reducing the need for resources such as hands or storage areas like a coat pocket)	1.0	77%		84.6%	x
36	Minimize the number of steps and consider simple movement (e.g. clicking) over complex movements (e.g. dragging, drawing certain shapes). Also, interaction based on tap length (invoking different functionality on long tap) should be avoided	0.0	77%		100.0%	x
48	When in motion, user can query the system using voice, when not in motion, users can interact with the system using tabs and gestures	2.0	69%		100.0%	x

Table 28: Final Consensus Calcuation Breakdown – Workspace-Location

SCSI						
G#		IQR	4 + 5%		3+4+5%	Consensus
1	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	1.0	77%	or	100.0%	x
2	Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	1.0	85%		92.3%	x
5	Any function designed for the adaptation to the variable contexts and environments must function in real-time and as a background task without altering the normal operation and use	1.0	92%		92.3%	x
12	Avoid two-handed, multiple-finger interaction	2.0	46%		76.9%	
19	Design features to reduce contextual stress. (e.g. facilitate the ease of safety check-ins, users locating one another, and compensate for lack of communication synchronicity).	1.0	62%		92.3%	x
20	Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	1.0	69%		100.0%	x
27	For any given task the design should specify which modalities are appropriate for each context and offer additional value to users that are not directly interacting with the screen	1.0	31%		76.9%	
29	In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	1.0	85%		100.0%	x
38	Notification settings should leverage users' existing contact info metadata in order to select when, where and how to be notified by certain people.	2.0	54%		69.2%	
39	Passively identify potential situational impairment events so that the device can react independently of users' direct feedback.	1.0	77%		92.3%	x

Table 29: Final Consensus Calculation Breakdown – SCSI

Guidelines for the Addressing of Situational Impairments

The goal of this study was the creation of guidelines for the addressing of various types of situational impairment events. Table 30 below represents each guideline from the original draft set of guidelines that was selected for use in one or more of the situational impairment themes. In all, 26 guidelines were employed although there is a total of 34 records as some guidelines were used for more than one theme. The table displays the topic areas of the sources that were primarily used to create the guideline in the third column. The last column of the table shows the frequency with which each guideline was used across the six theme categories.

G#	Guideline	Source Topic Area(s)	Frq of use
1	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	Mobile Visual Display/Visual Impairments	3
2	Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	Cognitive Impairments/Web Accessibility	3
4	Account for the fact that users may engage in distracting activities because they may not realize that their performance is degraded or overconfident in their ability to deal with distractions while engaged in the primary activity.	Distractive Driving	1
5	Any function designed for the adaptation to the variable contexts and environments must function in real-time and as a background task without altering the normal operation and use	Visual Impairments/SIID in Cold Environments	1
8	Avoid distractions (i.e. blinking images) and discourage unconscious action in tasks that require vigilance.	UD and Designing for Older Adults	1
9	Avoid gestures needing precision, large areas to perform, or cause physical pain after prolonged use	Motor Impairments/Hearing Impairments	1
11	Avoid touch input that is too sensitive (prevent accidental presses) and tackle the fear of accidentally initiated commands	Designing for Older Adults	1
12	Avoid two-handed, multiple-finger interaction	Accessibility	1
13	Connect with different communications and data networks to ensure high availability of services.	Mobile Services in Unstable Environments	1

14	Connectivity and power issues should be transparent for the end-user. Use automatic logging as an efficient way to obtain continuous battery information and highlight/educate the user regarding their battery life limitations and performance improvements	Shared Workspace Accessibility/Smartphone Energy Efficiency	1
19	Design features to reduce contextual stress. (e.g. facilitate the ease of safety check-ins, users locating one another, and compensate for lack of communication synchronicity).	Cognitive Impairments	1
20	Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	Accessibility	3
21	Design technology such that it poses little burden/encumbrance (i.e. reducing the need for resources such as hands or storage areas like a coat pocket)	Visual Impairments	1
22	Detect breakpoints (when the user is not actively manipulating the device) using additional sensors, such as GPS, accelerometer, proximity and light sensors	Interruption Notification on Smartphones	1
23	Device should be easy to recharge via a cradle rather than a plug.	Designing for Older Adults	1
24	Employ a simple and universal external mechanism to provide power for phone (e.g. implemented in a carry bag or in a coat pocket) making it accessible	Capacitive Touch Input on Clothing	1
25	Ensure the AI system's language and behaviors do not reinforce undesirable and unfair stereotypes and biases.	Human-AI Interaction	1
26	Explicitly distinguish between periods of active use and passive use, then use the passive periods to conduct power and data intensive operations	Communication in Constrained Computing Environments	1
27	For any given task the design should specify which modalities are appropriate for each context and offer additional value to users that are not directly interacting with the screen	Adaptive Multi-modal Mobile Input	1
29	In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	In-Vehicle Device Interaction	2
33	Low energy consuming localization methods should be used as substitute for power hungry	Smartphone Energy Efficiency	1

	localization techniques (e.g., GPS).		
36	Minimize the number of steps and consider simple movement (e.g. clicking) over complex movements (e.g. dragging, drawing certain shapes). Also, interaction based on tap length (invoking different functionality on long tap) should be avoided	Accessible Mouse-based Widgets/Designing for Older Adults/ Nose-based Interaction.	2
39	Passively identify potential situational impairment events so that the device can react independently of users' direct feedback.	SIID in Cold Environments	1
41	Provide subtle feedback, such as vibration from within a pocket, or personal audio, in situations where individuals are hesitant to carry their devices in public.	Visual Impairments	1
45	Under certain ambient conditions (e.g. extreme cold) account for reduced accuracy (e.g. offset skew) in target acquisition, particularly in one-handed interaction	SIID in Cold Environments	1
48	When in motion, user can query the system using voice, when not in motion, users can interact with the system using tabs and gestures	Visual Impairments	1

Table 30: Final Guidelines Selected

Tables 31-36 below are the final set of guidelines arranged by situational impairment theme. Also included are the domains from which each guideline came. A detailed discussion of the implications of these results will occur in the next chapter. However, one salient point to note in the below results is the preponderance of chosen guidelines that have come completely or in part from publications in either the Assistive Technology or the Accessibility domains. Of the 34 guidelines deployed, 20 (58.8%) were at least partially sourced from Assistive Technology/Accessibility research publications, offering further support to the premise that situational impairment guidelines can at least begin to be addressed by examining how more permanent impairments are being supported.

Ambient-Environmental						
G#	**Guideline**	**Mean Rating**	**IQR**	**4 + 5%**	**3+4+5%**	**Source Domain**
2	Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	4.3	1.0	77%	92.3%	Accessibility/ Assistive Technology
11	Avoid touch input that is too sensitive (prevent accidental presses) and tackle the fear of accidentally initiated commands	3.8	1.0	69%	92.3%	Accessibility
27	For any given task the design should specify which modalities are appropriate for each context and offer additional value to users that are not directly interacting with the screen	3.5	1.0	54%	92.3%	Mobile Interaction
45	Under certain ambient conditions (e.g. extreme cold) account for reduced accuracy (e.g. offset skew) in target acquisition, particularly in one-handed interaction	4.3	1.0	85%	92.3%	Mobile Interaction

Table 31: Final Guidelines – Ambient Environmental

Complexity						
G#	**Guideline**	**Mean Rating**	**IQR**	**4 + 5%**	**3+4+5%**	**Source Domain**
1	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	4.5	0.0	92%	92.3%	Assistive Technology/ Mobile Interaction
4	Account for the fact that users may engage in distracting activities because they may not realize that their performance is degraded or overconfident in their ability to deal with distractions while engaged in the primary activity.	3.8	0.0	77%	92.3%	Car Interaction
8	Avoid distractions (i.e. blinking images) and discourage unconscious action in tasks that require vigilance.	4.4	1.0	85%	92.3%	Accessibility
20	Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	3.9	2.0	69%	92.3%	Accessibility
22	Detect breakpoints(when the user is not actively manipulating the device) using additional sensors, such as GPS, accelerometer, proximity and light sensors	3.6	1.0	62%	92.3%	Mobile Interaction
29	In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	4.2	1.0	77%	100.0%	Car Interaction
36	Minimize the number of steps and consider simple movement (e.g. clicking) over complex movements (e.g. dragging, drawing certain shapes). Also, interaction based on tap length (invoking different functionality on long tap) should be avoided	4.4	1.0	77%	100.0%	Accessibility/ Assistive Technology/ Mobile Interaction

Table 32: Final Guidelines - Complexity

Social-Cultural						
G#	Guideline	Mean Rating	IQR	4 + 5%	3+4+5%	Source Domain
1	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	4.1	1.0	85%	84.6%	Assistive Technology/ Mobile Interaction
20	Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	3.9	0.0	77%	92.3%	Accessibilty
25	Ensure the AI system's language and behaviors do not reinforce undesirable and unfair stereotypes and biases.	4.4	1.0	92%	92.3%	Mobile Interaction
41	Provide subtle feedback, such as vibration from within a pocket, or personal audio, in situations where individuals are hesitant to carry their devices in public.	4.3	1.0	85%	92.3%	Assistive Technology

Table 33: Final Guidelines – Social-Cultural

Technical						
G#	Guideline	Mean Rating	IQR	4 + 5%	3+4+5%	Source Domain
13	Connect with different communications and data networks to ensure high availability of services.	4.8	0.0	100%	100.0%	Mobile Interaction
14	Connectivity and power issues should be transparent for the end-user. Use automatic logging as an efficient way to obtain continuous battery information and highlight/educate the user regarding their battery life limitations and performance improvements	4.6	0.0	85%	100.0%	Accessibilty/ Mobile Interaction
23	Device should be easy to recharge via a cradle rather than a plug.	3.8	1.0	62%	92.3%	Accessibilty
24	Employ a simple and universal external mechanism to provide power for phone (e.g. implemented in a carry bag or in a coat pocket) making it accessible	3.7	2.0	54%	92.3%	Mobile Interaction
26	Explicitly distinguish between periods of active use and passive use, then use the passive periods to conduct power and data intensive operations	4.2	1.0	85%	100.0%	Mobile Interaction
33	Low energy consuming localization methods should be used as substitute for power hungry localization techniques (e.g., GPS).	3.9	1.0	69%	100.0%	Mobile Interaction

