DOCTOR OF PHILOSOPHY

Improving Content Design on Mobile Devices to Reduce Situational Visual Impairments

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Improving Content Design on Mobile Devices to Reduce Situational Visual Impairments

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Declarations

Candidate's Declaration

I, Garreth Tigwell, hereby declare that I am the author of this thesis; that I have consulted all references cited; that I have done all the work recorded by this thesis; and that it has not been previously accepted for a degree.

Supervisor's Declaration

I, Rachel Menzies, hereby declare that I am the supervisor of the candidate, and that the conditions of the relevant Ordinance and Regulations have been fulfilled.

Abstract

Billions of mobile devices are used worldwide for a significant number of important tasks in our personal and professional lives. Unfortunately, mobile devices are prone to interaction challenges as a result of the changing contexts of use, resulting in the user experiencing a situational impairment. For example, when typing in a vehicle being driven over an uneven road, it is difficult to avoid incorrect key presses.

Situational visual impairments (SVIs) are one type of usability and accessibility challenge mobile device user's face (e.g., not being able to read and reply to an important email when outside under bright sunlight), which suggests that current mobile industry practices are insufficient for supporting designers when addressing SVIs.

However, there is little HCI research that provides a comprehensive understanding of SVIs through qualitative research. Considering that we primarily interact with mobile devices through the screen, it is arguably important to further research this area. Understanding the true context of SVIs will help to identify adequate solutions.

To address this, I recruited 174 participants for an online survey and 24 participants across Australia and Scotland for a two-week ecological momentary assessment to establish what factors contribute to SVIs experienced when using a mobile device. My findings revealed that SVIs are a complex phenomenon with several interacting factors. I introduce a mobile device SVI Context Model to conceptualise the problem. I iden-

tified that mobile content design was the most practical first step towards addressing SVIs.

Following this, I surveyed 43 mobile content designers and ran four follow-on interviews to identify how often SVIs were considered and how I could provide effective support. I found key similarities and differences between accessibility and designing to reduce SVIs. The participants requested guidelines, education, and digital design tools for improved SVI design support. I focused on identifying the necessary features and implementation for an SVI design tool that would support designers because this would have an immediate and positive influence on addressing SVIs.

Next, I surveyed 50 mobile app designers using an online survey to understand how mobile app interfaces are designed. I identified a wide variety of tools and practices used, and the participants also raised challenges for designing mobile app interfaces that had implications for users experiencing SVIs.

Using my new understanding of SVIs and the challenges mobile designers face, I ran two design workshops. The purpose of the first workshop was to generate ideas for SVI design tools that would fit within a typical designer's workflow. I then created high-fidelity prototypes to elicit more informed feedback in the second workshop.

To address the problem of insufficient support for designers, I present a set of recommendations for developing SVI design tools to support designers in creating mobile content that reduces SVIs in different contexts. The recommendations provide guidance on how to incorporate SVI design support into existing design software (e.g., Sketch) and future design software. Design software companies following my recommendations will lead to an improved set of tools for designers to expand mobile content designs to different contexts. The development and inclusion of these designs within mobile apps (e.g., allowing alternative modes such as for day or night) will provide users with more control in addressing SVIs through enhanced content design.

Acknowledgements

Over the course of the PhD, I've heard that "*nobody outside of your PhD committee will read your thesis*" and that "*the viva is the best opportunity to have a deep conversation about your work.*" So, if you are neither my supervisors, PhD viva committee, nor the poor souls I asked to proof-read a draft, then congratulations on finding and looking at my thesis. I hope you are reading these acknowledgements – perhaps you jumped straight to this section first to see if there was anything good? I can't promise it's good, but I will say that for me this is one of the most important sections of my thesis because I could not have completed this work alone.

I'm incredibly fortunate to have two supportive supervisors: Dr David Flatla and Dr Rachel Menzies. Both have done so much for me over the years, and they have ensured I was able to take part in many great opportunities, even if I was apprehensive about doing some of them, and I'll be forever grateful! I was given a lot of freedom in making my PhD what I wanted it to be, as well as exploring other research projects that aren't part of my thesis (e.g., investigating Emoji) and working with many other great people along the way. A highlight during my PhD was being hosted by the Human-Computer Interaction Lab in Saskatoon, Saskatchewan, Canada during the CHI rush so that I could run my final study. You all made me feel welcome, introduced me to Polar Pops, and made the last part of my PhD significantly more interesting.

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Kathleen joked that I was getting the award for the 'Most Travelled PhD Student'. I am very, very grateful for the chance to have visited so much more of the world. The various countries and cultures have enhanced my PhD experience and expanded my view on life. I now have many more international friends.

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Dr Nick Taylor, University of Dundee (Internal Examiner)

Dr Alison Pease, University of Dundee (Convener)

Finally, I would like to take this opportunity to sincerely thank every one of my participants. My PhD would not exist without your volunteering to contribute to science.

(*this thesis was fuelled by sushi*)

dedicated to my late grandfathers

A J Cairns

&

M J Tigwell

Publications

Peer-reviewed publications related to this thesis

Tigwell, G. W., Flatla, D. R. & Menzies, R. (2018). It's Not Just the Light: Understanding the Factors Causing Situational Visual Impairments During Mobile Interaction. In *Proceedings of the 10th Nordic Conference on Human-Computer Interaction* (*NordiCHI '18*). ACM, New York, NY, USA. DOI: `https://doi.org/10.1145/3240167.3240207`.

Tigwell, G. W., Menzies, R., & Flatla, D. R. (2018). Designing for Situational Visual Impairments: Supporting Early-Career Designers of Mobile Content. In *Proceedings of the 2018 Designing Interactive Systems Conference* (*DIS'18*). ACM, New York, NY, USA. DOI: `https://doi.org/10.1145/3196709.3196760`.

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Chapter 1

Introduction

If you have not already done so, it is likely that at some point today you will use a mobile device (e.g., a smartphone, a tablet, a smartwatch) to complete a task.

Mobile devices have widely increased the prominence of digital technology within society. Portability, paired with increasing computing power, sensors such as accelerometers and cameras, and connectivity modules such as Bluetooth, have made them popular as the chosen method for completing a wide variety of different tasks. The popularity of mobile devices is shown by the continued growth of the mobile device market share [GSMArena, 2011] and usage [Gartner, 2014; Khalaf and Kesiraju, 2017; Statista, 2018].

Mobile devices are used for personal and professional reasons. Tablets are a useful teaching aid in classrooms [Coughlan, 2014]. Pilots are using iPads rather than paper reference manuals because a tablet is lighter, supports searching information quickly, maintains organised files, and can be kept up-to-date [Wikipedia, n.d.]. Dentists can enhance communicating procedures with patients [Brattesani et al., 2012]. The camera and augmented reality capabilities of mobile devices can assist with on-site tasks in architecture, engineering, and construction [Chi et al., 2013]. Medical professionals are increasing their use of mobile devices for both educational and clinical support [Andrawis et al., 2016; Avitzur, 2010; Burdette et al., 2008; McNulty et al., 2012; West et al., 2012], and mobile devices have been found to be useful for doctors and patients in rural communities [West et al., 2012]. Mobile devices are valuable tools in the workplace and can be potentially lifesaving, yet it is important that mobile devices function well and are adaptable for the different situations in which people use them [Alfredsson et al., 2012].

Unfortunately, mobile devices are prone to interaction challenges as a result of the changing contexts in which people use them. A situational impairment occurs when a person experiences a temporary inability to complete a task that in another context the person would typically have no issues with. Situational impairments have been broadly discussed within the human-computer interaction (HCI) research community over the last few decades [Newell, 1995; Sears et al., 2003], but the importance of situational impairment research has only recently grown with the substantial growth in mobile use. This has led to investigations into improving mobile device interaction for challenging environments [Goel et al., 2012; Ketna and Leelanupab, 2017; Rajanna and Hammond, 2018].

With such a substantial reliance on mobile devices, it is imperative that people can use them without hindrance. There is little HCI research on ambient light situational impairments [Sarsenbayeva et al., 2017], and considering that we primarily interact with mobile devices through the screen, it is arguably important that research fully investigates the effects of situational impairments during visual tasks. Therefore, I focused on *Situational Visual Impairments* (SVIs) which involve the difficulty or inability of completing a visual task due to a mobile device user's context (e.g., not being able to read and reply to an important email when outside under bright sunlight).

Our current understanding of SVIs and solutions to SVIs are limited. Although there is some research that provides insights into the challenges that people face when using mobile devices under variable lighting conditions [Gong et al., 2012; Kim et al., 2008], the research mainly focuses on identifying the limitations of the technology rather than approaching the problem from an HCI perspective. There is a lack of qualitative data, which means we do not adequately understand the specific causes of SVIs, how people deal with SVIs, and what people's feelings are towards SVIs. Although some help for SVIs is available (such as guidelines and design toolkits [Magnusson, 2011; Patch et al., 2015]), without understanding the true context of SVIs, any solutions will be limited.

1.1 Problem

The problem to be addressed in this thesis is: *Situational visual impairments (SVIs) cause usability and accessibility problems for mobile device users, which suggests that current mobile industry practices are insufficient for supporting designers when addressing SVIs.*

1. Research has investigated some aspects of SVIs. However, there is no comprehensive understanding of the causes and prevalence of SVIs, or how people manage SVIs. Some work has investigated SVIs through the collection and analysis of of quantitative data, yet there are limitations to building an understanding with only quantitative data [Dix et al., 2003]. Qualitative data allows for a deeper understanding of context and insights into people's thought [Tracy, 2013] and will complement the prior quantitative work [Field, 2013; Tracy, 2013].

2. Content design is likely one factor causing SVIs. Although some guidance for designers exists, it is not clear if designers actively address SVIs through design or if existing support is helpful. A mobile content designer is someone who creates content that is specifically made for a mobile device. Some examples

would include mobile-friendly websites, mobile apps, mobile games, illustrated e-books. In addition, a mobile content designer may only be responsible for parts of the apps and services accessed on a mobile device (e.g., the design of a mobile app's interface rather than the content viewed within the app).

3. An SVI design tool is one type of support that designers require. It is essential to identify the necessary features of an SVI design tool so that it can be seamlessly incorporated into a designer's typical design process.

1.2 Motivation

By providing mobile content designers with sufficient support in designing to reduce SVIs, then usability and accessibility challenges caused by SVIs will subside. Users will have a more reliable experience in diverse contexts when accessing information, learning, communicating, controlling other appliances, having fun, and working. Mobile devices are also used to complete a wide variety of important tasks in the medical industry [Brattesani et al., 2012; West et al., 2012], airline industry [Wikipedia, n.d.], and construction industry [Chi et al., 2013], and failure to complete these tasks could have serious health and safety consequences.

1.3 Solution

To address the problem of insufficient support for mobile content designers to reduce SVIs, I have provided recommendations for developing SVI design tools that will support designers when creating mobile content. Based on my work, it is especially important to support the many small businesses and independent app designers without the resources to dedicate to addressing SVIs, and an effective way to do this would be offering solutions within the tools they are already using. If software design companies decide to build SVI design tools, my recommendations provide the necessary guidance on how to incorporate SVI design tools within existing design software (e.g., Sketch) and future design software. The outcome of companies following my recommendations will be an improved set of tools for designers to expand mobile content designs to different contexts. The development and inclusion of these designs within mobile apps (e.g., allowing alternative modes such as for day or night) will provide users with more control in addressing SVIs.

1.4 Steps in the Solution

Six major steps were carried out in identifying the recommendations:

1. SVI online survey: I ran a convenience-sampled online survey with 174 participants to identify many causes and (largely ineffective) solutions that people use when experiencing SVIs specifically in bright environments.

2. Two-week Ecological Momentary Assessment (EMA) study: I was able to build upon the findings of the first study by looking more deeply into SVIs over time. Overall, 24 participants (12 from Australia and 12 from Scotland, balanced by age and gender) helped to reinforce and expand the findings from the first study. I used the findings to build a mobile device SVI Context Model that conceptualises the complexity of the many interesting factors that contribute to SVIs as a whole. One factor causing SVIs that was present in both studies was content design, and the EMA study highlighted that content design can be a factor that cannot easily be overcome by any user action.

3. Online survey for designers: I then conducted an online survey with 43 mobile content designers to understand current design practices for accessibility (for

context) and SVIs, and the support needed to address SVIs.

4. Interviews with designers: I then carried out follow-on interviews with four participants from my online survey (#3) to: 1) more deeply understand typical design processes, 2) engage in a more in-depth discussion regarding accessibility and SVIs, and 3) to identify effective methods for providing the requested support from my online survey.

5. Mobile app interface design survey: I surveyed 50 mobile app designers using an online survey to understand how they design mobile app interfaces. In particular, I was interested in learning more about the tools and software they use, and how mobile app designers explore a variety of design ideas.

6. Design workshops: I then ran two design workshops with mobile content designers. The goal of the first design workshop was to use paper-based prototyping to identify potential SVI design tools that would fit within a designer's typical workflow. Based on these findings, I then developed high-fidelity prototypes of possible tools. The goal of the second design workshop was to identify any necessary refinements to the high-fidelity prototypes, which allowed me to define my final set of recommendations for design tools to support designing for SVIs.

1.5 Contributions

The main contribution of this thesis is a set of recommendations for developing SVI design tools that support designers in creating mobile content that reduces SVIs in different contexts. The recommendations provide guidance on how to incorporate SVI design support into existing design software (e.g., Sketch) and future design software. The outcome of design software companies following my recommendations will be an improved set of tools for designers to expand mobile content designs to different contexts. The development and inclusion of these designs within mobile apps (e.g., allowing alternative modes such as for day or night) will provide users with more control in addressing SVIs through enhanced content design.