Table 34: Final Guidelines - Technical

Workspace-Location						
G#	Guideline	Mean Rating	IQR	4 + 5%	3+4+5%	Source Domain
2	Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	4.5	0.0	85%	92.3%	Accessibility/ Assistive Technology
9	Avoid gestures needing precision, large areas to perform, or cause physical pain after prolonged use	4.5	1.0	85%	100.0%	Assistive Technology
12	Avoid two-handed, multiple-finger interaction	3.9	1.0	77%	92.3%	Accessibilty
21	Design technology such that it poses little burden/encumbrance (i.e. reducing the need for resources such as hands or storage areas like a coat pocket)	4.1	1.0	77%	84.6%	Assistive Technology
36	Minimize the number of steps and consider simple movement (e.g. clicking) over complex movements (e.g. dragging, drawing certain shapes). Also, interaction based on tap length (invoking different functionality on long tap) should be avoided	4.0	0.0	77%	100.0%	Accessibility/ Assistive Technology/ Mobile Interaction
48	When in motion, user can query the system using voice, when not in motion, users can interact with the system using tabs and gestures	4.1	2.0	69%	100.0%	Assistive Technology

Table 35: Final Guidelines – Workspace-Location

SCSI						
G#	Guideline	Mean Rating	IQR	4 + 5%	3+4+5%	Source Domain
1	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	4.5	1.0	77%	100.0%	Assistive Technology/ Mobile Interaction
2	Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	4.4	1.0	85%	92.3%	Accessibility/ Assistive Technology
5	Any function designed for the adaptation to the variable contexts and environments must function in real-time and as a background task without altering the normal operation and use	4.5	1.0	92%	92.3%	Assistive Technology/ Mobile Interaction
19	Design features to reduce contextual stress. (e.g. facilitate the ease of safety check-ins, users locating one another, and compensate for lack of communication synchronicity).	3.8	1.0	62%	92.3%	Accessibilty
20	Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	3.8	1.0	69%	100.0%	Accessibilty
29	In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	4.5	1.0	85%	100.0%	Car Interaction
39	Passively identify potential situational impairment events so that the device can react independently of users' direct feedback.	3.9	1.0	77%	92.3%	Mobile Interaction

Table 36: Final Guidelines – SCSI

Chapter 4 Summary

This dissertation's three-study research arc had as a goal the development of actionable guidelines for the addressing of various types of situational impairments. Because of a dearth of specific advice for the mobile design community regarding how to account for the onset of a situational impairment, this study sought advice from parallel and related research domains.

By examining mobile interaction, assistive technology, and accessibility research via an exhaustive systematic literature review, 49 guidelines were curated. Those 49 guidelines were then validated by an expert panel using a novel variation of the Delphi method. Of the 49 guidelines, 26 were determined by consensus of the panel to provide guidance to one or more of the types of situational impairments that users may encounter when attempting a mobile transaction *in the wild*. The validation of these guidelines by expert consensus demonstrates that new guidance can be created and existing guidance can be strengthened to better account for the presence of situational impairments faced by users of mobile technology, therefore supporting RQ1.4.

In addition, the majority of the validated guidelines came from research that is presently being done in the Assistive Technology and Accessibility domains. This aspect of the result offers concrete support to the notion once suggested by Nicolau (2012) of a practical connection between situational impairments and impairments of a more omnipresent variety.

A further analysis as to the meaning and implication of these findings will be discussed in the next chapter of this dissertation. In addition, the next chapter will discuss some of the limiting aspects of the research and point to directions for future research that these findings may suggest.

Chapter 5: In Search of Guidelines for the Addressing of Various Types of Situational Impairment Events (Discussion Limitations and Future Research)

Introduction

The previous chapter described the methodology and results of the third and final study (Study 3) within this research arc. The purpose of this chapter will be to provide a detailed analysis of the findings of Study 3 and their implications for the design of mobile interactive devices and demonstrate the degree to which RQ1.4 has been addressed. The advantages obtained from the novel adaptations of the two research methodologies (Chapter 4) will also be highlighted. In addition, a breakdown of the final list, by the themes defined from Study 1, will be examined. Finally, this chapter will explore what can still be achieved if this research thread were to continue by reviewing the limitations of Study 3 and what might be done to build upon what has been achieved.

There are several key take-aways to note from the results of Study 3 and its implications. These include: (1) confirmation that little to no direct guidance currently exists towards the addressing of situational impairments; (2) new guidance can be created and existing guidance can be strengthened to better account for the presence of situational impairments faced by users of mobile technology (RQ1.4); (3) a significant portion of that guidance can be gleaned by examining related domains, particularly Assistive Technology and Accessibility; and (4) the value of the Delphi method as a tool for validating guidance.

It is important to stress the nascent quality of the guidance presented in this study. It has been shown that there is little current guidance on how to address the onset of situational impairments and, in particular, the different variants by which a situational impairment can present (Study 1). The guidelines presented in this study are both new in that (1) some have been in existence, but they have not been applied to addressing situational impairments and (2) some have been constructed from elements of parallel domain guidance to truly produce a new element. The introduction of these guidelines, therefore, can prove a tremendous benefit to both designers and researchers in the mobile interaction problem space in the pursuit of maximizing the mobile user experience.

Discussion of the Results of Study 3

The Value of a Holistic Approach to Design Guidelines

Study 3, while a separate research unit, was necessarily dependent upon, and a product of, the findings and results of both Study 1 and Study 2. The themes from Study 1 were used as a structure for the situational impairment scenarios that were analyzed in Study 2. The findings of Study 3 were also framed by the themes from Study 1 as well as supported by the design implications garnered from Study 2. This was done to provide an appropriate and manageable foundation by which the guidelines gleaned in Study 3 might more effectively be validated.

As outlined in Chapter 1, while research has certainly been conducted that recognizes mobile as a new interaction paradigm (Wobbrock, 2006), the approach has for the most part been from a more traditional usability perspective. Researchers, such as Marshall and Tennant (2013), have identified the types of physical and cognitive challenges that interacting while mobile might engender. Studies such as those by Kane, Wobbrock, & Smith (2008) have identified specific mobile interaction issues and designed prototypes that presented targeted potential solutions to those specific mobile interaction issues.

Certainly there is value to be gained from this research that can help influence the addressing of situational impairments. One of the SIID themes from Study 1, for example, refers to issues of constant available power and data sources while on the go. Technical research into better battery life and more omnipresent data connection can directly address this theme. The final list of guidelines for the Technical Issues theme (as shown in Study 3) certainly includes recommendations drawn from this more technical approach.

But perhaps the solution to the deleterious effects brought about by the contexts surrounding mobile interaction require a more holistic approach. Approaching mobile interaction issues exclusively from a UI perspective is limiting. It may address the issue of situational impairments from the "situational" perspective but not the "impairment" perspective.

The results of Study 3 support the need for a more holistic approach to the situational impairment phenomenon in several ways.

- Stage 1 (Structured Literature Review) revealed that out of the nearly 350,000 raw hits from both the ACM and IEEE databases, only 1,245 hits (less than a half of a percent) were returned using search criteria relating to situational impairments.
- Stage 1 also showed a greater volume of AT and Accessibility guidelines research over the other categories by almost two to one.

- Stage 2 (Delphi) showed that the above ratio carried through to the solutions to situational impairments as indicated by the percentage of design guidelines taken from research emanating from the AT and Accessibility domains.

This is not to say that addressing SIID events from a UI perspective did not prove of value. If approximately two-thirds of the final guidelines were from the AT/Accessibility domains, then approximately one-third were gleaned from research specifically focused on mobile device UI. And as was discussed in Chapter 4, some guidelines were created/curated from multiple sources which at times crossed-over domains. Other sources, while from AT/Accessibility domains, addressed issues of mobile interaction experiences by other-abled users. But the fact that the majority of the solutions were not coming exclusively from mobile UI research illustrates the need to go beyond UI to a more holistic solution that can maximize the mobile user experience. In nearly every final theme list, there was one guideline that came from a combination of AT/Accessibility and mobile interaction sources (the exceptions being Ambient/Environmental (zero) and SCSI (two)). This will become more evident with a detailed analysis of how guidelines mapped to each theme as described in the next sub-section.

<u>Analysis of the Final Guidelines by Theme</u>

Introduction

In this sub-section, each of the themes that were defined in Study 1 will be analyzed individually based on the final set of guidelines that were mapped to each as the result of the consensus of experts. Each theme table from Chapter 4 is reproduced here showing the guidelines chosen, the scoring that led to their inclusion, and the source domain(s). In addition, the definition of each theme from Study 1 and the sub-categories that were defined are provided here as a reference. Finally, how well each of the theme issues is being addressed and whether user needs/desires (as defined in Study 2) are being accounted for is discussed below each table along with sample commentary from Stage 2 that supports the conclusions reached.

Ambient Environmental Issues

Definition from Study 1: Anything about the environmental context of the transaction space that is hindering or preventing effective transaction completion.

Sub Categories:

- **Meteorological Conditions:** Some aspect of the weather (i.e. sun, rain, heat, or cold) that is hindering or preventing effective transaction.
- **Ambient "Noise" Conditions:** Some non-meteorologically ambient condition is creating "noise" in the communication channel hindering or preventing effective transaction. The "noise" can be any non-meteorological input that is negatively affecting the signal-to-noise ratio of the transaction signal (not necessarily just audible noise) including another human.

Ambient-Environmental						
G#	Guideline	Mean Rating	IQR	4 + 5%	3+4+5%	Source Domain
2	Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	4.3	1.0	77%	92.3%	Accessibility/ Assistive Technology
11	Avoid touch input that is too sensitive (prevent accidental presses) and tackle the fear of accidentally initiated commands	3.8	1.0	69%	92.3%	Accessibility
27	For any given task the design should specify which modalities are appropriate for each context and offer additional value to users that are not directly interacting with the screen	3.5	1.0	54%	92.3%	Mobile Interaction
45	Under certain ambient conditions (e.g. extreme cold) account for reduced accuracy (e.g. offset skew) in target acquisition, particularly in one-handed interaction	4.3	1.0	85%	92.3%	Mobile Interaction

Ambient environmental issues focus on impairment events that occur due to the constant flux of the ambient context of the mobile transaction space. The four guidelines chosen by the expert panel showing potential design solutions focus on effective incorporation of alternative modalities. All were from the Limited Physical Resources category established during coding in Stage 1. The sources for the four guidelines chosen were evenly split between sources from the mobile interaction domain and the AT/Accessibility domain. These all speak to the need for technology to be able to effectively adjust to variable circumstances.

The results seem to point to a common need for addressing diversity. The mobile interaction community needs to account for a diversity of conditions as is demonstrated in the two mobile sourced guidelines which point to "context" (#27) and "ambient conditions" (#45). The AT/Accessibility community needs to account for diverse abilities as reflected in Guideline #2 ("Suggesting the use of alternative modalities") and Guideline #11, which offers a more general view of diversity of needs focused on the users' unique set of strengths and abilities. Guideline #11 also points to the need to account for adjusting touch sensitivity, which certainly can be applicable to both personal and situational conditions. This is reflected in the justifications offered by the participants for their choices. A few examples appear below:

Guideline #2 comments:

"Allowing more input levels is paramount. When a user has extra outlets, it reduces frustration if one input doesn't cooperate."

"The more options for different input the better. Especially since the ambient environment is so complex and always changing."

"This would address issues relating to Meteorological Conditions where using your fingers would not be effective e.g., very rainy or cold scenarios, too much sun."

Guideline #11 comments

"Sensitivity needs to be uniform, and should give appropriate feedback to the user."

"This is a very specific guideline, but one that is still important."

"This guideline should be for all design issues."

"...the environmental situation is tough by itself and the user is already involved in something that they do not like."

<u>*Guideline #27 comments:*</u>

"When environment is not friendly, it will give the user the option of doing it another way instead of just the screen."

"There should be the possibility of overriding context-aware interaction, just in case the user does not want it."

"Specifying appropriate input methods (e.g., button > touchscreen in cold) would make it easier for users to use their devices in undesirable weather conditions."

<u>*Guideline #45 comments:*</u>

"This would be very useful because…the environment is adding a larger cognitive load."

"This allows the system…to be not as precise, but doesn't create a frustration barrier."

"One of the main causes for situational impairments is due to ambient-environmental conditions, and therefore this should be a priority guideline for people to follow."

"Inspectors often need a free hand to collect samples such as soil or water, use free hand for phone, free hand to help balance themselves in difficult terrain."

"Extreme cold poses a tough challenge as it is inevitable users will make mistakes when moving towards a target. Having a system react appropriately is a must."

Complexity Issues

Definition from Study 1: Issues that hinder or prevent effective transaction completion resulting from task or ambient complexity.

Sub Categories:

- **Cognitive Load**: The cognitive resources required to effectively complete a transaction are unavailable or not easily accessible to the user as the result of having to hold aspects of the current transaction in working memory or having "other things on their mind" that are not directly related to the current transaction.
- **Number of Steps**: The number of steps that would be required to complete a transaction are perceived as too numerous or too cumbersome to effectively complete the transaction.
- **Walking Over Tasks**: The transaction cannot be completed due to another transaction attempting to occupy the active transaction space (i.e. a modal pop-up that appears while attempting to type a text message) or other interruption that may or may not be technology related (i.e. children interrupting an attempt to place a call via Bluetooth).
- **Gulf of Execution/Evaluation** (Norman, 1988): The user has insufficient knowledge from personal experience or from the current context to either effectively complete a transaction or evaluate whether a transaction has been effectively completed.

Complexity						
G#	Guideline	Mean Rating	IQR	4 + 5%	3+4+5%	Source Domain
1	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	4.5	0.0	92%	92.3%	Assistive Technology/ Mobile Interaction
4	Account for the fact that users may engage in distracting activities because they may not realize that their performance is degraded or overconfident in their ability to deal with distractions while engaged in the primary activity.	3.8	0.0	77%	92.3%	Car Interaction
8	Avoid distractions (i.e. blinking images) and discourage unconscious action in tasks that require vigilance.	4.4	1.0	85%	92.3%	Accessibility
20	Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	3.9	2.0	69%	92.3%	Accessibility
22	Detect breakpoints(when the user is not actively manipulating the device) using additional sensors, such as GPS, accelerometer, proximity and light sensors	3.6	1.0	62%	92.3%	Mobile Interaction
29	In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	4.2	1.0	77%	100.0%	Car Interaction
36	Minimize the number of steps and consider simple movement (e.g. clicking) over complex movements (e.g. dragging, drawing certain shapes). Also, interaction based on tap length (invoking different functionality on long tap) should be avoided	4.4	1.0	77%	100.0%	Accessibility/ Assistive Technology/ Mobile Interaction

When addressing issues where the mobile transaction space may increase the overall complexity, it is not surprising that the guidelines selected by the expert panel reflect solutions that either address ways to reduce the amount of cognitive load needed to complete the mobile interaction (#4, #8, #20, and #36) or suggest that technology take a greater role in assessing the environmental context, then making intelligent adjustments as needed (#1, #22, and #29). The latter technology role is succinctly summarized in Guideline #1, which indicates that technology "should read the right thing, at the right time, and at the right pace…" as well as protecting users from data/information that is irrelevant to the context. The value of technology effectively performing this type of service was clearly recognized by the expert panel, as the mean score (4.5) was the highest within this theme. The IQR value of 0.0 also illustrates the strong universal agreement within the panel showing that everyone other than one outlier gave this guideline a score of "4" or "5", justifying their choices with comments such as:

> *"…using this guideline, the* device *can reduce the cognitive load of the user."*
>
> *"The whole point of having a system…is to make things…easier and less burdensome on the user."*

Overall, four of the seven guidelines chosen for this theme were completely or partially sourced from the AT/Accessibility domain, including two guidelines with a mean score of 4.4 (#8 "Avoid distractions…" and #36 "Minimize the number of steps…"). These reflect the importance that the panel collectively placed on recognizing not only the limits of human cognition but also how the test of these limits is being exacerbated in the mobile interaction space:

Guideline #8 Comments

> *"…essential guideline since this will help user [with] walking over task."*
>
> *"This should be a universal guideline - common sense design."*

Guideline #36 Comments

> *"This is essential when addressing situational impairments."*
>
> *"Every step is another chance for errors, bail-outs, and frustration."*

One other interesting finding was that two of the guidelines chosen by the panel (#4 and #29) were sourced from mobile interaction research specifically targeted to interaction with technology while driving. While technically catalogued as mobile interaction, the researcher chose to list these guidelines in the table as specifically being sourced from "Car Interaction". As referenced in several points within this dissertation document, interactions with technology while operating a vehicle (either a mobile device or embedded) have become increasingly common among mobile device users. Interaction with anything not specifically purposed to the driving task can test the limits of human attention. Nevertheless, as one of the key findings of Study 2 points out, even though users know of the danger that exogenous device interaction can place on themselves and others, most (if not all) do it anyway. The increased complexity that can be mapped to attempting a mobile interaction while driving was clearly extrapolated by the panel for consideration of the increased complexity of mobile interactions in general with the inclusion of these two guidelines.

Guideline #4 Comments

"Users spend most of their time multi-tasking due to the pace of modern life. Systems now need to account for distraction."

"Anything that will help people, especially when they have an incorrect perception of their own ability, is a good thing."

"I got distracted answering this, so I guess it's the real deal."

Guideline # 29 Comments

"Certain information could be delayed (e.g. SMS's from friends/unknown numbers etc.)"

"User's mind will act as a pot, and non-important serves as the water. There's no reason to have a boiling pot that over flows."

Social-Cultural Issues

Definition from Study 1: These issues offer no physical barrier to transaction completion but nevertheless can hinder or prevent effective transaction completion.

Sub Categories:

- **Fear of Reprisal from an Authority**: Completing the transaction may result in a violation of the law or reprimand from a boss, teacher, or other type of authority figure (i.e. texting while driving, in class, or while at work).
- **Safety**: The completion of a transaction is hindered or prevented due to concern over the potential harm the attempted completion may cause (i.e. getting into an accident while texting and driving or having your device stolen while using it on the street in a "bad neighborhood").

- **Socially Acceptable Behavior**: The social context is perceived by the user to be inappropriate within the perceived cultural norms or personal moral code for effective completion of the transaction.

Social-Cultural							
G#	Guideline	Mean Rating	IQR	4 + 5%	3+4+5%	Source Domain
1	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	4.1	1.0	85%	84.6%	Assistive Technology/ Mobile Interaction
20	Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	3.9	0.0	77%	92.3%	Accessibilty
25	Ensure the AI system's language and behaviors do not reinforce undesirable and unfair stereotypes and biases.	4.4	1.0	92%	92.3%	Mobile Interaction
41	Provide subtle feedback, such as vibration from within a pocket, or personal audio, in situations where individuals are hesitant to carry their devices in public.	4.3	1.0	85%	92.3%	Assistive Technology

This theme represents a type of SIID where the main obstacle preventing transaction completion is user volition. The author was certainly curious to learn whether any external sources have offered any guidance. As expected, most of the sources returned in Stage 1, and indeed most of the corpus that comprised the initial set of 49 draft guidelines seemed to reflect a focus in the design and research communities on addressing technical barriers and physical issues. Nevertheless, of the 49 draft guidelines that were coded in Stage 1, four were coded as "Socially Acceptable" as they related to issues of volition.

The four chosen by the panel of experts as guidelines for addressing social/cultural barriers to transaction completion reflected on designing technology to help the user to not stand out or be embarrassed as the result of using the technology in public. In particular, two of the four draft guidelines coded as "Socially Acceptable" speak directly to the "Socially Acceptable Behavior" sub-category of this theme. Guideline #25 seeks to ensure that the system does not produce socially/culturally insensitive output. Guideline #41 regarding subtle feedback to account for user hesitancy to carry devices in public can also be seen as addressing “Socially Acceptable Behavior” and perhaps “Safety” in scenarios where the user is concerned that public display may lead to theft of the device. As one panelist noted, “*[When] waiting for an important notification when in an unfamiliar/unsafe location, [the user] wouldn't have to worry about constantly checking*.” Some of the panelists also noted the value of #41 in addressing embarrassment as well as the “Fear of Reprisal from an Authority” sub-theme. As one panelist noted, “*Better for meetings or places where discretion is needed*.”