My thesis also includes four secondary contributions:

1. The mobile device SVI Context Model (see Chapter 3). The mobile device SVI Context Model is rooted in empirical evidence from a large online survey with 174 participants and a two-week ecological momentary assessment with 24 participants (12 from Australia and 12 from Scotland, balanced by age and gender).

2. An understanding that mobile content designers are for the most part not currently addressing SVIs, plus ways that they can be supported in addressing SVIs (see Chapter 4). An online survey with 43 mobile content designers revealed key similarities and differences between accessibility and designing to reduce SVIs. A thematic analysis of follow-on semi-structured interviews with four designers provided an understanding of typical design processes, the challenges of addressing SVIs, and how to improve guidelines, education, and digital design tools to better support designing to reduce SVIs.

3. An understanding of the range of tools mobile app interface designers are using, as well as common approaches to exploring a variety of design ideas, gathered from an online survey with 50 participants (Chapter 5).

4. Sample high-fidelity prototypes of SVI design tools. I obtained paper sketches and ideas from an initial design workshop with four designers and developed those ideas into high-fidelity prototypes (Chapter 5). A second workshop with four designers was used to gather feedback (Chapter 5). I determined a set of recommendations from the feedback and then refined a final set of high-fidelity prototypes (see Chapter 6).

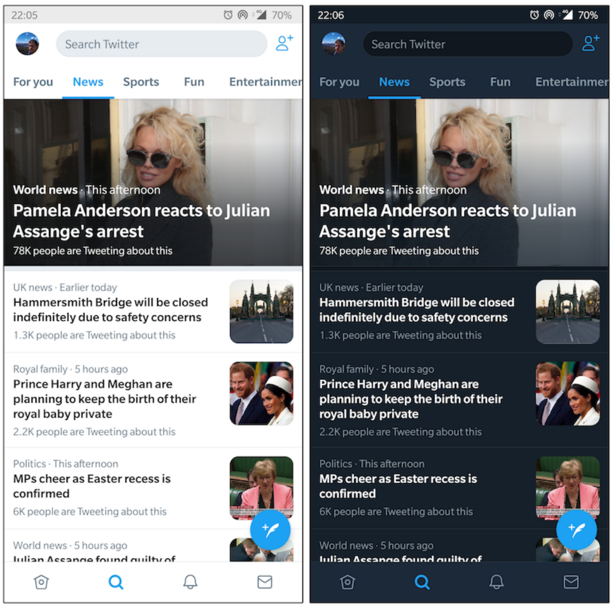


Figure 1.1: Twitter app shown in normal mode and dark mode.

1.6 Current Practice in Mobile App Interface Design

When I began this research in 2015, alternative modes for mobile app interfaces were not common (e.g., a dark mode for improved comfort reading at night). I first investigated the factors causing SVIs and identified content design to be one of those factors. It became clear over the course of my research that a solution to address SVIs would be to use different designs for different contexts of use. Previous work has indicated the benefits of interface adaption in addressing situational impairments [Wobbrock, 2006]. As I was identifying what designers did to address SVIs, there was an evident shift within the mobile app market towards including alternative modes – in particular a dark mode.

Typically, alternative modes only adjust colours, and unfortunately, designers selectively apply those colour adjustments to the elements making up the overall app interface. An example of a popular app with an alternative mode is Twitter. Figure 1.1 shows

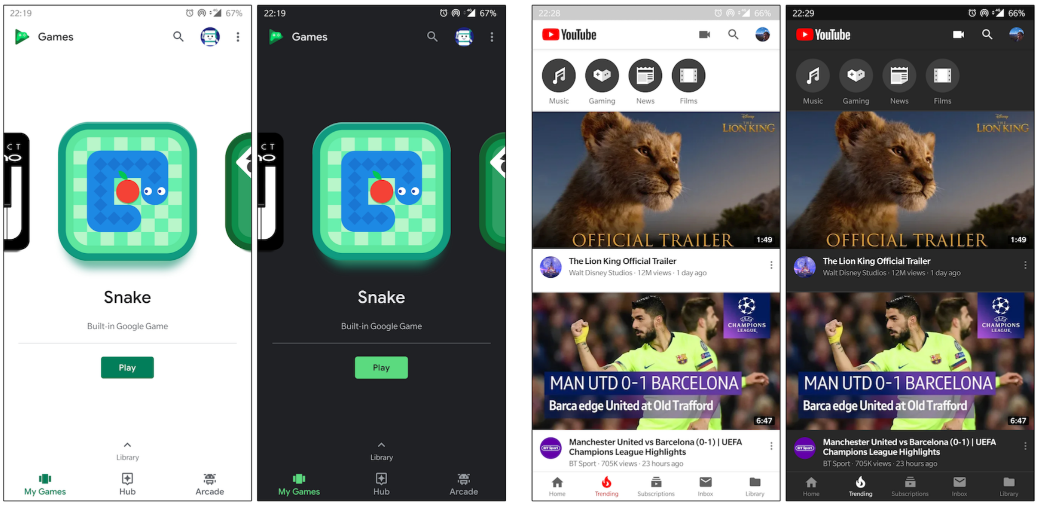


Figure 1.2: Google Play Games (left images) and YouTube (right images) Android apps shown in both normal mode and dark mode.

the difference between Twitter for Android in both its normal mode and dark mode, and it is clear that many elements (e.g., text size, icon design) remain the same across both modes.

Twitter for Android was first released in 2010[1], yet Twitter only introduced a simple dark mode in July 2016[2], which used a dark blue background with white text for easier viewing at night or in the dark. In June 2017, Twitter improved the dark mode so that it would automatically enable at sunset[3], therefore saving the user the time and effort in enabling and disabling the feature, but no further adjustments were made to improve the design of the dark mode. In 2019, Twitter began work on improving their dark mode by making it even darker[4], however, further refinements were needed to address design issues that arose from the colours used[5], thus highlighting the complexity of creating a suitable alternative mode. It is interesting to note that at the time of writing,

[1]https://techcrunch.com/2010/04/30/official-twitter-app-launched-for-android-2-1

[2]https://www.theverge.com/2016/7/26/12285842/twitter-android-night-mode-announced

[3]https://phandroid.com/2017/06/20/twitter-night-mode-sunset/

[4]https://techcrunch.com/2019/03/28/twitters-introduces-a-battery-saving-lights-out-dark-mode-option

[5]https://techcrunch.com/2019/04/11/twitter-updates-twttr-prototype-app-with-engagement-swipes-conversation-tweaks-better-dark-mode-and-more

Facebook – another large social media company– still does not offer a dark mode, although Facebook Messenger included one in March 2019[6].

Dark mode has become more common (Figure 1.2 shows some additional examples of this trend) and there are plans for Android Q to include a system-wide dark mode.[7] While progress is being made there is still much to do to support designers so that all the elements of an app are adapted for optimal usability. Furthermore, dark modes will only address some SVIs. Alternative modes for other contexts are also needed (e.g., using apps in bright environments). Chapter 5 and Chapter 6 provide more details on these challenges and offer solutions.

1.7 Overview of Thesis

This thesis reports on the work described in this introductory chapter, presented in the following sequence of eight chapters:

Chapter 1 - Introduction

Chapter 2 - Background and Related Work: Presents background details on the popularity and use of mobile devices. This chapter also presents related work on situational impairments, situational visual impairments, perception, technology, and design.

Chapter 3 - Understanding Situational Visual Impairments: Describes the motivation, method, and findings of two studies used to investigate: 1) In what contexts SVIs occur? 2) What are the causes of SVIs? 3) How frustrating are SVIs? 4) What strategies are used to overcome SVIs?; and 5) How often are SVIs experienced?

[6]https://www.theverge.com/2019/3/3/18248614/facebook-messenger-dark-mode-trick-to-activate-emoji

[7]https://www.xda-developers.com/android-q-dark-mode-overview

Chapter 4 - Identifying Designers' Needs for Addressing Situational Visual Impairments: Describes the motivation, method, and findings of two studies investigating the extent that mobile content designers consider SVIs and the support they require to design to reduce SVIs.

Chapter 5 - Supporting Designers in Reducing Situational Visual Impairments: Describes the motivation, method, and findings of three studies investigating how mobile app interfaces are designed and to explore SVI design tools that would fit within a typical designer's workflow. Initial new SVI design tools that will support designers in reducing SVIs are proposed.

Chapter 6 - SVI Design Tool Recommendations and Recommendations in Practice: Presents a set of recommendations for incorporating SVI design tools within design software to support designers. This chapter puts the recommendations into practice by further refining high-fidelity prototypes and describes a narrative for how those tools would be used throughout the design process.

Chapter 7 - Discussion: Summarises the main findings from the previous chapters and discusses the implications, limitations, and future directions of this research.

Chapter 8 - Conclusions: Briefly summarises this thesis, and outlines future directions for this research.

Chapter 2

Background and Related Work

2.1 Introduction

Mobile devices (e.g., smartphones, tablets, wearables) have widely increased the prominence of digital technology in society on account of their portability, ever-increasing computing power, sensors such as accelerometers and cameras, and connectivity modules such as Bluetooth. Mobile devices now enable people to complete many different tasks covering most aspects of their lives.

The popularity of mobile devices is clear when looking at the continued growth of the mobile device market share. Smartphone sales have overtaken desktop computers [GSMArena, 2011] and Flurry, a mobile analytics company owned by Yahoo!, reported that U.S. consumers are spending an average of five hours per day on their mobile devices [Khalaf and Kesiraju, 2017]. A 2014 report predicted that by 2018 50% of mobile device owners would choose their devices to complete online tasks rather than using PCs [Gartner, 2014], which was confirmed by a 2018 report that found 52.2% of all global web pages were served to mobile phones [Statista, 2018].

People are inundated with choice when it comes to the selection of mobile devices that they can purchase. Within the broad category of mobile devices, there is a new trend towards wearable devices (e.g., smartwatches, fitness trackers, smartglasses). A recent report from the International Data Corporation (IDC) indicates that 27.9 million wearable device units were shipped in the second quarter of 2018, and the overall market has seen continued growth from the previous year [IDC, 2018]. Some wearable devices share common features with other mobile devices such as smartphones. For example, the Apple Watch[1] and other smartwatches (e.g., Huawei Watch 2[2]) use full-coloured displays and allow for gesture interactions, arguably making them more sophisticated when it comes to their potential usefulness in day-to-day tasks compared to simpler fitness trackers (e.g., Fitbit Flex 2[3]), which are typically screenless.

Although people primarily use mobile devices for personal reasons, there is a benefit to incorporating them within the workplace. Tablets are a useful teaching aid in classrooms [Coughlan, 2014]. Pilots are using iPads rather than paper reference manuals because a tablet is lighter, supports searching information quickly, maintains organised files, and can be kept up-to-date [Wikipedia, n.d.]. Dentists can enhance communicating procedures with patients [Brattesani et al., 2012]. The camera and augmented reality capabilities of mobile devices can assist with on-site tasks in architecture, engineering, and construction [Chi et al., 2013]. Medical professionals are increasing their use of mobile devices for both educational and clinical support [Andrawis et al., 2016; Avitzur, 2010; Burdette et al., 2008; McNulty et al., 2012; West et al., 2012]. In particular, mobile devices are especially useful for doctors and patients in rural communities, such as remote doctors diagnosing people living in isolated areas of India [West et al., 2012]. Mobile devices are useful tools in the workplace and can be potentially lifesaving, yet it is important mobile devices function well or are adaptable for the different situations in which people use them [Alfredsson et al., 2012].

[1] https://www.apple.com/uk/watch
[2] https://consumer.huawei.com/uk/wearables/watch2
[3] https://www.fitbit.com/au/flex2

Mobile devices are prone to interaction challenges as a result of the changing contexts that people use them in. Considering the importance that mobile devices have within people's lives (both personal and professional), it is vital that mobile devices function well in the diverse range of situations in which people use them and to investigate the challenges that people may be experiencing in a typical day. Table 2.1 summarises the related work that is discussed in detail in the following sections.

Topic	**See Section**	**Referenced Work**
Mobile interaction challenges due to SVIs	Section 2.2.2	Barnard et al. [2005, 2007]; Huang et al. [2017]; Kane et al. [2008, 2009]; Vatavu [2017]; Ylipulli et al. [2014]
Effects of light on visual perception	Section 2.3.1	Antona et al. [2018]; Aparicio et al. [2010]; Dobres et al. [2017]; Fry and Alpern [1953]; Holton et al. [2011]; Mantiuk et al. [2009]; Paulsson and Sjöstrand [1980]; Puell et al. [2004]; Rempel et al. [2011]; Shin et al. [2004]; Vos [2003]
Display Technology Limitations	Section 2.3.2	Gong et al. [2012]; Kelley et al. [2006]; Kim et al. [2007, 2008]; Lin and Kuo [2011]; Liu et al. [2014]
Screen & content adaption	Section 2.4.1	Blankenbach et al. [2014]; Kim et al. [2017]; Lee et al. [2007]; LiKamWa and Zhong [2011]; Su et al. [2018a,b]; Soudi et al. [2016]; Wanat and Mantiuk [2014]; Ward et al. [2017]; Yu et al. [2015]

Table 2.1: Summary of the key SVI research investigating environmental, application, and human factors.

2.2 Situational Impairments

2.2.1 Introduction

For many years, there has been academic interest in understanding the usability and accessibility challenges people face that are not necessarily related to their abilities or disabilities. Early work by Alan Newell [1995] discussed impairments caused by environmental factors. To help conceptualise the challenging situations that create barriers for individuals he proposed *Extra-Ordinary HCI* – the intersection between typical HCI and accessibility. On the one hand, there are extra-ordinary people in ordinary environments (e.g., a person using a wheelchair who encounters steps) and ordinary people in extra-ordinary environments (e.g., a soldier entering a war zone). It is especially important to consider the situational impairments that can arise under inhospitable environments (e.g., firefighters in a burning building) and work has begun looking at how to support these individuals [Wolf et al., 2017], including addressing severe situational impairments [Saulynas and Kuber, 2018]. However, the environment is only one factor that can cause interaction challenges.