This result set was greatly influenced by the AT/Accessibility community. Three out of the four guidelines were fully or partially sourced from these domains, which reflects, in general, an understanding that use of assistive technology often makes users feel self-conscious. As one panelist noted in regard to #25, “*This is huge. Users will abandon technologies that bring negative stigma to them.*” It was clear that the panel also recognized that even users who do not have more omnipresent physical or cognitive challenges can also feel stigmatized in certain situations.

It was also interesting to note that the other two guidelines chosen by the panel for this category were coded as “Contextually Aware” (#1) and “Limited Cognitive Resources” (#20) in Stage 1, and in fact were two of the guidelines that also were part of the “Complexity” solution set. Guideline #1 (“…right thing, at the right time, and at the right pace…”) was recognized by the panel as helpful in remaining inconspicuous. As one panelist noted, “*If the device is context aware and* *only provides messages at the right time, users are less likely to receive notifications at bad times, like meetings.*" For Guideline #20 ("Design flexible limits for task completion…"), one panelist notes, "*User may incorrectly complete tasks if they did not notice a warning / feedback…example, completing steps in a recipe…if not done correctly, will result in failed product.*"

Technical Issues

Definition from Study 1: A technical fault, glitch, or other non-user or environmental issue that prevents effective completion of a transaction.

Sub Categories:

- **Connection**: Something technical prevents connecting to an information source (i.e. bad cell or no Wi-Fi).
- **Power**: There is no, or insufficient, electrical power (i.e. low battery) to effectively complete the transaction.
- **Other Technical**: A technical issue other than connection or power that prevents effective transaction.

Technical						
G#	**Guideline**	**Mean Rating**	**IQR**	**4 + 5%**	**3+4+5%**	**Source Domain**
13	Connect with different communications and data networks to ensure high availability of services.	4.8	0.0	100%	100.0%	Mobile Interaction
14	Connectivity and power issues should be transparent for the end-user. Use automatic logging as an efficient way to obtain continuous battery information and highlight/educate the user regarding their battery life limitations and performance improvements	4.6	0.0	85%	100.0%	Accessibilty/ Mobile Interaction
23	Device should be easy to recharge via a cradle rather than a plug.	3.8	1.0	62%	92.3%	Accessibilty
24	Employ a simple and universal external mechanism to provide power for phone (e.g. implemented in a carry bag or in a coat pocket) making it accessible	3.7	2.0	54%	92.3%	Mobile Interaction
26	Explicitly distinguish between periods of active use and passive use, then use the passive periods to conduct power and data intensive operations	4.2	1.0	85%	100.0%	Mobile Interaction
33	Low energy consuming localization methods should be used as substitute for power hungry localization techniques (e.g., GPS).	3.9	1.0	69%	100.0%	Mobile Interaction

The results from this theme were the most straightforward and predictable. The Technical Issues theme differentiates itself in that these issues are not the result of any user physical/cognitive limitation, any user choice, or any limitations brought about by the external environment. The inability to effectively complete a mobile transaction that is the result of an SIID in this category stems from the limitations of the mobile technology itself, in particular the need to maintain a constant connection to a data source and having a sufficient electrical supply to maintain operation. Of course, one needs a good connection to the Internet and a power supply to interact with any information appliance, but because mobile devices are usually used while mobile and in changing contexts, these issues can often be exacerbated.

Seven of the initial 49 draft guidelines were coded as "Limited Technical Resources". Not only did all of the guidelines chosen by the expert panel come from this coded set, all seven were selected. It was expected that most of the guidelines would be sourced from non-AT/Accessibility research, and this turned out to be the case for the most part. However, two of the seven were at least partially sourced from the AT/Accessibility domain. One of these was Guideline #14 ("Connectivity and Power issues should be transparent to the end user…"), which has a mean score of 4.6 and an IQR value of 0.0. Comments from the panel as to why this could prove to be a value as a guideline for technical issues included:

> *"This is an essential guideline since the user can know the battery information beforehand and reduce abrupt power connection problems."*
>
> *"This allows users to plan their activities and make smarter decisions based on the battery life of their device."*

Guideline #23 ("Device should be easy to recharge via a cradle…") was sourced from the Accessibility community and the panel found this useful in recognition of how being mobile can put users in positions where the ability to recharge may not always present itself.

> *"This would be really useful for different situations we find ourselves in such as while driving or on a plane."*
>
> *"This is an important guideline since the user can use more than one option of charging the device so that [he/she] can perform effective transactions."*
>
> *"Something easy here, makes user acceptability higher. A HUGE importance."*

Guidelines were also chosen that specifically address the sub-theme "Connection". The panel's choices showed a recognition of the importance of being able to have an omnipresent source of data. Of particular importance was Guideline #13 ("Connect with different communications and data networks"). 100% of the panel scored this guideline a "4" or "5" (mean 4.8/IQR of 0.0). Some of their rationales included:

> *"Driving on the highway using GPS and losing signal resulting in missing directions or having to pull off miles away to get back on network."*
>
> *"This would be great. A bit like when you can roam on other networks but on a larger scale."*
>
> *"Saving money or increased connectivity rates are both good."*

Guideline #24 ("Simple universal mechanism for power") was determined to be of value because, as one panelist notes, it *"…helps user not worry about switching phones or asking others for a charger or trying to charge the phone in a public place."*

Guideline #26 ("Distinguishing between periods of active/passive use") was also deemed valuable for both connection and power issues. Some of the rationales included:

“Reduced ‘cognitive load’ is good for electronics as well.”

“Helps maintain data performance that could otherwise be frustrating and confusing for the user.”

“This guideline is essential…the user can use power according to [his/her] convenience…”

“Avoids lag in interaction when the device is computationally overloaded and needed by user.”

Workspace-Location Issues

Definition from Study 1: Issues that hinder or prevent the ability to effectively complete a transaction that are geospatial in nature. Either the workspace area is of insufficient size or the resources required are not within sufficient proximity to permit the effective completion of the transaction.

Sub Categories:

- **Inaccessible Location**: The information appliance is within reach but in a space that cannot be easily accessed in sufficient time to complete the transaction effectively (i.e. in a jacket/pants pocket or bag).
- **Workspace Size**: Some aspect of the workspace is affecting movement of resources required in the transaction and therefore hindering or preventing effective transaction (i.e. not big enough to effectively negotiate the input space).
- **Relative Location**: The relative location of the user and information appliance is such that interaction cannot effectively take place.
- **Unavailable Resources**: The resources needed to assist in the completion of the interaction are unavailable (i.e. hands full, phone powered off or on silent).

Workspace-Location						
G#	Guideline	Mean Rating	IQR	4 + 5%	3+4+5%	Source Domain
2	Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	4.5	0.0	85%	92.3%	Accessibility/ Assistive Technology
9	Avoid gestures needing precision, large areas to perform, or cause physical pain after prolonged use	4.5	1.0	85%	100.0%	Assistive Technology
12	Avoid two-handed, multiple-finger interaction	3.9	1.0	77%	92.3%	Accessibilty
21	Design technology such that it poses little burden/encumbrance (i.e. reducing the need for resources such as hands or storage areas like a coat pocket)	4.1	1.0	77%	84.6%	Assistive Technology
36	Minimize the number of steps and consider simple movement (e.g. clicking) over complex movements (e.g. dragging, drawing certain shapes). Also, interaction based on tap length (invoking different functionality on long tap) should be avoided	4.0	0.0	77%	100.0%	Accessibility/ Assistive Technology/ Mobile Interaction
48	When in motion, user can query the system using voice, when not in motion, users can interact with the system using tabs and gestures	4.1	2.0	69%	100.0%	Assistive Technology

Issues of workspace and location refer to the inability of the user to access their device due to: user and device are in different locations; resources needed to access the device are not available, or something about the makeup of the workspace itself is inhibiting access. It was expected that most of the guidelines that were chosen would come from the draft guidelines coded as "Limited Physical Resources". In fact, only half of the six guidelines selected by the panel were coded as "Limited Physical Resources". The others came from draft guidelines coded as "Limited Cognitive Resources" (2) and "Context Aware" (1). All six were sourced all or in part from AT/Accessibility domains demonstrating a strong connection to research on mobility or motion issues to SIIDs. The fact that the panel found these to be of value with situational issues of space shows the strength of incorporating AT/Accessibility research in the addressing of situational impairments. It was this type of impairment (issues with tremors) that was the focus of Nicolau's (2012) research that first explored the possibility of an SIID-AT/Accessibility connection.

It was interesting to note that two guidelines were also guidelines chosen for other themes as well. Guideline #2 ("Access via different input methods…"), for example, was also chosen as a guideline to address Ambient-Environmental Issues, perhaps reflecting the common thread of non-stable interaction context found in both issues. In this category, it was tied for the highest mean score (4.5) as well as tied for the lowest variance (IQR 0.0). Some of the reasons for choosing this guideline reflect on the value of having an alternative interaction choice for the "Workspace Size" and "Unavailable Resources" sub-themes:

> *"Helpful if your hands are full"*
>
> *"…may need head pointers or mouth pointers when physical space (very tight area) does not allow for hands on device to provide input."*

Guideline #36 ("Minimize the number of steps…"), chosen for this theme, was also chosen by the panel for the "Complexity" theme. It had a mean rating of "4" and an IQR value of 0.0; 77% of the panel rated it a "4" or "5", and no one rated it below a "3". At first it did not seem intuitive to include a guideline coded as "Limited Cognitive Resources" for this theme, but the rationales provided by the participants proved interesting in the addressing of "Workspace Size" and, conceivably, "Inaccessible Location":

> *"This guideline would be great for speeding up interaction when it might be cumbersome in certain workspace locations, and where it might be too noisy for voice input."*
>
> *"When limited access is available in interacting with the phone, and the space is limited, this will reduce the complexity of interaction."*

The other guideline coded as “Limited Cognitive Resources” that was chosen for this theme was Guideline #21 (“Design technology such that it poses little/burden encumbrance…”). The rationales primarily supported the addressing of “Unavailable Resources”:

> *“Keeps users from having full hands.”*
>
> *“Particularly helpful in situations where the user does not have access to both hands or a proper sized space to interact with the phone for a long time.”*

Guideline #9 (“Avoid gestures needing precision, large areas…”) had a mean score of 4.5 with justification also reflecting its value for “Inaccessible Locations” and “Workspace Size”:

> *“Part of this at least seems to relate to having gestures that will work on smaller input areas.”*
>
> *“This is essential guideline because if user is using the device in a small area like car, the space may not be enough for user to use gesture interaction to complete the task.”*

Only Guideline #48 (“When in motion, user can query system using voice…”) seemed to address the sub-theme of “Relative Location” as this comment indicated: *“Allows access to interaction with the phone even when …not in reach or the motion avoids effective touch screen interaction.”* Some other comments indicated that this guideline could also support “Workspace Size” and “Unavailable Resources”:

> *“Often when in motion, the user may need at least one hand for stabilization and to minimize an impaired state.”*
>
> *“This would be extremely useful in cramped spaces.”*
>
> *“This guideline is essential if there [are] resources unavailable like if the user’s hands are full and cannot use hands to perform the task, the user can interact with the device using voice.”*

Severely Constraining Situational Impairments (SCSI)

Definition from Study 1: An occurrence of a situational impairment where a workaround is not available/easily obtained, or where a technological solution was found that only led to the introduction of a new situational impairment and disability.