Situational impairments (first referred to as situationally-induced impairments and disabilities or SIIDs [Sears and Young, 2003]) is a term applied to the interaction challenges people experience due to context. Dey et al. [2001] define the context in which human-computer interaction occurs as being determined by collectively considering the user, the application, and the location. Andrew Sears and his colleagues paired Dey's definition with Schmidt et al.'s [1999] three dimensional concept of context to emphasise that situational impairments arise from *Environmental*, *Application*, and *Human* factors [Sears et al., 2003].

Interest turned towards mobile devices when it became clear that their prominence and pervasiveness were continuing to grow. HCI "on-the-go" became an important phenomenon to investigate and situational impairments were one aspect that needed addressing [Wobbrock, 2006]. It is important to design mobile devices and interfaces in such a way to reduce situational impairments, including built-in automatic adjustments [Biswas et al., 2014; Wobbrock, 2006].

Not all situational impairments experienced when using a mobile device are well understood. Sarsenbayeva et al. [2017] published a systematic overview of known mobile device situational impairments that people experience when using a mobile device. The work highlights particular detection methods of specific situational impairments and design guidelines that can be utilised to reduce their occurrence. Seven situational impairments were identified: "Ambient Temperature", "Mobile State of the User", "Encumbrance", "Ambient Light", "Ambient Noise", "Mood", and "Stress". At the time of publication, ambient light, ambient noise, mood, and stress were lacking in-depth research to understand the issues properly.

2.2.2 Research into Situational Impairments

Since people typically use mobile devices on-the-go, it is necessary to understand what challenges this presents for a user. Research has found that compared to sitting, walking can have a significantly detrimental effect on reading text on a mobile phone [Barnard et al., 2007] and an increase in walking speed will result in a higher perceived task load [Mustonen et al., 2004].

PDAs were popular mobile devices that have largely been replaced by smartphones. Few smartphones include a stylus pen[4], but it was common for PDAs to come with a stylus. Lin et al. [2007] investigated how people use a stylus when operating a PDA while walking and concluded that even when participants reduced their walking speed

[4] an exception would be the Samsung Galaxy Note series

to compensate for an obstacle course, there was still an increase in the number of recorded errors. Selection time and accuracy improved with increases in target size, demonstrating that Fitts' Law was still an effective model. A later study by Chen et al. [2010] also confirmed mobile Web users experience several different typing and pointing input errors when using a PDA.

Although the technology in mobile devices has changed, the initial concept of a typical hand-held computing device has remained. With an increasing set of feature and daily use, mobile devices continue to be of interest in understanding the limitations people face using such devices.

Ng et al. [2013] wanted to understand how mobile interactions were affected when users held different objects. An initial observational study identified bags and boxes as common objects that users would typically carry. Ng et al. recruited 18 participants to take part in a target acquisition task that involves holding those common objects. Each participant took part in all conditions in which they were instructed to hold a small bag, a medium bag, a thin box, a thick box, and nothing at all. In addition, for the conditions that required the participants to hold an object, they would do so for both their dominant and non-dominant side. Finally, the participants would complete each of the nine encumbrance levels when standing still and walking. The results showed that holding those objects negatively affected the participant's ability to make selections on a touchscreen accurately, but only if those objects were held by the dominant hand (i.e., the participant had to select targets with the non-dominant hand). Accuracy also decreased when participants were walking while encumbered.

Recently, Eardley et al. [2018b] investigated how body posture can affect interaction with smartphones. Eardley et al. investigated three body postures (sitting and resting arms on a table, standing, and lying with back to the floor) and found that different postures had significant implications with regards to how people could use their smartphone (e.g., when participants were in a lying position they had different rotational movements compared to the sitting and standing conditions). The findings in this study were presented to designers to support them in designing new user interfaces to address the problem [Eardley et al., 2018a].

Since everybody can experience a situational impairment, research has also investigated the similarities and differences between people with and without a disability.

Abdolrahmani et al. [2016] investigated situational impairments experienced by people who are blind. Semi-structured interviews with eight legally-blind participants revealed several challenges as a result of situational impairments experienced when using a mobile device (e.g., using a mobile device while walking with a cane). The paper presents strategies used by the participants (e.g., resorting to guesswork when unsuccessfully 'scanning' documents with a phone camera and the accessibility feedback is insufficient). Based on the findings, Abdolrahmani et al. made some design suggestions to improve mobile device interaction; however, the participants in the study were blind, and the strategies and solutions identified may not apply to all situational impairments experienced by sighted people [Henry et al., 2014].

Kane et al. [2009] used interviews and a diary study to understanding the challenges people with visual and motor impairments face when using mobile devices in their daily lives. The study reported on situational factors that affected how people with visual and motor impairments could use a mobile device (e.g., a person with low vision would have difficulty using a mobile device while trying to navigate crowded spaces).

While in some contexts, a person has freedom in choosing how they situate themselves in their surroundings (e.g., stand, walk, run) there are other contexts in which the environment will play an influencing role (e.g., physical restrictions imposed by a crowded place, having to sit while in a moving car). Similarly, while the movement of a person walking affects mobile interaction, the movement due to their environment (i.e., the car driving over an uneven road) also introduces challenges to successful mobile interaction.

Since the environment is an inescapable factor and often changes, there has also been research that seeks to understand how mobile interaction is affected by exposure to different conditions (e.g., noise, cold, rain).

Sarsenbayeva et al. [2018] investigated how different types of ambient noise (slow and fast music, outdoor and indoor urban noise, meaningful and meaningless speech) affect mobile interaction. The study involved 24 participants taking part in three different mobile interaction tasks (target acquisition, visual search, and text entry) for the different ambient noise types with silence as a control condition. The conditions were counter-balanced, and the participants were given one minute to familiarise themselves with the sound before beginning the tasks. The participants were interviewed after they completed the main experiment. Overall, both types of music resulted in faster target acquisition, but with less accuracy when the music was slow. Memorising an icon for visual searching was faster when urban noise was present, but there was an increase in mistakes made during outdoor urban noise. Finally, outdoor urban noise and meaningful speech significantly reduced text entry speed.

In cold conditions (e.g., ambient temperature of -10ºC, wind velocity below 0.1 m/s, and humidity of 70-75% [Sarsenbayeva et al., 2016]), people are less precise and take longer at tapping tasks (more so for one-handed interaction) yet although the cold resulted in a significant increase in time to memorise an icon, there was no significant change in search time [Sarsenbayeva et al., 2016].

Ylipulli et al. [2014] ran two studies in Finland to investigate how weather and climate affect the use of information and communication technology. A diary study was conducted, followed by a notebook study in both autumn (late September and early October) and winter time (late February and early March). The first study allowed participants to self-document their use of mobile phones and computers, whereas the second study focused on an interactive public display positioned outside. During winter, the participants preferred using mobile phones because they are a necessary device, whereas travelling with a laptop in the cold was unappealing. However, mobile phones are not without their challenges and can still be difficult to use. In particular, the cold weather can create problems such as interaction challenges with gloves and the device slowing down. One participant mentioned that they viewed the summer as a time for using mobile phones.

Our mobile devices need to be designed in a way that supports our successes when trying to complete tasks in different contexts. Mobile devices have a particular set of input and output channels that may help or hinder us complete tasks (such as the challenge of interacting with a touchscreen in the cold), and the applications we use on our devices also play a part in this.

Adaption is a possible way of addressing situational impairments experienced when using a mobile device [Wobbrock, 2006]. Kane [2009] determined that a successful adaption system for addressing mobile device accessibility challenges must utilise three core elements: (1) establish the needs of the user at that moment in time, (2) have pre-made adaptions to improve the accessibility according to what is detected, and (3) allow customisation for a more personalised accessibility solution. Although the article discusses the development of this system for people with disabilities, the core idea would benefit everybody since a person without a disability can find themselves in extraordinary situations that impede their abilities.

When using a mobile device outside it would be expected that people will end up in the rain. Older mobile devices that used resistive touchscreens (i.e., they detect interaction by sensing pressure on the screen) would not be susceptible to issues such as rain. However, the majority of current mobile devices use capacitive touch screens (i.e., they detect interaction through the distortion of an electrostatic field). RainCheck was recently developed to help improve the accuracy of interacting with a display exposed to water by addressing the issue of a device sensing phantom and incorrect touch positions [Tung et al., 2018].

Additional studies have been conducted to compare people with and without disabilities to identify the similarities and differences and thus utilise current accessibility guidelines or inform the design of better systems.

Yesilada et al. [2010] found that there are similarities between the input errors from people with a motor-impairment using a desktop compared to the errors made by people using small devices. In a later study, Yesilada et al. [2011] looked at identifying what web-browsing accessibility challenges overlap for people with a disability using a desktop compared to people without a disability who browse on mobile. Yesilada et al.'s findings suggest that there is an overlap of common accessibility issues between people with low vision and people using a mobile device compared to other people with disabilities.

Nicolau et al. [2014] investigated the similarities and difference of mobile touchscreen interaction between motor-impaired and able-bodied users to determine suitable interface guidelines for different users' needs. Fifteen tetraplegic and 18 able-bodied participants took part in an evaluation measuring tapping and gesture performance. The results demonstrated that tapping and crossing a target were interaction techniques that would be appropriate for both tetraplegic and able-bodied participants, with similar error rates when the target size is 12mm. The participants also performed similarly when interacting with the middle of the display and so designing touch interfaces that required interaction with the edge of the display would need to be carefully considered. The tetraplegic participants were less accurate when selecting targets further away and when required to perform directional gesturing (i.e., the participant was asked to gesture in a particular direction, such as dragging their finger upwards). Overall, this study identified key similarities and differences between two population groups that use mobile devices. The authors recommend design guidelines based on the findings, and since touchscreens can display different interfaces, it would be possible for an application to adapt as necessary to the different users' needs. Within the accessibility research area, work has investigated improving the input options available for people with a disability or in a challenging environment (e.g., [Carter et al., 2006; Trewin, 2004]).

Trewin et al. [2004] developed the Dynamic Keyboard for people with a dexterity or motor impairment, as well as for people whose environment is making it challenging to type. The purpose of the keyboard was to eliminate the need for the user to change the configuration of their input device in order to be able to use it. Instead, the system would continuously update the accessibility settings to account for changes in a person's typing behaviour over time. The interesting idea of the Dynamic Keyboard is that it is a solution to an accessibility problem that can occur in many ways (i.e., from a situational, acquired, or congenital impairment). The solution is one that follows the recommendation of an adaptable system for the user [Kane, 2009; Wobbrock, 2006].

There are currently many studies that have looked into various aspects of the human, environment, and application context of situational impairments. Unfortunately, ambient light, mood, and stress are still not well understood [Sarsenbayeva et al., 2017]. Considering that we primarily interact with mobile devices through the screen, it is arguably important that research first investigates ambient light. Mobile devices typically have an ambient light sensor that can detect the level of lighting in the environment, and adapt the screen brightness accordingly. Sarsenbayeva et al. [2017] suggested the presence of adaptive screen brightness may explain why there was limited research on situational impairments caused by ambient light. However, considering that situational impairments are not created equally because many different factors can account for their occurrence [Saulynas et al., 2017], the adaptive screen brightness may not be a sufficient solution on its own.

As a result, in my work I am focusing on *Situational Visual Impairments* (SVIs), which are visual impairments that arise from a mobile device user's context (e.g., the challenge of watching Netflix under bright sunlight). There are a few situational impairment studies worth highlighting that touch upon mobile device interaction and ambient lighting, although these do have limitations such as ambient light not being the primary factor under investigation.

2.2.3 Situational Visual Impairments

Vatavu [2017] writes a comprehensive review of the literature on visual impairments and mobile touchscreen interaction ranging from "pathological" visual impairments (both severe to less severe) to situational visual impairments. Vatavu's article suggests design guidelines based on the findings of previous work. Although convenient, Vatavu's approach fails to answer research questions that were not part of the original studies. One of Vatatu's design suggestions for SVIs is to take a sensing, modelling, and adapting approach (i.e., detect and use context) to address mobile interaction challenges; however, there is still a need for research to better understanding SVIs before sensing, modelling, and adapting can succeed. Another suggestion Vatavu makes is that wearable devices can address some limitations of people who have a visual impairment using mobile devices; however, since those wearable devices will be used in different contexts, the person is likely to experience a situational impairment at some point, and therefore we need a deeper understanding of the problem to pre-empt these challenges.

Barnard et al. [2007] set out to evaluate some ways in which context (namely motion and lighting) affected performance on reading comprehension and word search when using a mobile device. For motion, the paper focuses on walking vs sitting, the appropriateness of each condition had previously been evaluated in a prior publication [Barnard et al., 2005]. Barnard et al. found motion (walking vs sitting) and lighting (high vs low illumination) had varying degrees of influence on reading comprehension and word searching tasks. For example, during the word search task, there was a significant effect on time to complete the task when the room illumination changed. The researchers argue that their results demonstrate there is no constant variation to a person's behaviour when the environment changes and this in itself indicates a need to investigate this area of research further. It is worth noting that the PDAs used in the study use a reflective display, so the same conclusion cannot apply to modern mobile devices (see Section 2.3 for a discussion on this). This does highlight the importance of repeated studies as technology changes, and the importance of considering the technology used in older studies so that we do not erroneously apply the findings to newer devices.