SCSI Characteristics/Types:

- **"Super" Situational Impairment Event**: Multiple impairment events combined in a single transaction. (E.g. "Thought of something I wanted to search the web for while I was cutting grass, but couldn't use phone because it was too bright out and couldn't use Siri because it was too noisy- By the time I reached a shady area, I ended up forgetting what the task was.")
- **Expiration of Transaction "Half-Life":** The value of a transaction becomes zero before conditions conducive to transaction completion can be achieved. (E.g. A SMS is received (and unattended) while in a store. The text is read upon returning from the store and was a request from the spouse to purchase an item.)
- **Solution to One SIID Produces New SIID**: An existing design solution to an SIID creates a new and different SIID. (E.g. voice input can overcome hand encumbrance, but not necessarily if that input contains information that cannot be disseminated in public.)
- **Competing Modal Transactions**: Common communication channel needed for competing modal transactions. (E.g. "GPS navigation in car interrupted by telephone call.")
- **Pre-Abandonment**: Transaction voluntarily terminated due to [a] concern over the violation of certain contextual social/cultural norms, or [b] past history leads user to not make transaction attempt. (E.g. "Operation to get files from a secured 'cloud' service, download them to my phone with an app, then upload them to a web service is simply too cumbersome to do on the phone... If even possible at all…")

SCSI						
G#	Guideline	Mean Rating	IQR	4 + 5%	3+4+5%	Source Domain
1	A system should read "the right thing, at the right time, and at the right pace" (e.g. shield users from unimportant minutiae, smart asynchronous notifications for managing interruptions, or correcting automatically transcribed texts)	4.5	1.0	77%	100.0%	Assistive Technology/ Mobile Interaction
2	Access should be guaranteed by different input methods (e.g. keyboards, simulators, switches, mouth pointers and head pointers) with attention to particular users' needs and strengths.	4.4	1.0	85%	92.3%	Accessibility/ Assistive Technology
5	Any function designed for the adaptation to the variable contexts and environments must function in real-time and as a background task without altering the normal operation and use	4.5	1.0	92%	92.3%	Assistive Technology/ Mobile Interaction
19	Design features to reduce contextual stress. (e.g. facilitate the ease of safety check-ins, users locating one another, and compensate for lack of communication synchronicity).	3.8	1.0	62%	92.3%	Accessibilty
20	Design flexible limits for task completion and warnings/feedback should stay on the screen as long as the user does not respond to them	3.8	1.0	69%	100.0%	Accessibilty
29	In highly demanding situations, the user should be saved from overload by either oppressing or delaying non-important information.	4.5	1.0	85%	100.0%	Car Interaction
39	Passively identify potential situational impairment events so that the device can react independently of users' direct feedback.	3.9	1.0	77%	92.3%	Mobile Interaction

Severely Constraining Situational Impairments (SCSI) have been separated from the other SIID themes as they represent severe cases of the SIID themes or amalgamated collections of different themes. It was not surprising that four out of the seven were guidelines that were chosen to combat one or more of the SIID themes as this category runs across themes. Five out of seven were coded as "Context Aware". This was also not a surprise, as the findings of Study 2 indicated that having technology be more context aware and even act more like a personal assistant was desired by users to address SCSI events. The other two represented (one each) were "Limited Physical Resources" and "Limited Cognitive Resources". Five out of the seven guidelines were sourced at least in part from the AT/Accessibility domain.

Of the guidelines that appear elsewhere, Guidelines #1, #2, and #29 had mean scores of 4.4 or higher. The rationales for Guideline #1 reflected its almost universal applicability as well as its value in addressing the SCSI characteristic of "Expiration of Transaction Half-Life":

> *"Applicable to most of the sub category guidelines."*
>
> *"If our devices can become smarter like this then it would make for a much better user experience. Especially during SCSIs since it is one less thing for the user to worry about."*
>
> *"Essential guideline because this guideline may help the user in the expiration of transactions in half-life. If the user gets the notification of a message at right time, the right thing at the right pace then the transaction will not have a half-life and instead, the user will reply to the message quickly and won't leave it pending."*

Justification for Guideline #2 also reflected on its universal nature as well as its relevance in addressing the SCSI characteristic "Competing Modal Transactions":

> *"This seems relevant to most categories. It gives users more choices on how to interact with the technology."*
>
> *"SCSIs are complex and users need as many methods to interact with their device as possible."*
>
> *"This is essential guideline because if the user is facing competing modal transaction issues, for example if the user is using GPS navigation and is interrupted by cell phone then the user can use multi modal interaction feature."*

Guideline #29 was viewed by some on the panel as helping address the SCSI characteristic of "Pre-abandonment" as well as "Competing Modal Transactions":

> *"Pre-Abandonment - timely completion of task is interrupted."*
>
> *"This could help the user to make the interaction efficient in cases when they are using a wrong modality because of stress or any other cognitive load task."*
>
> *"This is essential guideline because if the user is using email application and at the same time user gets a phone call then the device should be able to delay either phone call or emails according to respective high priority information and can make the decisions."*

While the SCSI guidelines that appear in other lists help illustrate some of the compounding effects that a SCSI event may engender, the guidelines chosen only for SCSI reflect strongly on the solutions suggested from Study 2 to address the unique severity aspects of SCSI events. For example, one guideline chosen just for SCSI that scored high (mean rating 4.5) was Guideline #5 ("Relating to the technology adapting in real-time"). The comments really hammer home the importance of context awareness in addressing the added load of a SCSI event:

"Critical, as access should be as simple as possible when a SCSI is produced."

"Real-time solutions are essential for situational impairments, especially when not affecting normal use."

"This guideline is essential because if the user is using multiple applications on his device, the user can switch the application while using it without closing the application completely and conveniently finish the task."

"To avoid disruptions in what the user is involved in performing and also by being real time, it allows the user by timeliness in interaction not to miss key moments."

Guideline #19 ("Design to reduce contextual stress…") had the following comments:

"This guideline is very useful for addressing SCSIs because it seeks to reduce a factor that is problematic."

"This guideline is essential for the user using the device to reduce the stressful situation. For example, in cases the user is not able to complete the transaction due to 'Half-life' situation then, if the user has feature for ease of transaction made available using predetermined steps suggestions, the user can carry out transaction smoothly."

Guideline #39 refers to the passive identification of situational impairment events, which the panel found of value for the following reasons:

"Supports user in the SCSI situation by reducing the need for identifying what modality is better for the interaction or how things should be modified to support that situational impairment."

"Anything that saves the user from fixing the problem is a good thing."

"This is technology that helps produce calm."

> *"This guideline is important because if the device is context aware of the user's situational impairment then the user can perform the task and complete it without any interruptions."*

The value of Delphi and what the second round added

The value of using this somewhat novel application of the Delphi method to the context of SIIDs was evident in the results, particularly in the rating rounds. The ability to offer their ratings anonymously in the first round allowed opinions to be recorded without the influence of other opinions. This, as has been previously mentioned, can be a tremendous advantage of Delphi studies in general over focus groups, where participation may not be equally distributed and ideas will be influenced by others.

The influence of others, however, can be valuable in shaping ultimate solutions to problems. Therefore, this study also benefited from the strengths of multiple opinions, by offering a subsequent rating round. Each participant benefited from seeing group metadata that compared to their scores and unstructured opinion statements that supported the positions taken. The value of anonymity was evident even in this round. No participant knew who anyone else was (which was explained to them during the IRB process), so no participant had to have concern over what other people felt about the choices they made. There were no personalities to dominate the conversation and no egos to bruise. Even the authors of the unstructured opinion statements were unknown to the other participants.

As the results in Chapter 4 showed, the second round did have an influence on the final outcome. The process of showing people guidelines for a second time that were rated differently by other participants influenced nearly all participants to change some of their scores. Two points are important to note here: (1) the direction of score change was both the offering of higher scores as well as lower scores, which suggests that there was little to no *change to please the researcher* bias in the choices made, and (2) no value was gained by a participant changing anything. Indeed, the simplest way for a participant to have completed Round 2 would have been to change nothing. The fact that this was not the case demonstrates that participants were able to take in the data represented to them and make an informed decision as to whether their original idea still made sense to them.