Kane et al. [2008] evaluated a user interface design called walking user interfaces (WUIs) in a real-world setting (i.e., rather than on a treadmill as in previous studies [Barnard et al., 2005, 2007]). An initial study was conducted to determine the effects of walking while interacting with soft buttons of different sizes. The results indicated an interaction between movement and target size, in particular, there were fewer errors per trial when target size increased. The second study involved an evaluation of a music player WUI. A simple static interface with large buttons was found to be better than an adaptive interface, but this could be for a couple of reasons. The first being that for the complex adaptive interface the small buttons were not easy to press and second there is a performance trade-off when changing the button size as a person walks. During the second study, the weather was noted as affecting the performance of participants. Cloudy weather reduced task time, whereas sunlight increased task time, and if a participant wore sunglasses, it would affect the legibility of text.

I discussed part of the work by Ylipulli et al. above (see Section 2.2.2), which highlighted the need to consider weather and climate [Ylipulli et al., 2014]. For the public display part of the study, it was briefly noted that changing ambient light can be a problem that needs to be considered when designing the displays. It would be interesting to more deeply investigate the strategies people use to overcome the challenges of ambient lighting when using a mobile device, probably through employing a qualitative approach.

Lighting and weather were also factors in a study looking at understanding the challenges people with visual and motor impairments face when using mobile devices in their daily lives [Kane et al., 2009]. Specifically, five participants who had low vision found it difficult when the ambient lighting was either too bright or too dim. However, Kane et al.'s study did not specifically look at SVIs, and the small sample of participants that discussed the challenges of ambient lighting had a pre-existing disability that will likely have factored into the scenario.

A later study by Huang et al. [2017] recruited 21 young Taiwanese adults and 20 older Taiwanese adults to investigate how age and ambient illumination affect visual comfort when reading on a mobile device. Older participants preferred higher contrasts, and female participants (particularly young female participants) preferred less contrast than male participants. These results were consistent regardless of ambient illumination. Huang et al. recommend that designers consider these finding for improved GUI design. However, since the study used a maximum ambient illumination of 1200 lx, which is roughly a quarter of what an overcast day would measure [Bright and Cook, 2010], let alone a sunny day at ~100,000 lx [Parkin, 2016], these findings are limited because the study did not occur under real-world conditions. Furthermore, the study did not collect any qualitative data to provide further insights into the differences found.

2.2.4 Summary

Unfortunately, a lack of specific SVI research and gathering of qualitative data means we do not adequately understand SVIs. From the previously summarised literature, the studies that use qualitative methods (e.g., interviews, diary studies) offer interesting insights such as the strategies people are using to overcome certain situational impairments. Solutions can be more appropriately designed with the deeper understanding of SVIs that would be provided by qualitative studies.

It is evident that changes in ambient light will affect both people's visual perception and how the visibility of a display functions within the environment. Since there is not much research looking at understanding and addressing SVIs, I will next summarise the literature that provides insights into the physiological response to changing ambient lighting, how current mobile device technology behaves, and what solutions exist.

2.3 Understanding Visual Perception and Mobile Displays

This section will discuss the related work of the effects of ambient light on both our visual system and display technologies. I am focusing on the displays of mobile devices because their smaller size makes them highly convenient to use in many different contexts. With an increase in the contexts of use, there will also be an increase in the chance of experiencing a situational visual impairment.

2.3.1 Visual Perception and Ambient Lighting

It is beneficial to understand how our visual perception works in different environments to identify typical challenges that users' will experience.

Figure 2.1: Simulation of colour perception changes due to ambient light levels. Scotopic vision (left), mesopic vision (middle), photopic vision (right).

When we perceive an image of our surroundings, our brain has interpreted a signal that has been received from the eyes and sent through the optic nerve [Goldstein, 2014]. Our eyes focus the light in our surrounds onto the retina, which contains the necessary receptors to convert the light into the electrical signal for our brains. The retina of the eye contains photoreceptors called rods and cones [Goldstein, 2014]. Rods are more sensitive to light and help the person to see when levels of light are low, while cones are the photoreceptors that distinguish colour and detail when the light levels are high enough [Goldstein, 2014]. Humans have three different cone pigments, which are sensitive to different wavelengths of light: S-cones for short-wavelengths of light (blue light), M-cones for medium-wavelengths of light (green light), and L-cones for long-wavelengths of light (red light) [Goldstein, 2014].

How much light enters the eye will affect people's task performance because the eye goes through different stages of visual sensitivity as light increases (as demonstrated in Figure 2.1). When ambient light is very low, visual perception will begin in a state referred to as scotopic vision [Shin et al., 2004]. As the light level increases visual perception enters mesopic vision, and finally photopic vision (under high ambient light) in which full-colour vision occurs [Shin et al., 2004]. Under both photopic and mesopic conditions, age can have a significant negative effect on contrast sensitivity [Puell et al., 2004], and the presence of glare can reduce contrast sensitivity [Paulsson and Sjöstrand, 1980] and apparent brightness of objects [Fry and Alpern, 1953]. Aparicio et al. [2010] investigated the effect of surround luminance on contrast sensitivity when reading letters. Thirty-one participants were required to read letters on a chart through a gap in a wall and the letters gradually decreased in contrast against the white background of the chart. Behind the wall and in front of the chart were two halogen lamps. Aparicio et al.'s results indicated that surround luminance does affect contrast sensitivity, although it was a small effect. Contrast sensitivity increased when the surround was illuminated.

In addition to light levels, even the type of lighting can affect people's visual performance. For example, people with impaired vision due to age-related macular degeneration (ARMD) experience worse contrast sensitivity when ambient light is from a fluorescent rather than an incandescent light source [Holton et al., 2011]. Furthermore, long wavelength light (light that is predominantly towards the red end of the visible spectrum) has less effect on the rods in the eye; thus it is unlikely to cause disability glare [Mantiuk et al., 2009], which occurs when incident light reduces perceived contrast by scattering within the eye and hitting the retina [Vos, 2003]. Long-wavelength light helps to activate the cones in our eyes, which can perceive more detail than the rods, but importantly it does not affect our dark adaption [Mantiuk et al., 2009]. When the light is turned off a person's rods are still likely to be sensitive to the dark, whereas if the light had shorter wavelengths there would be a period required for adaption as scotopic vision begins to take over [Mantiuk et al., 2009]. Considering that bright sources of light in the dark can be problematic and can interfere with dark adaption, it would be important to consider designing interfaces that utilise dark colours towards the red end of the visible spectrum. A straightforward method to improve the experience of looking at screens in the dark would be to reverse the polarity of text and the background [Rempel et al., 2011].

It would seem intuitive that viewing a darker screen is better in low ambient illumination. However, it is not a straightforward solution. Dobres et al. [2017] ran a more thorough investigation of how glance-like reading performance is affected by changing the display polarity. Positive polarity would be when dark text is on top of a light background, whereas negative polarity is when light text is on top of a dark background. Dobres et al. chose also to adjust ambient illumination and letter size to identify how these other factors may affect a previously found "positive polarity advantage" where reading performance benefits from dark text on top of a light background. The results demonstrated that under bright ambient conditions there was a similar time required to identify words for positive and negative polarity, but under dark ambient illumination negative polarity resulted in worse performance for both letter sizes. For design, there would need to be consideration of a performance trade-off due to worsened asthenopic symptoms (e.g., irritated eyes) when viewing a smartphone in the dark [Antona et al., 2018] if the mobile content is very bright and potentially poorer reading performance if the mobile content is very dark [Dobres et al., 2017].

As well as understanding what happens when the light in the environment changes, it is also important to understand how mobile device technology behaves within different environments.

2.3.2 Mobile Devices and Ambient Lighting

Older mobile devices typically used reflective displays (i.e., the display uses ambient illumination and reflects this back to the user) [Bae et al., 2011]. However, most modern mobile devices (in particular from 2007 following the release of the first Apple iPhone) have what is called a transmissive display. Transmissive displays emit (as opposed to reflect) light [Bae et al., 2011], using either filtered backlighting or colour LEDs to produce an image (see Figure 2.2). The outcome of using a display that works with a light from behind is that it is difficult to perceive when the ambient lighting is too bright relative to the brightness of the display.

It is important to evaluate the performance of displays – in particular how well they

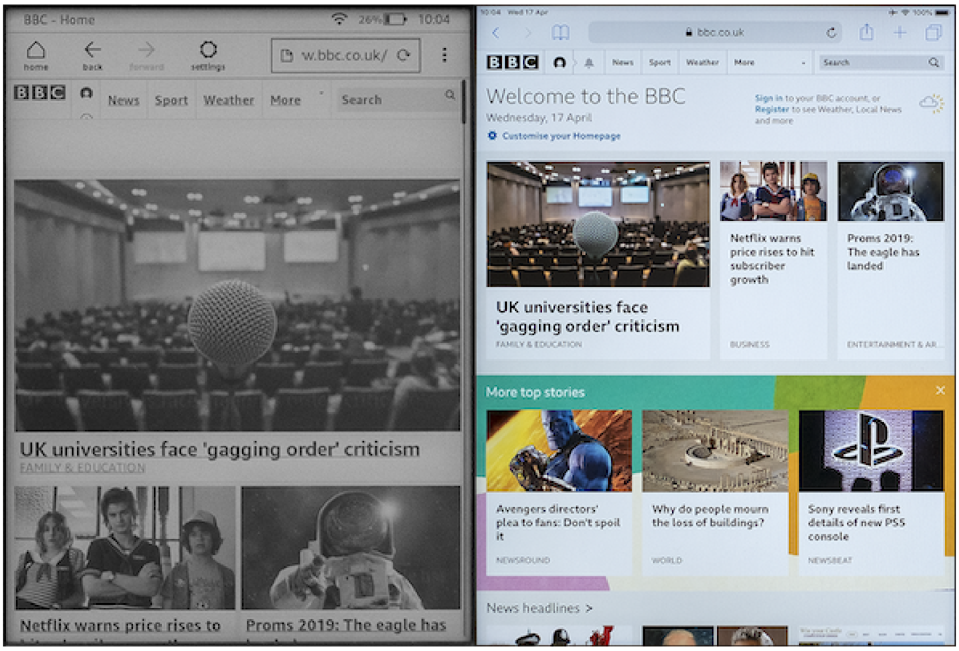


Figure 2.2: Comparison between a reflective e-paper display (left), which requires ambient lighting and a transmissive IPS panel display (right), which is backlit using LEDs.

perform under conditions of high ambient lighting, such as outside under bright sunlight. There have been many studies conducted to understand how the display characteristics for different display technologies may change under different ambient light conditions. Kelley et al. [2006] recognised that shining a light source onto a display is not an objective method for determining the display's legibility under sunlight. To address this, a procedure was developed that accounts for not only the direct source of the light (i.e., the sun), but also the general sky ambient lighting, to more accurately measure the display legibility [Kelley et al., 2006].

It has since been well established that image quality on transmissive displays is reduced when viewing in bright environments [Kim et al., 2007, 2008; Lin and Kuo, 2011]. "Naturalness" (i.e., how close to the expected reality) and "clearness" (which is obtained from sharpness and contrast) both have strong positive correlations with image quality, and as the ambient lighting gets brighter, image quality ratings decrease and the role of good "clearness" becomes more important to ensure better-perceived quality [Kim et al., 2008].

Different types of transmissive display technologies have also been investigated. Gong et al. [2012] chose to look at two display technologies (AMOLED and IPS), which are popular with smartphone manufactures. Active Matrix Organic Light Emitting Diode (AMOLED) displays are thinner, they can consume less power, and they can display a greater range of colours, whereas In-Pane Switching (IPS) displays allow for greater viewing angles, resolution and peak luminance [Gong et al., 2012]. Image quality was subjectively evaluated because the results would be more applicable to real-world experiences rather than evaluating the displays based on scientific measurements. The results indicate that although both displays suffer reduced perceived brightness and contrast when viewed under higher ambient illumination, the more saturated colours of an AMOLED display somewhat compensate for this and therefore it receives better ratings for colourfulness. AMOLED screens are increasing in popularity [IHS Inc., 2013], yet the fact remains that they are still susceptible to the effects of increasing ambient light.

Liu et al. [2014] recognised the importance of mobile displays in the context of medical image analysis. They investigated how image quality degrades by increases in ambient light, which would be important to understand how suitable these displays are in the medical field. The experiment made use of the DENOTE (Detection of Noisy Text) method [Zafar et al., 2012], which involves the presence of grey characters overlaid on a background of greyscale noise. The overall room luminance level and contrast of the screen image was changed in a series of trials. The participants were required to identify the grey characters. Liu et al. used two slightly different types of AMOLED mobile displays (one AMOLED, the other Super AMOLED, which has a higher maximum brightness and low panel reflectivity). The Super AMOLED mobile display did result in better performance. The participants found it more difficult to identify characters on screen as the lighting got brighter and the performance decline occurred at a faster rate when the lighting continued to rise above 1000 lx. It should be noted that an overcast day can be 5000 lx [Bright and Cook, 2010] and sources have indicated a bright sunny day can reach up to ~100,000 lx [Parkin, 2016].

A limitation of these studies that look at how displays function under increasing ambient lighting is that they do not gather qualitative data from users or seek to find out what it is like to experience this problem when using mobile devices day-to-day.

In 2017, GSMArena[5] (a website that provides extensive reviews on mobile phones) ran an opinion poll for one week to find out "What makes a great display?" [GSMArena, 2017]. The website presented visitors with nine options: "Pixel density", "Contrast", "Sunlight legibility", "Accurate colors", "Punchy colors", "Power efficiency", "120Hz", "Always-On Display", "Force touch". In total, 37,210 votes were cast; however, this is the total number of items that were ticked, and since participants could select more than one then I cannot determine how many individuals took part apart from calculating the minimum number of 4134 participants (37,210/9).

"Sunlight legibility" (17%) was the most frequently selected feature, suggesting that respondents recognise the current limitations of mobile displays. Considering that consumers desire mobile devices that are easier to use in bright environments, I will next look at what previous work has been done to address SVIs.

There are other display technologies that could address some of the limitations previously discussed (e.g., reduced image quality with increasing ambient lighting), yet they are not widely adopted in popular consumer mobile devices for various reasons, which I will explain further.

First, high dynamic range displays have increased brightness, contrast, and colour gamut [Seetzen et al., 2004], which would help to minimise the negative effects of increased am-

[5]https://www.gsmarena.com

bient lighting. Although some high-end mobile devices have begun to include this feature[6], they are not cheap. Furthermore, although this technology will become commonplace, there are still billions of mobile devices currently used by people around the world that do not have HDR displays.

Second, electronic paper or e-paper displays (also known as e-ink displays) are a type of reflective display technology that offers a similar experience to reading on paper [Siegenthaler et al., 2011]. Given that e-paper displays work by reflecting ambient light they are suitable to use in very bright conditions, thus overcoming the limitations of other LCD technologies [Siegenthaler et al., 2011]. However, there are several limitations to e-paper displays. Without the inclusion of a backlight the display cannot be easily used in the dark. Furthermore, the refresh rate of e-paper displays make it difficult to display content with moving images, and colour e-paper displays are expensive with limited colour quality [Kroeker, 2009]. Yota is a smartphone company that has included a secondary grey-scale e-paper display on a smartphone[7], but this is not a common smartphone feature and the user will still be restricted to e-paper display limitations.

Third, transflective displays, which combine the benefits of both reflective (good visibility in bright environments) and transmissive (good visibility in dark environments) displays [Bae et al., 2011; Ge et al., 2009]. Some older devices, such as the Nokia N80 used a transflective display but a limitation of such technology was lower contrast ratios and poorer performance outside of bright ambient light conditions [Soneira, 2006]. In recent years transflective displays for mobile devices have become very uncommon, and transmissive displays remain a popular choice of device manufacturers.

[6]The Samsung S10 range of smartphones include HDR10+ displays https://www.samsung.com/uk/smartphones/galaxy-s10/

[7]http://yotaphone.com/gb-en

2.4 Current Solutions for Situational Visual Impairments

A *Situational Visual Impairment* (SVI) is a visual impairment that arises from a mobile device user's context (e.g., the challenge of watching Netflix under bright sunlight). It involves the difficulty or inability of completing a visual task.

2.4.1 Addressing display limitations

As demonstrated with previous literature, the displays typically used in mobile devices can be difficult to use in bright environments. Improvements to increase the brightness of mobile device displays have been made, including company-specific approaches, such as Nokia's ClearBlack Display [Clayton, 2012] and general improvements to the early transmissive display designs, such as the One Glass Solution [Hawkins, 2017]. The ClearBlack Display makes use of linear and circular polarising filters to reduce the effects of ambient light that falls on the screen (i.e., it minimises reflections without the use of a matte screen). The One Glass Solution is a method of creating a capacitive touchscreen display that requires fewer layers between the top glass and the LCD panel, giving several benefits including a brighter display. However, even newer screen technologies have the issue of reduced brightness and contrast when people use them under bright ambient lighting [Gong et al., 2012; Liu et al., 2014]. On a sunny day it can get extremely bright [Parkin, 2016], and therefore it is necessary to understand what other factors may also contribute to the challenges of using a mobile device under different levels of ambient lighting.

One interesting area of research has been investigating how to adapt the colour, contrast, and brightness of the display or display images to improve user experience and overcome SVIs.

Mobile devices typically allow people to adjust display brightness; however, one problem with adjustable brightness is that when the display brightness decreases, changes in human vision mean that the display image will not look that same [Wanat and Mantiuk, 2014]. However, it is possible to successfully do luminance retargeting to maintain the naturalness of an image when the display brightness changes (e.g., the image of a bright scene retaining a natural look on a dim display) [Wanat and Mantiuk, 2014].

When viewing displays under bright or highly-variable ambient lighting, the content on the screen can be difficult to see – resulting in an SVI. Some studies address this problem by automatically adjusting the display or display images. For example, a notable problem for drivers is the variable conditions they will drive through that affect their vision (e.g., it is a sunny day, the driver enters a tunnel, and it gets dark, and after exiting the tunnel it is bright again). Variable ambient light also affects displays in cars, so to improve driver safety, adaptions to colour and contrast can be used to improve readability [Blankenbach et al., 2014; Soudi et al., 2016]. Researchers have also applied colour, contrast, and luminance adaptions to enhance viewing content on mobile displays under different levels of ambient brightness [Lee et al., 2007; Kim et al., 2017; Su et al., 2018a,b; Yu et al., 2015].

In addition to adapting the display content based on ambient light levels, there has been research that has taken a more sophisticated approach. LiKamWa and Zhong [2011] developed a system called SUAVE – the Sensor-based User-Aware Viewing Enhancement system measures both the ambient lighting levels and the angle of the device that the user is holding. The ambient light sensor is used to detect how bright the environment is. SUAVE recognises when the user has tilted the device to remove glare by using both a face-tracking algorithm and the mobile device motion sensor. The mobile device backlight is then adjusted accordingly, as is the global and local contrast of the image content. Overall, this approach is likely to provide some benefit to mobile device users; however, the extent to which it is useful is unclear since similar to the previous adaption research, it was not evaluated in an extensive qualitative user study and the idea for SUAVE was not grounded in clear data on SVIs.

An alternative approach to screen and image adaption involved mounting a camera above the display to identify the areas behind the user that would cause highlights to appear on the display [Ward et al., 2017]. The system then calculated where there is glare from reflected highlights and adjusted brightness in those regions of the display image (and preserved the colour and contrast when necessary) [Ward et al., 2017]. However, it is not clear how this level of real-time processing would affect using a mobile device (e.g., battery drain, apps slowing down).

Although these studies offer potential solutions, they do not explicitly gather information on what tasks people are typically doing when they experience SVIs, the consequence of SVIs as perceived by the user, and whether any other factors are contributing to the problem, leaving these important questions unanswered.

Since screen content adaption has been shown to alleviate some of the effects of SVIs in bright environments, I will next review more specific design guidelines for mobile content.

2.4.2 Current Support For Designers

There is a competitive market for apps and websites to have the most appealing designs. So much so that there are often emerging design trends such as a shift in the early 2010s towards flat design, which reduces 3D effects in favour of a simpler looking interface[8]. The issue presented by these new design decisions has not gone unnoticed. For example, Apple has been criticised by Norman and Tognazzini [2015] for their low-contrast font design, which can cause people with typical vision to find reading a challenge. The art-

[8]https://en.wikipedia.org/wiki/Flat_design

icle discusses the case of a woman relying on the accessibility settings of the devices to make the text more readable by increasing the contrast and font size. However, this solution was impractical because she found the text would not always fit on the screen when it was increased. In addition to trends explored within the design community, companies of mobile operating systems use guidelines to ensure that there is a common design language among apps used on their system (e.g., Google's Material Design for Android[9]). This section will focus on resources available to designers that seek to improve accessibility through design and whether they address SVIs.

Ross et al. [2017] introduce a framework for assessing the accessibility of mobile applications on a large-scale by taking influence from epidemiology. Within this framework, there is a spectrum of factors that can result in poor accessibility and they range from intrinsic factors (e.g., visual design) and gradually become more extrinsic (e.g., design tool factors are less extrinsic than device factors, and device factors are less extrinsic then company factors) [Ross et al., 2017]. In an analysis of 100 mobile apps 94% and 85% included text and image contrast errors. The framework has been used to find discrepancies in both design guidelines and developer tools that could account for image-based button labelling accessibility barriers [Ross et al., 2018], demonstrating the value in looking more widely for potential causes of inaccessibility.

Petrie et al. [2015] set out to define web accessibility by using 50 published descriptions that were available from different sources (online, papers, books, etc. between 1996-2014) to encompass the many important components of accessibility. The authors produced a concentric circle diagram (see Figure 2.3) to show the frequency of specific concepts among the 50 definitions that they sourced, and based upon the six concepts created the definition:

> "*All people, particularly disabled and older people, can use websites in a range of contexts of use, including mainstream and assistive technologies; to achieve*

[9] https://developer.android.com/guide/topics/ui/look-and-feel/

Figure 2.3: The six core concepts of web accessibility [Petrie et al., 2015].

this, websites need to be designed and developed to support usability across these contexts." p.3 [Petrie et al., 2015].

Within this definition "contexts of use" refers to the different situations a device is used and thus where SVIs can arise. Furthermore, the inclusion of "all people" further highlights that anybody can find themselves in an environment that affects their task performance, albeit some more than others. The quote above highlights the enormity of the challenge designers face since they should really design for everyone in every context.

Mobile devices have become a popular method for accessing the internet, and some Web guidelines list examples of how accessibility issues such as the use of colour and font size can also be a problem for all mobile users without disabilities [Yesilada et al., 2013]. The current version[10] of the Mobile Web Best Practice (1.0) [Rabin and McCathieNevile, 2008] provides some basic guidelines for improving the Web browsing experience on a mobile device. For example, there is a human test recommended for assessing colour contrast that suggests the designer shines a strong light on the screen

[10] 29th July 2008

of the mobile device while browsing the page. While some advice and guidance are better than nothing, there are potential issues with this approach since it is left up to the designer to make a judgement call on whether the colour contrast is suitable or not. It would likely be more beneficial to provide designers with a tool that highlights the problem for different contexts, similar to ColorCheck [Reinecke et al., 2016], which demonstrates the challenges different proportions of the population will have in perceiving colours within a design. A purpose-made SVI design tool that advises the designer on potential issues would be appropriate, especially when guidelines such as the Mobile Web Best Practices [Rabin and McCathieNevile, 2008] include advice on using machine testable (or automated) checks for identifying inaccessibility. Currently, no such SVI design tool exists.

A "Mobile Accessibility" working draft paper[11] published by the W3C has been made available to highlight the way in which designers can apply current accessibility guidelines to improve mobile accessibility [Patch et al., 2015]. The draft paper acknowledges the higher possibility of using a mobile device in increasingly challenging environments such as outside under bright sunlight, which the Web Content Accessibility Guidelines (WCAG) 1.0 [Chisholm et al., 1999] or 2.0 [Caldwell et al., 2008] do not explicitly address[12]. The draft paper highlights previous guidelines from WCAG 2.0 for making content more perceivable, yet this is a limited solution. For example, the contrast ratios listed in WCAG 2.0 were believed to be sufficient for a desktop setup (viewing content on a 15-inch monitor with a resolution of 1024x768 and viewed from a distance of 24-inches [Patch et al., 2015]). The designers are advised of this limitation and recommended to account for the mobile viewing experience (e.g., smaller screen, different viewing distance, changing environment).

However, there are several issues worth highlighting: 1) The application of these guidelines

[11] 26th February 2015

[12] WCAG 2.1 [Kirkpatrick et al., 2018] has been publicly available as of June 2018; however, the screen contrast criteria remain unchanged

is limited due to the older display technology used for their creation, 2) the contrast ratios were not established outside of a controlled environment, and 3) the designer is left to decide how best to proceed.

The minimum contrast ratio was determined using two standards [ANSI/HFS 100-1988; ISO 9241-3:1992]. Both documents were developed to ensure office environments followed the best ergonomic practices for workers using a desktop computing setup indoors, which means the displays and environments used when judging those calculations are not the same as the displays used in modern mobile devices. Although beneficial, standards can present the challenge that it takes time to create them and new technology is released quickly, which means that there is potential for them to be outdated and not optimal in different situations [Reed et al., 1999]. Furthermore, the ANSI/HFS 100-1988 was not concerned with health and safety but instead with human performance [Reed, 1994]. Considering that situational impairments could be a health and safety concern due to the dangerous situations that can occur [Saulynas and Kuber, 2018; Wolf et al., 2017], it may be inappropriate to use current guidelines, particularly when the contrast ratios were not established outside of a controlled environment. Unfortunately, the designers are not sufficiently instructed on how best to proceed with the current guidelines. The extent of this problem is concerning when realising that mobile design guidelines for iOS [Apple, n.d.], Android [Google, n.d.], and Universal Windows Platform [Microsoft, n.d.a] advise mobile designers use the WCAG 2.0 guidelines for sufficient text and icon contrast, and it also raises concerns about whether the accessibility needs of mobile users are even being met because of how the contrast ratios were calculated.

Another form of support for designers is a design toolkit, which can be used during the early part of the design process to consider user behaviour in different settings [Clarkson et al., 2007; Magnusson, 2011]. For example, the workbook by HaptiMap [Magnusson, 2011] called 'Context is Everything' aims to draw attention to the many situations in which a person may use a system. The workbook is accompanied by 'context cards' that have a variety of different situations (e.g., 'at the beach') and environmental prompts (e.g., 'in the dark') that are used to help designers think about the implications of those conditions. Similarly, Microsoft has introduced 'Inclusive: A Microsoft Design Toolkit'[13]. The Microsoft Design Toolkit highlights that there is an increase in experiencing situational impairments as technology becomes more mobile, and provides activity and support cards for guidance and awareness (e.g., the activity card 'situational adaption' encourages the designer to consider how their solution can adapt to situational impairments and the support card 'conditions' emphasises that situational impairments vary as a result of the environment). However, a limitation of both toolkits is that they only prompt the designer to consider the context of use more thoroughly and do not give guidance on how to reduce situational impairments (including SVIs). Although toolkits are useful, it would be better if something more actionable was considered (e.g., the proposal of new features within the software that designers are using).