This can be seen, not only in the volume of changes made (see Chapter 4) but also in the justifications for changing their rating. Tables 37-42 below show some examples of change rationales (grouped by SIID theme):

Ambient-Environmental

G#	Old Rating	New Rating	Justification
11	3	4	*"I think that the examples from the sample comments help to show how this guideline would be relevant more often than not. You don't want users to have to backtrack on to repeat or undo previous interactions in unfavorable environmental situations."*
11	4	3	*"I agree that this guideline is not specific to this category and trying to implement it for such would result in inconsistency."*

Table 37: Participant Change Rationales - Ambient-Environmental

Complexity

G#	Old Rating	New Rating	Justification
4	5	4	*"I agree with the other rater's point that this guideline could be defined more clearly. It's good for designers to understand that*

			users might be distracted, but this is still a very broad statement."
4	2	3	*"A 2 was too low. Revisiting I think 3 is about right. Somewhat more important."*

Table 38: Participant Change Rationales - Complexity

Social-Cultural

G#	Old Rating	New Rating	Justification
20	3	4	*"I agree with the statements about the relationship between this guideline and safety."*
20	5	4	*"This does seem to not be as specific as I first thought, but I think there is still value in the guideline."*
20	1	3	*"I suppose this could come into play in some social situations and hence the increase from 1 to 3."*

Table 39: Participant Change Rationales - Social-Cultural

Technical

G#	Old Rating	New Rating	Justification
24	4	3	*"I still think there might be some value here. Maybe this doesn't need to be a guideline since there could be a change in law. E.g., the EU are currently trying to standardize charging for devices made by different companies."*
24	2	3	*"I may have under looked the importance of this recommendation previously."*

Table 40: Participant Change Rationales - Technical

Workspace-Location

G#	Old Rating	New Rating	Justification
12	1	4	*"After reconsideration, 'two handed' interaction is not preferable as it can add considerably to complexity in interface navigation and usage."*
36	1	3	*"After reconsideration, transaction completion could be impacted in a workspace constrained environment."*

Table 41: Participant Change Rationales - Workspace-Location

SCSI

G#	Old Rating	New Rating	Justification
2	2	4	*"If access is the goal then SCSI could come into play."*
19	2	3	*"A two may have been harsh. Reducing contextual stress when users are severely constrained makes sense. The examples provided with this guideline seem pretty specific and dependent on the device's intended purpose."*
20	2	4	*"I guess this recommendation is quite important, giving it a second thought was useful."*
39	5	4	*"I agree with another raters comment that this guideline is dependent on the changes not impacting users in a negative way."*

Table 42: Participant Change Rationales - SCSI

Not all rating change decisions led to guidelines being added to the final list. There were some where the net aggregate change ended up being a wash (fairly equal distribution of increasing scores and lowering of scores) so their status remained unchanged.

Implications for Design

Each of the Study 1 theme frameworks were effectively accounted for by one or more of the guidelines that were vetted by the panel of experts. All sub-themes were either directly or indirectly addressed by one or more of the vetted guidelines. For example, one sub-theme of "Complexity Issues" is "Number of Steps". Guideline #36 was chosen by the panel to address "Complexity issues" and specifically states, "Minimize the number of steps…." Its value in addressing this type of SIID was validated by the panel, with 77% rating it a "4" or "5" and 100% rating it at least a "3".

As an example of an indirect application, Guideline #2 ("Access should be granted by different input methods…") does not directly address any of the sub-themes of Ambient-Environmental Issues (i.e. meteorological or ambient noise issues). However, the panel chose this guideline as having different input methods clearly supports both weather and noise issues.

As this study has shown, guidance for designers on how to account for SIID and SCSI events when designing for mobile interaction is presently somewhat sparse. Study 1 provided a framework by which we could begin to classify SIID/SCSI events. Study 2 helped frame SIID/SCSI events from the perspective of user abilities, needs, and overall user experience. This present study has provided a means by which mobile design can now begin to account for SIID/SCSI events using these lists as guidance. While some aspects may be currently utilized in the domains from which they were found, this study affords the opportunity for their application on a more universal scope. It is hoped that the guidelines presented here might be utilized (e.g. as a checklist) by those developing and researching mobile interaction to begin to account for SIID events of all varieties.

Limitations and Future Work

Scope of Literature Review

The search terms were reduced for reasons addressed in Chapter 4. The study, therefore, did not attempt to examine in detail the relationship with more specific sub-genres within the domains. As was noted in Chapter 4, many of the hits that occurred as the result of the use of more general searches still yielded research addressing specific issues. Searching for “Assistive Technology”, for example, yielded results that included guidelines for hearing-impaired, visually impaired, physically impaired, and cognitively impaired users. Searching for “Mobile Interaction” revealed studies that examine not only mobile phones but also other smart devices (e.g. smartwatches) and interaction while driving. In addition, while all items selected were peer reviewed, a more acute search scope could have employed a deeper quality check analysis of the publications. Finally, while few contradictory guidelines resulted from the extraction process, a more targeted scope might have offered the opportunity for an examination of any contradictory advice that was being offered.

Perhaps a more focused approach could have yielded a deeper set of results. This would have been impractical with the present study, but future work might consider taking a more targeted approach. For example, a study could be conducted focusing exclusively on visual impairment research or focusing only on interactions while driving. The results of the more focused research could then be compared to the corpus of data collected from this study to see whether deeper insights might be gleaned.

The scope of the literature also limited the potential for more granular analysis of the domain breakdown. It may have been of interest, for example, not only to note how many guidelines were at least partially sourced from the Assistive Technology and Accessibility domains, but of those sources, how many guidelines were papers about visual impairments, or cognitive impairments, or motor impairments, etc. This would certainly be a logical next area to potentially examine.

Another interesting angle that could be explored is the correlation with situational impairments and impairments experienced by an aging population. Older adults experience most, if not all, of the "temporary" impairments brought about by the onset of a SIID. Older adults tend to have reduced hearing, sight, motor abilities, and cognitive abilities...all in one set of humans. Comparing the challenges faced by older adults with SIIDs to a younger population to see whether the guidance generated in Study 3 holds might prove a valuable avenue to pursue.

Exhausting Effort

It must be recognized that the amount of effort required to complete the entire Delphi process was intense. The participants, though experts in the domain, had to learn and quickly apply new concepts for this study to produce quality results. The application of these new concepts, in the first round in particular, involved a lot of time and cognitive effort. Each participant had to examine 49 guidelines and then map them to one of the six themes, justify their mapping, then repeat the process five more times before even being granted the privilege of advancing to the next round for more work.

There was a concern that the sheer volume of what was required in the initial round would result in participant attrition. The goal was ending the study with at least 10 participants, so even though there was an initial attrition from 20 to 13 and once more in the final round from 13 to 12, the participant count managed to stay above the minimum suggested by previous Delphi studies. Thankfully, therefore, this ended up not being an issue.

There was also a concern, however, that even if a participant braved the entire first round, by the time they attempted to complete the final few modules, participants might be mentally exhausted and not produce the same quality output at the end. To help mitigate this issue, the researchers implemented a Latin Square order for the presentation of the five SIID theme modules. In this way, attempting to complete the last SIID theme module on their list (when participants may be the most fatigued) would not be the same for each participant. In addition, because SCSIs were always presented last, there was the risk that they would have been underassessed.

Finally, the issue of fatigue may have affected the process of showing people guidelines for a second time. Seeing that some guidelines were rated differently by other participants certainly influenced many of them to change their scores, when they may not have necessarily otherwise done so. While, as was noted from the panel free responses shown in the previous section, this was mostly a positive influence towards the end result, not everyone offered free responses for their choices, suggesting that some participants might have been experiencing burnout.

Too Many Guidelines to Consider?

The fact that the participants needed to consider 49 guidelines may have also contributed to the overload. Because of the scope of this study, the number of guidelines was voluminous. The researchers hoped, in part, to mitigate this issue by the natural structuring of the guidelines (at least after the initial round) by theme.

In addition, the ordering of the presentation of data (via Latin Square for the module themes and alpha order for the draft guidelines) was done to help reduce any bias that fatigue may have played on the choices made. Other than alpha order, presenting the draft guidelines in a randomized order for each participant may have offered another way of reducing order effect. However, there was no evidence to suggest that items at the end of the list were not being considered as effectively as guidelines elsewhere in the order, as some of the later list items (e.g. 41,45,48) made the final cut. Indeed, the distribution of guidelines by number appears to be quite evenly dispersed. It should also be noted that using the same alpha order for each guideline for each participant allowed each guideline to retain a common ID number (i.e. Guideline #1 was always Guideline #1 for all participants).

A more targeted set, however, might have mitigated the level of potential fatigue. Future work might consider the development of a generalized set of design principles to accompany the guidelines. Similarly, future work might examine these guidelines and develop a practical set of heuristic "checklists" for designers and researchers. Finally, because of the volume of guidelines that needed consideration, the data sought from the expert panel in this study was primarily limited to ratings and brief justifications of those ratings. While there was room at the end of each module in the narrowing down round to allow for the suggestion of additional guidelines and free response comments, few participants took advantage of this opportunity. Future more focused study might, through interviews or more open-ended questioning, better utilize the rich resource that is a panel of experts to expand upon the possibilities that could be considered and/or obtain deeper and richer insights.

Is There Value in Examining Why Some Guidelines did not Achieve Consensus?

The focus of the research was on determining what might *work* or be of value to designers of mobile interaction. The analysis of the results mainly attempted to explain why the guidelines that did meet consensus were chosen. It may have been interesting to have also engaged in an examination of the guidelines where consensus was not met to see if any patterns may have emerged that could explain why a consensus was not reached. The result set could offer greater insight as to what may not be important (or at least as important) in the design of mobile technology and therefore also add valuable design implications. In a similar vein, while we did not require a comment in the final rating round from any participant that did not change their score, some value may have been added by asking for a justification regardless of whether the score was changed or not.

The Next Step: A More Focused Approach Testing with Prototypes and/or Additional Delphi Panels

The selections were made by humans, not an unbiased algorithm. Much effort was devoted to reducing the effects of bias in the process, but it is difficult to conclude that all bias was eliminated. This may have been particularly true in Stage 1, with the process of selecting artefacts to include in the corpus of potential guidelines. The researchers knew what they were looking for. This prescience might have inevitably led them to favor excerpts that fit their understanding of the frameworks outlined in Study 1 as well as the implications for design from Study 2. In addition, while the study needed to be broad in scope, that scope had the potential to contribute to fatigue amongst study participants.

To address the issue of potential researcher bias in the results that were offered to the expert panel, as well as reduce participation fatigue, future studies could offer a more targeted approach. Now that a set of guidelines exists for each type of situational impairment, the next logical stage would be testing designs that incorporate these guidelines to see how well they work. For example, a prototype mobile app might be developed that incorporates the four guidelines for Ambient-Environmental issues. Tests in the wild could be conducted to see how well the guidelines address this impairment type and also potentially discover aspects of Ambient-Environmental Issues that are not effectively being addressed with the guidelines.

The prototypes that would be developed could be informed from prototypes used to examine and address HIIDs discovered during the literature review or beyond. It would be important to note, however, that any insight from existing impairment prototypes would have to reflect an adjustment to the contextual factors present in the mobile interaction space. (e.g. A prototype designed with blind and visually impaired users in mind to address interaction on a webpage, may not be accounting for the additional contextual factors present in a mobile interaction when a sighted user may be temporarily impaired from viewing the screen (e.g. if glare is present).) Also, it is important to note that SIIDs can also impact individuals with disabilities (Abdolrahmani, Kuber, & Hurst, 2016). For issues that represent a greater level of complexity and/or require the incorporation of technology that is not ready for practical use, a "Wizard of Oz" style study might be deployed to at least determine relative usability.