2.5 Conclusion

In this chapter, I have described the current research on situational impairments. The foundational research on situational impairments seeks to understand what is happening, why it is happening, and how people deal with the problem. Understanding situational impairments is an important first step so that any solutions designed to address the situational impairment are suitable. I have identified a gap in our understanding of SVIs and investigating this is important because users are primarily interacting with mobile devices through the display. I have presented research that provides some insights into the challenges that people face when using mobile devices under variable

[13]https://www.microsoft.com/design/inclusive/

lighting conditions; however, the research mainly focuses on identifying the limitations of the technology rather than approach the problem from a human-computer interaction perspective. As pointed out by Sears et al. [2003], people who have an impairment (congenital or acquired) develop tactics over time when using technology; however, those who experience situational impairments are unprepared, and the context can differ each time, thus making each situation unique. It is therefore important to identify the specific causes of SVIs, how people deal with SVIs (or not), and what people's feelings are towards SVIs. Although some solutions exist to address SVIs, these have limitations. It is important to understand the true context of SVIs in order to inform the development of more appropriate solutions.

Chapter 3

Understanding Situational Visual Impairments

3.1 Introduction

As discussed in Chapter 2, previous research provides some insights into factors causing SVIs. However, no comprehensive study exists with the primary goal of identifying the specific causes of SVIs, how people deal with SVIs (or not), and what people's feelings are towards SVIs. As a result, previous solutions to address SVIs might not be informed by the true context of SVIs and so they are potentially inadequate until SVIs are understood more fully.

This chapter presents two studies to understand the users, context of use, and adaptation strategies around SVIs, in order to better inform future solutions for SVIs. Study 1 was designed to gather many responses quickly to help understand the diversity of SVIs. During Study 1, I ran a convenience-sampled online survey with 174 participants to identify many causes and (mostly ineffective) solutions. Study 2 was designed to look into SVIs more deeply over time. During Study 2, I ran a two-week Ecological Momentary Assessment (EMA) with 24 participants, balanced by age and gender across Australia and Scotland to more firmly ground my initial results from Study 1. The EMA methodology allowed me to more accurately capture how often SVIs occur in daily life and minimised memory biases because participants would tell me about their experiences with SVIs soon after the event occurred. Running the study in Australia and Scotland concurrently increased the potential to capture a diverse set of SVIs and it saved time.

3.2 Study 1: Online Survey

In my first study, I focused on bright light situational visual impairments (BL-SVIs) due to evidence that people want improved sunlight legibility above other mobile device improvements [GSMArena, 2017], casual observations of people using mobile devices, conversations, and online review comments (e.g., GSMArena[1], a website that conducts in-depth reviews for mobile phones across an extensive range of manufacturers, specifically includes a section on the performance of the screen under sunlight). I used an online survey to quickly collect data from a large number of participants worldwide, thereby not limiting my findings to one geographic location.

3.2.1 Materials and Procedure

The questionnaire (in Appendix B.5) included 11 questions designed to answer five research questions. Q1 and Q2 gathered participant age and gender. Q3-Q5 were used to answer RQ1: "*In what contexts do BL-SVIs occur?*". Q6 was used to answer RQ2: "*What are the causes of BL-SVIs?*". Q7 measured RQ3: "*How frustrating are BL-SVIs?*" using a

[1] https://www.gsmarena.com

rating scale from 1 (Not at all) to 5 (Extremely). Q8-Q10 were used to answer RQ4: "*What strategies are used to overcome BL-SVIs?*", and Q11 was used to answer RQ5: "*How often are BL-SVIs experienced?*".

I distributed the questionnaire by email through mailing lists and/or research groups at the University of Dundee, the University of New Brunswick (Canada), the University of Saskatchewan (Canada), and the University of Washington (USA). I chose those universities because I could access them through my personal network and this allowed me to quickly begin the snowball sampling process. There were no concerns about the participants from those universities being unsuitable since I was only interested in their personal experience of challenges when using a mobile device due to bright lighting. Furthermore, I broadened the participant sample by posting on social media (Facebook and Twitter), to websites advertising ongoing studies (Call for Participants[2] and Reddit's r/SampleSize[3]), and within the forum on xda-developers[4] – a website with a community mainly focused on mobile devices and software development for mobile. All questions were optional and visible to participants at once. After providing informed consent, the participants could access the questionnaire. I did not offer the participants any remuneration.

3.2.2 Participants

I received 198 responses to my questionnaire and removed a total of 24 participants from the analysis. I removed 13 of the 24 responses for reporting on the difficulty of using mobile devices in dark environments (which was outside of the scope of Study 1). I removed 11 of the 24 responses for different reasons, which made them unsuitable to include in the analysis. Six of the 11 responses were missing information detailing what

[2]https://www.callforparticipants.com
[3]https://www.reddit.com/r/SampleSize
[4]http://www.xda-developers.com

the participant was trying to do and/or were missing information detailing what made completing the task difficult, both of which were key questions in the short survey and necessary to contextualise the participant responses. One response was removed for including uncorrectable conflicting responses (e.g. explaining that the sun made it difficult to watch a movie on their smartphone, but then indicating they have never experienced the difficulty of seeing content on their device due to bright lighting). Four of the 11 responses were removed when task difficulty was unrelated to the study (e.g., there "*were people around*" and they were "*not tired*") and/or overly vague response or non-serious replies were provided (e.g., "*not too bad*" in response to the question looking to understand the source of difficulty). This left 174 responses. Assuming one response per participant, my respondents were aged 18-75 years old (mean=26.88, SD=10.47), comprising 93 males, 79 females, and 2 other.

3.2.3 Analysis of Open-Ended Questions (Q5, Q6, Q9, Q10)

I analysed the qualitative data of the survey using an open coding approach [Tracy, 2013]. After reading through each response to become familiar with the data, I analysed the data using the following process.

Generating and collating initial codes: I printed and read through the responses again, taking note of initial codes. These initial codes were generated using a data-driven approach, then collated and collapsed (e.g., "brightness on screen too low" and "screen brightness on minimum" collapsed to "screen quality and brightness").

Evaluating the suitability of my codes: I provided the initial codebook to both myself and another HCI researcher familiar with the study, plus a random selection of one-third of the responses for each question. We both agreed that participant responses would be coded for mentions rather than fitting a whole response into a single code (e.g., P177: "*The reflections in the screen and the low brightness of it as compared to the surroundings.*"

is too detailed to be coded once). After this agreement, we independently coded the selected responses for each question using the initial codebook.

We then discussed coding disagreements, leading to a refinement of the codes and their descriptions. We found that participants often misunderstood Q8 ("Were you able to complete your task?") as there was substantial overlap in responses to Q9 ('yes' → "What did you do so that you were able to complete the task?") and Q10 ('no' → "What did you end up doing instead?"). For Q9, I expected participants to describe the solution they used to overcome their BL-SVIs the moment it occurred, but this was not always the case (e.g., P180 responded 'yes' to Q8 but responded "*wait until I could go inside*" to Q9, so P180 did not complete his task at that moment). Another example of confusion was from P138 who was outside on his smartphone and browsing online. The screen visibility was poor and he responded 'yes' to being able to complete his task but wrote the solution of increasing the screen brightness under Q10, which was collecting information on what participants did when they could not completed their task. A final example of confusion was from P145 who was checking emails outside on her smartphone. The screen was not set to auto-brightness and she indicated 'no' to being able to complete his task but wrote that she used her "*hands over the phone to make it dark enough to see the screen to turn the brightness up*" under the question for people who were able to complete their task. A simple solution to addressing this confuse was to group Q9 and Q10 under the broader question: "What did you do?".

Before coding the full data set, I agreed with the other coder on the following rules for coding the full data set: 1) count all mentions, 2) if a general response also includes specific examples, count both (e.g., P11: "*Play a dark game like Quake or Doom*" – "play game" is general, while "Quake" and "Doom" are specific; all three were coded), 3) if a written response includes the word 'and', check to see if the participant is providing examples (add codes) or an elaboration on a previous point (no added codes, e.g., P65: "*too bright and the brightness was making it difficult to drive*", was counted as one mention of brightness).

Coding the full data set: Myself and the other coder then independently re-coded responses from the entire dataset with the new rules and updated codebook (see Appendix B.6). I could not use Cohen's Kappa to measure inter-rater agreement because we coded the responses more than once (violating the assumption of mutually-exclusive categories [Cohen, 1960]), so I opted to use 'percentage agreement' instead. Although 'percentage agreement' does not factor in agreement that can happen by chance [Howell, 2012], the chance agreement was low due to the number of codes available per open-ended question (9-15 codes) and the ability to code multiple times. I first calculated the code agreement percentage per participant response (equal weight). Averaging these, I found high agreement (Q5: 93.2%, Q6: 92.3%. Q9+Q10: 93.6%). We reached consensus by discussing conflicted coding.

Defining themes: The other coder and I then reviewed the final coding to identify similarities that allowed for thematic grouping. The main themes (described below) provide answers to my research questions for the "*causes of BL-SVIs*" (RQ2) and the "*strategies used to overcome BL-SVIs*" (RQ4).

3.3 Results

I have framed the results section around my five research questions.

3.3.1 RQ1: In what contexts do BL-SVIs occur?

When BL-SVIs occurred, 161 participants (92.5%) reported using a smartphone, 11 (6.3%) a tablet, and one a smartwatch. 166 participants (95.4%) experienced BL-SVIs outside and eight (4.6%) experienced BL-SVIs while inside.

Task	Mentions	Examples
Text-based communication	77	Email; SMS; instant message; status update.
Seeking information	46	Reading text, books, eBooks; browsing Internet; checking time; accessing social media (except messaging); checking fitness stats.
Create, consume, or interact with media	39	Taking, viewing, editing a photo; watching video; selecting music; playing a game.
Nonspecific	20	Mentions of using device in which no specific task was given.
Navigation and maps	9	Navigating to a destination; checking current location.
Checking notifications	4	Facebook messenger notifications; system notifications.
Enacting a system change	4	Adjusting screen brightness; unlocking the device.
Making and receiving phone calls	4	Statement about making or receiving phone calls.
Shopping	1	Statements about shopping online.

Table 3.1: A summary of the tasks the participants were trying to complete ordered by most frequently mentioned.

The participants experienced BL-SVIs while attempting a wide variety of tasks, summarised in Table 3.1. The three most frequently-reported involved "*text-based communication*" (77 mentions), "*seeking information*" (46 mentions), and "*creating, consuming, or interacting with media*" (39 mentions). There were nine mentions of "*non-specific tasks*", four mentions each for "*checking notifications*", "*enacting a system change*" (e.g., unlocking device, adjusting brightness), and "*making and receiving phone calls*", plus one mention of "*shopping*". These results support previous work showing that mobile devices are mainly used for communication [Böhmer et al., 2011]. In some cases, the participants reported a task that was intended to resolve or reduce BL-SVIs (e.g., increasing screen brightness).

3.3.2 RQ2: What are the causes of BL-SVIs?

I identified five themes for causes of BL-SVIs: "External Influences", "Accessory Interference", "Problematic Hardware Design", "Operating System Inadequacy", and "Problematic Interface and Content Design". I have adjusted the quotes when appropriate to improve readability and clarity (e.g., adding punctuation, capital letters).

External Influences: There were 123 mentions of causes that related to the environment (e.g., sunlight) and position of the device (e.g., the angle the screen is being viewed from). I did not specify what the bright lighting could be. The sun was often blamed for causing BL-SVIs (92 times). There were also 19 mentions of non-sun bright lighting or environment. For example:

> P157: "*I have my mobile on low brightness thus making it difficult to write while there is bright lighting.*"

Eight participants were inside when they had difficulty using their device, so BL-SVIs are not exclusively an outside problem. In addition to indoor lighting being a problem, it is still possible for the sun to affect mobile device interaction while inside (e.g., P59 explained "*I was sitting beside the window so the glare made it impossible to read the email.*"). In addition to brightness, 12 mentions related to the direction of light or viewing the device at an angle. For example:

> P35 found "*the angle of the phone (attached to an arm-mounted holder), with the sun shining down*" made it difficult to adjust music on the running app.

Tilting the mobile device to reduce the amount of light falling on the screen helped in some cases (see more details in Section 3.3.4), although it was not always convenient or possible.

Accessory Interference: BL-SVIs can be caused by interference from accessories (e.g., running armbands, screen protectors, sunglasses). I identified both human accessories (four mentions - e.g., sunglasses) and device accessories (one mention - screen protector).

People wearing sunglasses have two factors causing BL-SVIs: 1) tinted lenses block light coming from the screen, making it appear darker, and 2) the screen has a lower perceived brightness because of the bright ambient light. Running armbands can cause glare by forcing interactions at an odd angle.

Problematic Hardware Design: There were 122 mentions of the physical design of mobile devices (e.g., screen material) increasing BL-SVI severity. Of these, 68 mentions suggested that the display quality (e.g., dark screen, dim backlight) contributes to BL-SVIs. For example:

> P43: "*The phone was a work phone and cheap quality. It was impossible to see screen at all.*"

In addition, there were 54 mentions of glare and reflections, which is not surprising since mobile device screens are typically very smooth glass or plastic because this helps ensure a sharp and colourful display image.

Operating System Inadequacy: Participants identified that their mobile's operating system could increase the BL-SVIs severity and impede usability. I found 11 mentions indicating that automated adjustment features (e.g., auto-brightness, power saving mode) can become a hindrance during BL-SVIs. For example:

> P77 found "*the screen brightness was too low and the auto adjustment thingy was taking too long to figure out how bright to make the screen*" when he was trying to read a text message.

Auto-brightness can be disabled and this can result in the display becoming too dark to see. However, the auto-brightness setting can also be problematic when it is enabled and it becomes unresponsive or delayed beyond an acceptable time. In addition, power saving mode can forcibly reduce screen brightness. Automated system adjustments are designed to improve usability by removing the need to change settings manually; however, my participants identified instances where this has reduced usability instead.

Problematic Interface and Content Design: 39 mentions were related to the displayed screen content increasing the severity of BL-SVIs. 32 of the mentions indicated it was difficult to perceive screen content (e.g., difficult to read track names). Although these 32 mentions were unspecific (e.g., P179 commented on the "*visibility of text*" when he was trying to read an email), and so I cannot say whether design choices were increasing the BL-SVIs severity, an additional seven mentions specifically highlighted the importance of design (e.g., thickness and colour contrast of icons or text, overall colour scheme). For example:

> P196 found that with reflections on her smartphone screen "*it was easy to read normal text on a website*" but "*it was difficult to perceive the different colors in the comics* and this was particularly difficult "*for the frame with [a] dark background.*"

Content displayed on the screen affects BL-SVIs and designers need to consider this carefully. Particular care should be given to the use of colour, contrast, fonts size, and icons size.

3.3.3 RQ3: How frustrating are BL-SVIs?

This question was asked within the context of Q6, tying the reported level of frustration to the task reported in Q5. Figure 3.1 summarises my results, where 54.0% of my participants rated their frustration at 4 (41.4%) or 5 (12.6%) on a 5-point scale from

"Not at all (1)" frustrating to "Extremely (5)" frustrating.

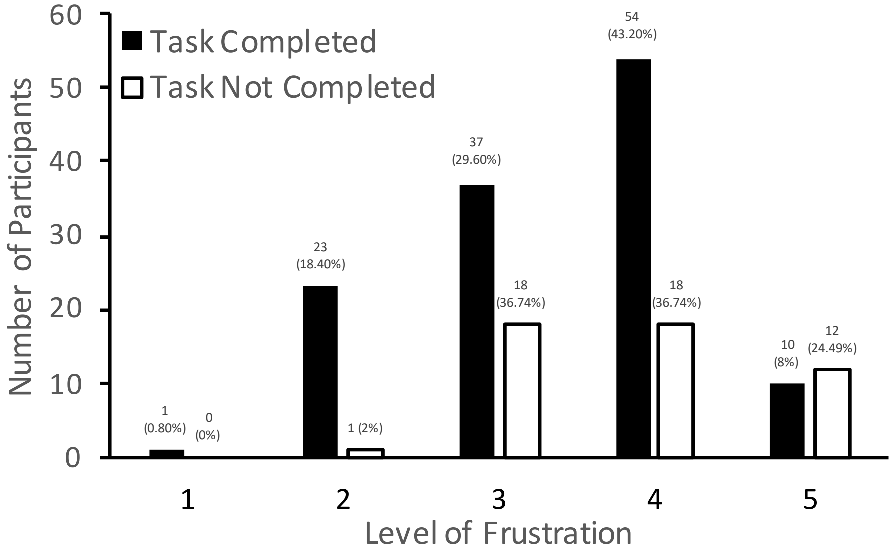


Figure 3.1: Level of frustration from 1 (Not at all) to 5 (Extremely), split by whether the participant could complete the task or not.

Frustration was significantly lower for participants who completed their task (Mann-Whitney test: *U=2323.50, z=-2.62, p<.01*), although this had low practical significance (*r=.20*). In addition, the median for both groups was 4.0, indicating that regardless of whether participants completed their task or not, half of each group was still at least very frustrated.

3.3.4 RQ4: What strategies are used to overcome BL-SVIs?

Overall, 125 participants (71.8%) could complete their reported tasks and 49 participants (28.2%) could not. P109 selected "yes" but reported two examples – describing both tasks he could and could not complete. P68 could not remember what she did instead when she was unable to complete her task. I identified seven BL-SVIs strategies: "Perseverance", "Change Tactic", "Fixing Accessories", "Adjusting Display", "Physical Solutions", "Waiting", and "Not Rely on Device". I have adjusted the quotes when appropriate to improve readability and clarity (e.g., adding punctuation, capital letters).

Perseverance: Some participants persevered with their tasks (17 mentions), reporting 'pushing through' (e.g., by concentrating more: P136 used his "*hand to block the sunlight interfering with the screen as well as concentrate on the task at hand more rigorously.*"). Five participants mentioned completing the task from memory. For example:

> P181 was trying to increase his screen brightness but had to do this "*from memory*" and he still had to "*tap a couple of times to find the slider.*"

Furthermore, four participants employed squinting as a strategy.

As a general solution, persevering does not appear to be a particularly useful strategy. Completing by memory can be problematic (e.g., P36 recalls "*remembering roughly (or stabbing randomly) where the right buttons on the screen*" are to successfully change the destination on his smartphone SatNav) and sometimes it is not possible to rely on memory, such as when using a new device or when showing somebody an image they have never seen before.

Change Tactic: It was common for the participants to report relocating as a solution (57 mentions) to find shade (e.g., P195 "*went inside*" because "*printing out the pages wouldn't be environmentally friendly.*")

There were also three mentions of switching to a different application to complete the task or switching task altogether. For example:

> P11 chose to access "*Facebook and Reddit*" on his tablet because these were "*easier to read*" compared to playing asethetically dark games like "*Quake or Doom.*"

Switching location, app, or task is highly inconvenient – there is likely a reason why people are where they are and doing what they are doing. Moreover, it may not be possible for a person to find more suitable surroundings. Regarding the switching of an application, there is likely a reason a person is using a specific app, to begin with, and by switching to another app, the user is making a compromise. Finally, the decision to switch task is also an inconvenience, and this could be especially problematic if the original task is important and needs completing as soon as possible.

Fixing Accessories: Some participants described problems caused by accessories. The solution was to remove the device from the accessory or to remove the accessory being worn. There were two mentions for this solution (e.g. P12 removed her smartphone from her "*armband and found a shaded area*" but still had to use her "*hand to provide additional shade.*")

It is interesting to note that although one participant (P81) specified the screen protector as part of the problem, P81 never removed the screen protector as part of a solution, possibly due to the inconvenience of later reapplying it (or that it defeats the purpose of a screen protector).

Adjusting Display: There were 34 mentions of adjusting the display as a solution to BL-SVIs. Thirty-one mentions for increasing screen brightness or contrast (via accessibility options). Furthermore, there were three mentions for toggling auto-brightness, or waiting for it to activate. For example:

> P104: "*Wait a few seconds for the phone to realise it was bright outside and light the screen up some more to compensate.*"

Increasing brightness is one solution to addressing BL-SVIs; however, BL-SVIs can occur from a combination of factors. If the content has low contrast, then increasing brightness might not have much effect. Furthermore, participants also reported concerns about increased brightness reducing battery life, which may make them hesitant to use this strategy.

Physical Solutions: My participants reported reducing the amount of light falling on the screen 86 times. There were 61 mentions of shading the device with their body, hand, or an item (e.g., book, clothing). For example:

> P82: "*Took a book and angled it over the phone to block the sun, which was annoying because I had to alternate between that and drawing (so my solution was cumbersome at best because it required active intervention).*"

Using a hand or item of clothing to shade the device is not convenient and increases the encumbrance of this solution, especially if the user has no free hand. There were also 25 mentions of reorienting their body and/or device to reduce the light falling on the screen. For example:

> P127: "*Shaded the screen by turning away from the sun and using my palm. It was enough to see whether the e-mail was important or not, but nothing more detailed could be done.*"

Strategies for reorienting the device might not always be possible (e.g., when a device is mounted on a person's arm while running or on the dashboard of a car for GPS).

Waiting: There were 16 mentions of participants waiting until the BL-SVIs subsided (e.g., P160 waited until he could go "*somewhere darker*" to check his social media accounts). It is likely that waiting until the problem subsides is not always going to be an option. If a task is urgent, then delaying it is likely not possible, or could have serious implications.

Not Rely on Device: There were 12 mentions of the participants stopping altogether or closing the application (e.g., P175 could not "*browse the internet*" due to refections on her device and therefore chose to "*stop using the device*"). There was one mention of speaking to somebody to ask "*for directions*" (P197) because it was too bright to follow direction from a map on her phone, implying the participant stopped using her device. Overall,

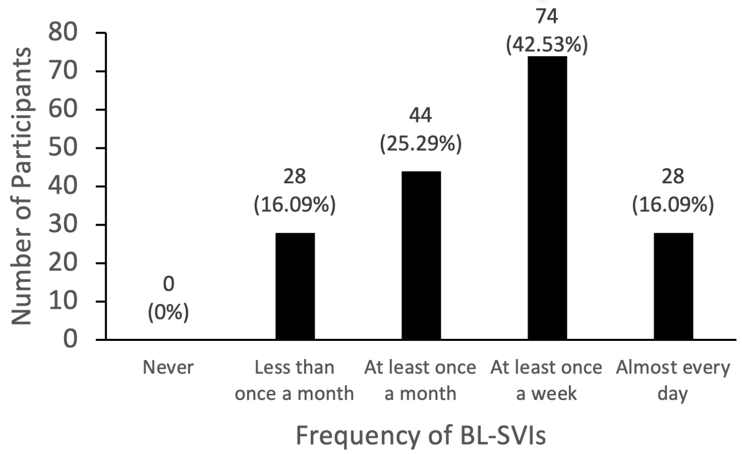


Figure 3.2: Reported frequency of experiencing problems using mobile devices under bright lighting (Study 1).

not being able to use your device to the point of giving up is clearly inconvenient and potentially dangerous. For example, if you are lost and alone in an unfamiliar location with a high rate of crime.

3.3.5 RQ5: How often are BL-SVIs experienced?

Responses to Q11 revealed that 74 participants (42.5%) experienced BL-SVIs when using mobile devices under bright lighting at least once per week, and 28 (16.1%) said BL-SVIs were a problem almost every day, suggesting that BL-SVIs can be a frequent problem in many people's day-to-day lives (Figure 3.2). 44 participants (25.3%) experienced BL-SVIs once a month, and only 28 (16.1%) reported a BL-SVI frequency of less than once a month. All participants had experienced a BL-SVI at least once.

3.3.6 Limitations

Through this initial web-based survey with 174 participants, I was able to identify that BL-SVIs can be very frustrating (54.02% of participants), is experienced often (once a week or more by 58.62% participants), and during a wide range of tasks. In addition to bright light, the direction of light, human accessories, the position of device, device accessories, hardware design, OS or automated system settings, and the design of content also contribute to BL-SVIs. Many strategies are used to overcome BL-SVIs, such as persevering, changing tactic, fixing accessories, adjusting their displays, physical solutions, waiting, and not relying on the device. Combining current solutions does not always eliminate BL-SVIs when they occur.

However, the sampling method employed was biased in favour of people willing to respond to the survey (potentially over-emphasising severe episodes of BL-SVIs). This bias may also have been amplified by having participants recall a past BL-SVI episode (rather than report a current one) since the memory of previous experiences can change over time and the current emotional state of a person can affect recall of valence information [Cutler et al., 1996; Ross, 1989]. Finally, the participant sample is skewed towards the younger end of the age range 18-75 years-old (mean=26.88, SD=10.47).

To address these limitations, I next conducted an Ecological Momentary Assessment (EMA) with a mobile user group balanced by age and gender. In addition, I removed 13 participants from Study 1 for submitting difficulties experienced in a dark environment because the primary focus was for BL-SVIs. However, since there were indications of experienced difficulties in the dark I chose to expand Study 2 to focus on any SVIs rather than only those experienced in a bright environment.

3.4 Study 2: Ecological Momentary Assessment

An *Ecological Momentary Assessment* (EMA – a type of experience sampling method or ESM) is used to understand what a person does, feels, and thinks in the moment, typically over a series of days [Larson and Csikszentmihalyi, 2014; Scollon et al., 2009].

An analysis of 461 studies utilising an EMA/ESM approach reported a median of 14 days [van Berkel et al., 2017]. Participants are usually prompted to submit data through completing self-reports, and the prompts can occur in three different ways (interval contingent, which involves regularly timed prompts; signal contingent, which involves randomly timed prompts; and event contingent, which involves the participant submitting a self-report after experiencing an event the researcher is interested in). Each prompt has its advantages and disadvantages [Fisher and To].

I used an EMA study because it allowed me to capture people's experiences of SVIs within the moment. Therefore I would collect a more precise understanding of the frequency of SVIs over a fixed period and the frustration SVIs cause, therefore, addressing the memory bias mentioned above (see Section 3.3.6). To follow best practice [Christensen et al., 2003; Scollon et al., 2009], I first ran a one-week pilot EMA with six participants before running a larger two-week study.

3.4.1 Pilot Study

Running a pilot study is a recommended part of an ecological momentary assessment [Christensen et al., 2003; Scollon et al., 2009]. A pilot helped ensure the full study would gather data that clearly described SVI frequency, severity, causes, and strategies.

Pilot Study Material and Procedure

I recruited the participants through advertising at the University of Dundee and online (e.g., Facebook), sample text available in Appendix B.7. The advertisement only described that I was interested in people's daily experiences when using a mobile device to avoid a self-selection bias. As per my Research Ethics Board (REB) approval, participants provided informed consent before taking part.

First, the participants were instructed to complete a short demographic questionnaire. The questionnaire included 10 close-ended and open-ended questions to determine the participants' age, gender, country of residence, highest level of education, level of computer literacy, visual impairments (plus if they wear contacts or glasses), number of mobile devices owned (plus the make and model of those devices), and average total number of hours of use per day for those devices.

Second, after all of the participants had completed the demographics questionnaire I continued training over email. I introduced the concept of situational impairments. I explained that I wanted self-reports on SVIs experienced when using a mobile device. I provided examples of what can cause an SVI, and I highlighted that combinations of different factors could also cause SVIs.

For data gathering, I used two different reports, which were mobile-friendly Google Form. First, there was a self-report, which was the primary means of collecting data throughout the day and participants completed this at the earliest opportunity. The self-report included nine close-ended and open-ended questions (Appendix B.8) to identify how many SVIs the participant experienced in the previous two to three hours, what device was used, if the participant was inside or outside, what the participant was trying to do, what made it difficult, how frustrated the participant was, what the participant did as a result of the SVI, how important the task was, and a final box for additional questions. I used my findings from Study 1 to determine the category choices for the "what were you trying to do?", "what made it difficult?", and "what did you do?" questions. These were close-ended questions to save the participant time when completing the self-reports. Each question included an "other" option to let participants report details that did not fit in the other categories and multiple options could be selected.