Smart technologies continue to be developed and continue to evolve. In addition to smartphones, for example, we now have smart wearable devices (e.g. smartwatches or fitness trackers). In addition, there are smart devices, appliances, and tools that exist outside of the mobile transaction space. Future study might take the guidelines that have been gleaned in this research and explore their applicability beyond that of smartphones. Could, for example, guidelines for addressing ambient noise be used when developing technology for a wearable device?

Finally, in addition to the testing of prototypes, the validation of each guideline theme could be strengthened through the deployment of a more focused Delphi study, albeit using a more traditional approach and perhaps incorporating more feedback content from other participants earlier in the process. For example, a Delphi study focusing just on SCSI events could be developed. Instead of having a draft set of guidelines to present to the panel, the discovery of issues stage could be structured in a more traditional brainstorming style. By the end of the process, the final list of guidelines created could be compared to the list obtained from Study 3.

Chapter 5 Summary

In this, the penultimate chapter of this dissertation, a discussion of the findings and design implications of the final study of this research arc were assessed. This chapter highlighted how existing guidance from parallel domains to that of SIIDs were curated and used, and/or edited and combined to create new guidance for the addressing of SIID events of all types and complexity. Guidance was then validated by a panel of experts as supporting the SIID events identified by the findings of Study

1 and supported by the findings of Study 2. Therefore, the results and subsequent analysis of the information gleaned in this study clearly address RQ1.4.

Chapter 6: Dissertation Summary and Conclusion

A Serendipitous Introduction

The journey that is represented within this three-study research arc began serendipitously. The author of this dissertation was driving to a meeting and wanted to get an estimated time of arrival from Google Maps. Not having access to the primary input modality (touch-screen) as a result of actively driving a car, a secondary modality (voice) was used (*"Hey Google…how far am I from…")*.

However, instead of responding with an ETA, the system responded with, "*Please say or type PIN code*" as in order to gain access to the information, authentication was needed. This led to the theoretical questions: Are all situational impairments created equal? Is the mobile interaction space accounting for SIID events, and if so, are they all being treated the same?

And what of events such as the one that was experienced in the car? Technology has been designed to overcome one aspect of this situational impairment event (the inability to use one's hands as a means of input) by offering an alternative input modality (voice). In this specific scenario, voice was used to authenticate and the needed information was disseminated. But simply having that alternative means of input would not have represented a valid solution if someone else was in the car at the time. Maybe there are some situational impairments that are so severe that they require a different type of solution set. Can technology account for all situations, no matter how different or complex, and still be able to provide adequate service that maintains a positive user experience? This line of questioning was what led to the progression of research that is represented in this dissertation.

Progression, Support for Research Questions, and Contribution

This section will summarize the progression of the research represented in this dissertation by examining to what extent the three studies were able to address the four overarching research questions posed in Chapter 1 as well as the contributions that this research has made to the study of mobile interaction and situational impairment research and design. The four overarching research questions as defined in Chapter 1 were:

RQ1.1 Can we better understand and classify the various types of situational impairment events that occur when attempting mobile interaction in the wild as well as how users of mobile technology are currently accounting for the onset of a situational impairment when attempting to complete a mobile I/O transaction?

RQ1.2 Are there certain types of situational impairment events that are so severely constraining that they increase the need for cognitive resources, leading to mobile I/O transaction failure, abandonment, or danger?

RQ1.3 Can mobile interaction design account for and reduce/eliminate the effects of all situational impairment events for users of all abilities?

RQ1.4 Can new guidance be created and can existing guidance be strengthened to better account for the presence of situational impairments faced by users of mobile technology?

Study 1: A novel classification system that addresses RQ1.1 and RQ1.2

By examining and cataloguing the types of situational impairments that mobile technology users are experiencing, Study 1 offered the first attempt at classifying and cataloguing situational impairments as events, and perhaps represented the most foundational of the contributions within this research arc. Study 1 has demonstrated that not all situational impairments are created equal. We can now examine situational impairment events using a lens that shows a variety of themes and characteristics, each suggesting possible different design considerations.

The uniqueness of the research was in the target data collected and the type of information that was gleaned. To the best of the author's knowledge, no research prior or since this study has offered a classification of different types of situational impairment events. Studies have certainly identified the different contexts affecting mobile interaction, for example accounting for cold environments (Sarsenbayeva et al, 2016). Researchers have also explored specific interaction modalities such as visual situational impairments (e.g., Tigwell, Menzies, & Flatla, 2018). Perhaps the closest example to a classification of SIID was described by Marshall and Tennent (2013), who identified four kinds of challenges of mobile device interaction. None of this research, however, attempted to identify and classify the types of situational impairment events that users are experiencing. As a single event, for example, one could be attempting an interaction and experiencing a visual impairment while also being affected by the temperature in a cold environment. By approaching the SIID phenomena as events, Study 1 was able to present to the research and design community a perspective of examining situational impairments that is event driven and more holistic in nature.

This more holistic perspective not only resulted in demonstrating that all situational impairments are not created equal (thereby addressing RQ1.1) but also allowed the defining and describing of the hyper-events that were dubbed “Severely Constraining Situational Impairments” (addressing RQ1.2). The study was published in 2017 as part of the iConference proceedings and has been non-incestuously cited four times since its publication.

Study 2: A Deeper Perspective Toward User Motivation and Desires for Technology

If there was an aspect of RQ1.1 that was not completely addressed in Study 1, it was the “how users…are currently accounting for the onset of a situational impairment…”. Study 1 depended on user self-observation (through the recording of events as part of a diary study). This was effective in helping create a corpus of situational impairment events, giving the researcher information about “what” is happening to users, but not the motivations for the actions that they take once the event presents itself. If a user chose to forgo an attempt, what was their motivation? Some users added motivation to their report (e.g. I could not use my phone because I was in class and did not want to get in trouble), but others did not (e.g. I could not use my phone because I was in class). Study 1 did conduct follow-up focus group sessions, which helped fill some of these gaps, but the greater question remained: How are users currently addressing an SIID when it presents (e.g. are workarounds attempted), and how could technology be designed to address the problems that they face?

Study 2 was designed to address this question by involving the researchers of mobile interaction as well as users in a series of interactive participatory design workshops. An initial set of interviews with users revealed some workarounds that users perform to complete transactions but more importantly, strong motivations to complete mobile transactions at any cost, even safety (further strengthening support for RQ1.1). The analysis of the data from the interviews now offers a deeper understanding toward user motivations when either attempting a workaround in the presence of an SIID or the voluntary choice to postpone or even abandon a mobile I/O transaction.

Also, the data from the interviews, coupled with the corpus of events and information from the focus groups from Study 1, facilitated the creation of three rich situational impairment scenarios representing common/typical tasks where users may encounter situational impairment events. Each scenario had an enhanced or "SCSI-ified" version so that the design teams could work on solutions for each. Through the iterative workshop series, the researchers were able to obtain a solid deeper understanding, not only of user motivations, but also of what users wanted/needed mobile technology to do. The incorporation of the mobile interaction researchers to the workshop teams helped add a *reality check* perspective to the solutions that were discussed.

The results revealed that users approach the onset of a SCSI event differently from that of a regular SIID event and, as a result, have different design needs. The insights into what mobile technology can currently do, based on the solutions produced, offer support for RQ1.3. In particular, many of the SCSI solution suggestions pointed to potential solutions that are newer or even still theoretical (e.g. context aware AI). Because the feasibility of these solutions was supported by the researchers on the design teams, even solutions that may not exist — or still require improvement before they can be practically deployed — further support RQ1.3.

Situational impairments were not viewed as events by the research community until the publication of Study 1. The contribution, therefore, of Study 2 was the offering of a unique addition to the discussion of situational impairments as events, both from a user motivational perspective as well as how design might address the events as holistic entities. Study 2 offers an understanding that, not only that all situational impairments are not equal, but also users' needs during a situational impairment event are not equal. The study was initially published as a "Late-Breaking Work" (interviews and scenario creation were included but not the workshops) in the proceedings of the 2018 CHI Conference and has been non-incestuously cited six times since its publication. The entire study was published in December 2019 in the *Universal Access in the Information Society* journal.

Study 3: A Novel Approach to the Establishment of Situational Impairment Guidelines

If it is now known that all situational impairments are not the same (Study 1) and that certain technological solutions need to be achieved to account for user motivations and address user needs (Study 2), what was left to do was create support for those who actually design for and research mobile interaction. Study 3, therefore, finally offers designers and researchers of mobile interaction something practical that they can use to assist in the development of mobile interaction to support user needs discovered in Study 2, while using the framework for the problem space that was defined in Study 1.

As referenced in Chapter 1, the ultimate goal of this research was the offering of guidelines by which design of mobile human-computer interaction can (1) recognize the new complexity of the diverse facets that present during mobile interaction and (2) properly and effectively account for the presence of SIID and

SCSI phenomena in the design of mobile device interaction. Study 3 was designed to produce design guidance to support these goals, thereby supporting designers developing solutions for situationally impaired users.

Recognizing (and later confirming) that little to no such guidance exists for the addressing of situational impairment events, Study 3 sought to find that guidance in domains that might be thought of as parallel to that of situational impairments. A structured literature review for possible guidelines from various domains, in particular research focusing on designing for users experiencing more omnipresent impairments (i.e. Assistive Technology and Accessibility), was conducted. Analysis of the sources returned by search, as well as guidelines added to the corpus, revealed that the majority of potential design solutions were coming from research in the Assistive Technology and Accessibility domains. This extends the findings of Nicolau (2012) that parallel needs — and potential solutions to those needs — exist with users experiencing all type of impairments whether permanent or temporary.

This initial result set needed to be validated. Therefore, the draft set of guidelines was presented to a panel of mobile interaction experts using a novel adaptation of the Delphi method. Guidelines were mapped by the experts to each of the themes describing the various situational impairment events from Study 1 to see whether indeed any (or all) of these guidelines could be used to better account for the presence of situational impairments faced by users of mobile technology and, therefore, support RQ1.4.

Through a statistically supported consensus of the experts in the panel, this novel adaptation of the Delphi method revealed that guidelines were present within the draft guidelines to address each of the themes and sub-themes from Study 1, offering support for RQ1.4 and bringing this research arc full circle.

Conclusion

The quick adopting of mobile technology by a mass consumer audience has fashioned the need for the design of that technology to be equally as swift. To the extent that the usage of mobile devices has exceeded our ability to keep up is ultimately the motivation for the research presented in this dissertation.

As the anecdote that began this chapter implies, technology that is designed to plug up a specific hole may not actually solve the underlying problem. Just because an alternative modality can be used for input does not mean that that alternative modality is the solution to the greater problem. The story was based on an event that occurred five years ago. Since then, mobile design has become a little smarter. Now, for example, when a user interacts with their mobile device using a personal voice assistant, some information is allowed to be output without having to authenticate (which would have solved the issue in the initial Satori moment).

Still, does it solve the holistic problem? To handle the totality of the complexity that any particular situation may engender, and what was demanded by the users who participated in the Study 2 workshops, the device needs to do more than just have a predefined set of information that it does or does not reveal without authentication. The users in the Study 2 workshops revealed that technology, in this situation, or similar sets of situations, needs to be smarter. Technology needs to assess all aspects of the context in which a mobile interaction is about to take place, adjust its response to all the variables present in that context, and do so in a way that is appropriate to the individual user.

When looking to solve problems of mobile device users, maybe the design and research community need to approach the phenomena from a more holistic perspective. Technology exists to make our lives easier. As we add complexity to our lives, we need technology to be able to help us with that excess complexity. A variable interaction context, after all, is one of the main aspects of mobile interaction that differentiate it from the stable desktop paradigm. If technology cannot account for this variability, it may forever lag behind where the user needs it to be. The research in this dissertation has attempted to add this discussion piece to the situational impairment puzzle.

Appendices

Appendix A: Chapter 3 Study 1 Data Tables

Table 1: Participant Demographics Table (by Cohort Group)

ID	Age/Sex	Education
Cohort 1 (mean age = 21, standard deviation 1)		
RD1P1	22/F	Current Undergrad Student
RD1P2	20/M	Current Undergrad Student
RD1P3	22/M	Current Undergrad Student
RD1P4	20/F	Current Undergrad Student
RD1P5	21/M	Some Undergrad
Cohort 2 (mean age = 32, standard deviation 7.9)		
RD2P1	29/M	Current Grad Student
RD2P2	27/M	Undergrad Degree
RD2P3	46/F	PhD (or terminal degree)
RD2P4	28/M	Undergrad Degree
RD2P5	30/F	Graduate Degree
Cohort 3 (mean age = 51, standard deviation 9.4)		
RD3P1	48/M	Graduate Degree
RD3P2	39/F	Graduate Degree
RD3P3	64/M	Graduate Degree
RD3P4	48/F	Graduate Degree
RD3P5	56/M	Graduate Degree
Cohort 4 (mean age = 21, standard deviation 0.4)		
RD4P1	21/F	Current Undergrad Student
RD4P2	20/M	Current Undergrad Student
RD4P3	21/F	Current Undergrad Student
RD4P4	21/M	Current Undergrad Student
RD4P5	21/M	Current Undergrad Student

Table 2: Five SIID Themes and Sub-themes

Category	Description	Subcategories

Technical Issues	A technical fault, glitch, or other non-user or environmental issue that prevents effective completion of a transaction.	**Connection**: Something technical prevents connecting to an information source (e.g., bad cell or no Wi-Fi). **Power**: There is no, or insufficient, electrical power (i.e., low battery) to complete the transaction effectively. **Other Technical**: A technical issue other than connection or power that prevents effective transaction
Ambient Environmental Issues	Anything about the environmental context of the transaction space that is hindering or preventing effective transaction completion.	**Meteorological Conditions**: Some aspect of the weather (e.g., sun, rain, heat, or cold) that is hindering or preventing effective transaction **Ambient "Noise" Conditions**: Some non-meteorologically ambient condition is creating "noise" in the communication channel, hindering or preventing effective transaction. The "noise" can be any non-meteorological input that is negatively affecting the signal-to-noise ratio of the transaction signal (not necessarily just audible noise), including another human.
Workspace/Location Issues	Issues that hinder or prevent the ability to complete a transaction effectively that are geospatial in nature. Either the workspace area is of insufficient size or the resources required are not within sufficient proximity to permit the effective completion of the transaction.	**Inaccessible Location**: The information appliance is within reach but in a space that cannot be easily accessed in sufficient time to complete the transaction effectively (i.e., in a jacket/pants pocket or bag). **Workspace Size**: Some aspect of the workspace is affecting movement of resources required in the transaction and, therefore, hindering or preventing effective transaction (i.e., not big enough to negotiate the input space effectively). **Relative Location**: The relative location of the user and information appliance is such that interaction cannot effectively take place. **Unavailable Resources**: The resources needed to assist in the completion of

		the interaction are unavailable (i.e., hands full, phone powered off or on silent).
Complexity Issues	Issues that hinder or prevent effective transaction completion, resulting from task or ambient complexity.	**Cognitive Load**: The cognitive resources required to complete a transaction effectively are unavailable or not easily accessible to the user as the result of having to hold aspects of the current transaction in working memory or having "other things on their mind" that are not directly related to the current transaction. **Number of Steps**: The number of steps that would be required to complete a transaction are perceived to be too numerous or too cumbersome to complete the transaction effectively. **Walking Over Tasks**: The transaction cannot be completed due to another transaction attempting to occupy the active transaction space (i.e., a modal pop-up that appears while attempting to type a text message) or other interruption that may or may not be technology related (i.e., children interrupting an attempt to place a call via Bluetooth). **Gulf of Execution/Evaluation** (Norman, 1988): The user has insufficient knowledge from personal experience or from the current context to either complete a transaction effectively or evaluate whether a transaction has been completed effectively.
Social/Cultural Issues	These issues offer no physical barrier to transaction completion but nevertheless can hinder or prevent effective transaction completion.	**Fear of Reprisal from an Authority**: Completing the transaction may result in a violation of the law or reprimand from a boss, teacher, or other type of authority figure (e.g., texting while driving, in class, or while at work). **Safety**: The completion of a transaction is hindered or prevented due to concern over the potential

		harm the attempted completion may cause (e.g., getting into an accident while texting and driving or having your device stolen while using it on the street in a “bad neighborhood”). **Socially Acceptable Behavior**: The social context is perceived by the user to be inappropriate within the perceived cultural norms or personal moral code for effective completion of the transaction.

Appendix B: Chapter 3 Study 2 Data Tables

Table 1: Sample Responses to Social/Cultural Concerns

Sub-Theme	**Participant Response (Context)**
Socially Acceptable Behavior	*"I don't want to feel like a zombie...like everyone else"* (Public Transport) *"Never when I'm at the movies…don't want to ruin the movie experience for others"* (Public Performance) *"[I would be] setting a bad example"* (Driving)
Safety	*"…accident, death, not seeing my wife, not seeing my children."* (Driving) *"Aware of my surroundings…don't want to get robbed"* (Public Transport) *"[Concern for] privacy"* (Public Performance)
Fear of Reprisal from an Authority	*"Don't want points taken off my grade in classroom"* (Public Performance) *"[There might be a] cop nearby"* (Driving)

Table 2: A Sample of the Reasons to Ignore Social/Cultural Norms

Driving	**Public Transport**	**Public Performance**
"Waiting on a phone call/text/email that I needed to reply to immediately" *"If there is traffic and I'm bored"*	*"Had to study for school work and it required my phone"* *"Boredom overtook the feeling of being judged"*	*"If …class is slow that day"* *"…info…was important enough for me to disregard others"*

Table 3: Common Situational Impairment Scenario and Rationale

Scenario 01: Driving	**Scenario 02: At the Movies**	**Scenario 03: Cooking**
SIID: You are driving to a meeting at a location that you have never been to and need to use your GPS navigation app to provide you with directions.	**SIID**: You are watching a movie in a crowded theater with patrons directly in front and in back of you, as well as directly next to you on each side, and your phone vibrates in your pocket.	**SIID**: You are making dinner, and your hands are full and messy. Your smartphone is in your pocket. Suddenly, the solution to a problem that you are having pops into your head and you want to record it on your Google Keep app before you forget.
SCSI "Enhancement": You	**SCSI "Enhancement"**: You	**SCSI "Enhancement"**: However,

are at the point in the journey where you are about to make three turns, all within 30 seconds of each other. As you go into the second of these rapid turns, you get a phone call that “overrides” your GPS directions.	are expecting an important message or phone call that you do not believe can wait until the end of the movie. Checking your phone in place will bother anyone in your general vicinity. In addition, you are in the middle seat of an aisle, so even the act of leaving your seat to go to the lobby will create a disturbance.	you are at a critical juncture in the dinner preparation process, and any deviation to wash your hands and retrieve your phone might ruin the meal. Because you have to actively think about the upcoming food prep step, you are concerned that if you wait until you have a free moment, the idea will be lost.

Scenario 01 Rationale: This scenario represents the common environmental context of operating a personal conveyance. It examines the SCSI characteristic of multiple transaction events attempting to occupy the same transaction space. It also displays three of the four challenges for humans attempting interaction while on the go as described in Marshall & Tennent (2013) (cognitive load, physical constraints, and terrain).

Scenario 02 Rationale: This scenario is representative of any situation in which a user is in a shared public space during an event where engaging with one’s mobile device would be considered socially or culturally inappropriate. In addition, even though the ambient condition is a stationary one, it also displays the fourth challenge for humans attempting interaction while on the go as described in Marshall & Tennent (2013) (other people).

Scenario 03 Rationale: This final scenario reflects situations where a user’s primary resources needed to complete the transaction are unavailable. The SCSI enhancement includes the characteristic of “transactional half-life” where, for the transaction to have any value, it must be completed in a timely manner. Finally, like Scenario 02, even though the ambient condition is somewhat stationary, it displays three of the four challenges for humans attempting interaction while on the go as described in Marshall & Tennent (2013) (cognitive load, physical constraints, and terrain).

Appendix C: Chapter 4 Study 3 Bibliography of All Sources Used in Stage 1 (Structured Literature Review)

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