Second, there was an end-of-day report, which served two purposes: to identify why a participant might have missed a self-report and to allow the participant an opportunity to report an experience of an SVI if there was one that they did not report earlier in the day. The end-of-day report included nine close-ended and open-ended questions (Appendix B.9). The first question in the end-of-day report differed from the self-report by asking "If you were you unable to complete any of the self-reports today, please tell us the reasons why?" rather than "How many times in the last 2-3 hours did you experience a SVI?". The participant then had an opportunity to report one BL-SVI if there was one to report.

I asked my participants for an email address which they would have the most access to throughout the day to minimise the number of missed submissions. I told the participants that I understood it would not always be possible for them to respond to every self-report and explained this was partly the reason for sending an end-of-day report. I reiterated only to complete a self-report when it was safe to do so. Finally, I gave the participants an opportunity to ask any further questions before the one-week EMA started.

I used an interval-contingent approach [Christensen et al., 2003], in which the self-report request email was sent four times each day around 10am, 1pm, 4pm, and 7pm[5]. I used an interval-contingent approach because data gathered from the first study suggested that SVIs due to bright lighting are a frequent experience. Since the current study looks more broadly at SVIs, and I found in Study 1 that one type of SVI (BL-SVIs) is experienced frequently, I did not want the participants to lose interest too quickly by submitting a report every time they experience an SVI [Scollon et al., 2009]. Since the participants were reporting on SVIs experiences within the previous few hours, I specified in the self-report emails that the participants had 30 minutes from receiving the email to completing the self-report to minimise any further time elapsing to avoid memory biases.

[5]Google's servers ultimately decide on a time that was +/- 15 minutes from when the server trigger was set

The end-of-day report was sent out around 9pm, and participants were given two hours to complete this questionnaire.

At the end of the one-week pilot EMA, I gave the participants an opportunity to provide feedback on the study to help me to determine any changes I needed to make with the procedure.

I reimbursed the participants with a £10 Amazon voucher for their time.

Pilot Study Participants

I recruited six participants (two male and four female) aged between 18 and 76 years-old (M = 35.00, SD = 27.48; two participants did not report their age).

Throughout the pilot study, all participants took part while in the same timezone – five participants were in the UK and one participant was in Gran Canaria, Spain.

The highest level of education attained by the participants was "High School" (one participant), "University (Undergraduate)" (two participants), and "University (Post-graduate)" (three participants). Four participants reported "Good" computer literacy and two reported "Excellent".

Four participants indicated they wear glasses or contacts and three participants specified some level of myopia (refractive near-sightedness).

I asked the participants how many mobile devices they owned. Two participants reported that they own one device and four owned two devices. I also asked the participants to estimate on average how many hours in total they use these mobile devices. Four participants reported one hour, three hours, four hours, and six hours, while two participants indicated seven or more hours of use per day.

ID	Number of Forms Completed	Percentage of All Forms Completed	Number of SVIs	Percentage of Responses that reported SVIs
P1	15 (10 SR + 5 EoD)	42.86%	1	6.67%
P2	17 (15 SR + 2 EoD)	48.57%	2	11.77%
P3	22 (15 SR + 7 EoD)	62.86%	4	18.18%
P4	28 (21 SR + 7 EoD)	80.00%	1	3.57%
P5	32 (25 SR + 7 EoD)	91.43%	2	6.25%
P6	35 (28 SR + 7 EoD)	100.00%	6	17.14%

Table 3.2: An overview of the participants involvement during the pilot study. SR (self-report) & EoD (end-of-day report).

Pilot Study Results

Throughout the week, each participant was expected to complete 35 responses (28 daily self-reports and seven end-of-day reports). Table 3.2 shows how many responses were submitted by each participant, including the number of SVIs the participants experienced. The mean rate of return was 70.95% (minimum 42.86% and maximum 100.00%). The participants gave several reasons for missing a self-report: "did not notice or see email" (P1 four times, P3 three times, P4 four times), "no time" (P2 once, P6 twice), "unsafe to do so" (P3 twice), and "no data connection" (P6 once). Five SVIs the participants reported did not relate to using a mobile device, so have been excluded from the data set (e.g., P4 mentioned the difficulty of accurately typing because the device's touch detection needed to be recalibrated).

The number of SVIs reported is the total from the self-reports and end-of-day reports. The participants may have experienced more SVIs than reported because the end-of-day report only asks the participant to give me the details of one that they missed reporting during the day. The median is two SVIs over seven days.

All participants except P3 submitted a form outside of the time limit. P1 and P4 both submitted two forms late, P6 submitted five forms late, and P2 and P5 submitted six forms late.

All questions were optional, which means some of the submitted forms were incomplete. Overall, there were a total of 16 SVIs experienced when using a mobile device with 15 SVIs described in detail. I used the codes created during Study 1 to save the participant time in completing the self-reports.

Most of the SVIs were experienced inside (nine reports) compared to outside (six reports).

The participants experienced SVIs during a range of tasks. "Text-based communication" was reported nine times (P2, P3, P4, P5, P6); "seeking information" was reported four times (P3, P6); "create, consume, or interact with media" was reported twice (P1, P4); "navigation and maps" was reported once (P3); "checking notifications" was reported twice (P3, P5); and "making or receiving a phone call" was reported once.

My participants highlighted the different factors causing the SVIs. "External influences" was reported nine times (P1, P2, P3, P4, P6); "human accessory interference" was reported once (P5); "problematic hardware" was reported twice (P3, P5); "operating system inadequacy" was reported twice (P3); "problematic interface and content design" was reported once (P6). P4 also wrote "*lying down to use the device is sometimes difficult for me as I cannot wear my glasses while lying on my side and have to hold [the] device at an uncomfortable angle*" and P6 on two occasions wrote "*slow connection*"[6].

Finally, the participants employed different strategies as a result of the SVIs. "Persevere" was reported five times (P2, P4, P5, P6); "change tactic" was reported twice (P1, P5); "fixing accessories" was reported twice (P6); "adjust display" was reported four times (P2, P3, P5); "physical solutions" was reported three times (P3); and "waited until the problem subsided" was reported four times (P6).

[6] While this does not immediately seem like a cause for SVIs, a slow connection can cause a number of issues, e.g., images not loading and video playing at a low resolution.

The participants rated their frustration when experiencing each SVI. The scale ranged from one (Not at all) to five (Extremely). The mean level of frustration was 2.47 (SD = 0.74) with the lowest rating of one and the highest rating of four.

I also asked the participants to rate how important the task was from one (not at all) to five (extremely). The mean level of importance was 2.4 (SD = 0.99) with the lowest rating of one and the highest rating of five.

Pilot Study Feedback and Resultant Changes to the Main Study

I received feedback from the participants about their experience in taking part in the pilot study, which allowed me to re-evaluate my study design and make several changes to my procedure and materials as a result.

There were a number of issues raised, such as the wording and options for close-ended questions (five participants), the structure of the questionnaire (one participant), not having a sufficient explanation detailing SVIs (two participants), the study was found to be demanding (five participants), and three participants said they lost interest within around two days due to the frequent self-report emails they were expected to complete. In addition, three participants raised the issue of the short amount of time provided to complete the self-reports. An interval-contingent approach (emailing the participants throughout the day with a short response deadline) was burdensome.

I made several changes to the demographics questionnaire, self-report, and end-of-day reports. It was important to encourage all participant taking part to provide as much information as possible in both the demographics form and during the EMA study. I made two important changes to ensure this happened. First, all important questions were now compulsory. If the participant did not want to submit the information, then they could choose not to submit a form. Second, I provided questions with examples for clarification and to show the level of detail I wanted to capture (e.g., the make and model of the mobile device).

I also included an additional two questions in the demographics questionnaire. I asked "Do you plan to visit another country or timezone during part 2 of this study (i.e., the 2-week EMA study)?" to ensure the participant would not be travelling a significant distance or switching timezone, which would affect the consistency of receiving emails. I also asked "Does your work or study mainly occur in outside or inside environments?" to get an idea of whether a participant is likely to be spending most of their time during the day outside or inside and therefore affecting their exposure to sunlight. For the question "On average, what is the total number of hours per day that you use these mobile devices?" I removed the maximum response "7 or more hours" and allowed participants to indicate 0 to 24 hours.

Within the self-reports and end-of-day reports, I included the question "Where did this SVI experience take place?" to give the submitted data more context. I also changed the categories offered for the following questions "What were you trying to do?", "What made it difficult?", and "What did you do?" because they were difficult for some participants to relate to. The decision to make these close-ended questions in the pilot was to save the participant time in providing an answer and to avoid responses that did not have enough details. To remove any confusion, I changed the questions to open-ended questions, which also gave me the opportunity to capture more detailed data.

I decided that switching from an interval-contingent approach to event-contingent would minimise the strain of taking part. I planned the main study to take place for two weeks, which meant that it was vital I reduce the burden felt by the participants. Instead of emailing the participants throughout the day, they would only need to submit a self-report when they experienced an SVI. This change also removed the need for the participants to complete the self-report within 30 minutes of receiving the email, which was another criticism I received.

With a change in study design that relied on the participants to not only remember to submit their self-reports but also to identify when they experienced an SVI, it was essential that I ensured the participants understood and internalised the concept fully. Two participants from the pilot study noted that more information regarding SVIs would have been beneficial. I created a single page SVI explanation that used details from both the Inclusive Microsoft Design Toolkit[7] and design cards (created by HaptiMap [Magnusson, 2011]). Furthermore, I emphasised that there was no minimum expected number of SVIs to be experienced each day because everybody will experience them differently due to the number of possible factors that can contribute to the experience.

3.4.2 Materials and Procedure

I chose to recruit participants from both Australia and Scotland. This was for several reasons. First, Australia is in the southern hemisphere and Scotland is in the northern hemisphere, which meant that the two countries were in different seasons (Summer vs Winter). This difference in the environmental conditions meant I would likely collect a diverse range of SVI reports. Second, Australia and Scotland are both English speaking countries with a lot of cultural similarities, which minimised the chances of confusion occurring when I set up and ran the study. Third, the EMA study required a lot of time and planning, and organising the study to run concurrently meant that I did not have to run the study in Scotland twice while I waited for winter to become summer.

I recruited participants by advertising at Australian and Scottish universities, as well as through other online platforms such as those in Study 1. To avoid the self-selection bias identified earlier, I advertised that I was "*investigating daily experiences of using a mobile*

[7] https://www.microsoft.com/design/inclusive/

device". Participants only provided age, gender, location, and an email address, giving me enough information to randomly select participants for balanced demographic groups, without other information influencing my decision.

After recruitment, I explained that the purpose of the study was to collect self-reports of SVIs experienced when using a mobile device over a two-week period. I provided participants with an explanation of SVIs (see Appendix B.10) that contained information from the Inclusive Microsoft Design Toolkit [Microsoft, n.d.b] and the HaptiMap design cards [Magnusson, 2011], and emphasised that there was no minimum number of SVIs to be reported each day. I included a link to the SVI explanation sheet in all email correspondence with participants throughout the study. Finally, I gave the participants an opportunity to ask any further questions via email before the study began.

I used an event-contingent approach [Christensen et al., 2003], in which participants actively recognise SVIs as they happen, and promptly report them when safe to do so. The self-report (see Appendix B.13) included nine questions to identify: what device was used, if the participant was inside or outside, where the SVI occurred, what the participant was trying to do, how important the task was, what made it difficult, how frustrated the participant was, what strategy/ies were used (if any) to overcome the SVI, plus any additional comments. Each morning at ~0700 (local time)[8], participants received an email reminder about the study that included links to the self-report and the SVI explanation page.

An end-of-day report (see Appendix B.14) was emailed every evening at ~2045 to check that the participants were still in that same timezone, if the participants experienced any SVIs and did not submit a report during the day, how many SVIs the participants did not report, and why the participants did not report the SVI at the time it occurred. If there were any missed self-reports, then the participants were asked to describe one of the unreported SVIs. I required the participants to submit an end-of-day report

[8]Google's servers automatically send an email +/- 15 minutes to the requested time.

every evening to check their engagement with the study; a participant might not experience an SVI every day therefore not submitting any self-reports, thereby appearing as potential study dropout.

I have given the participants an ID that indicates their location (A = Australia, S = Scotland) and gender (M = Male, F = Female) with a number from 1 to 6 increasing with age. For example, AM1 is the youngest male participant located in Australia and SF6 is the oldest female participant located in Scotland.

After the two-week period, I sent the participants a final questionnaire. All participants (except SM4 - who did not experience any SVIs) were asked four main questions to identify: 1) if their mobile device use was typical, 2) if their engagement was consistent, 3) what was the cause for frustration when experiencing SVIs, and 4) any additional comments. Additional questions based on the data submitted were asked on a per participant basis when necessary. Due to not experiencing any SVIs, SM4 received the first two questions, and I asked if he had experienced SVIs outside of the two week study period. I also asked 12 participants questions about their experience with auto-brightness, seven participants for additional information about their reported SVIs, six participants for clarification of the time a report was submitted, and two participants if an issue they were reporting had occurred before. Any further discussions to clarify responses were carried out over email. I reimbursed participants with a £20 or AU$36 voucher.

3.4.3 Participants

I initially recruited 239 participants to ensure that I had a large enough participant pool from which I could randomly sub-sample participants. The participants who signed up at this stage of the study only provided me with their age, gender, and location. I then used this basic demographic information to randomly invite 12 participants (six male and six female) from Australia and 12 participants (six male and six female) from Scotland to take part in the study.

Australia has different time zones and so I first had to determine which time zone I had the most participants to draw from. This requirement was necessary so that the Australian participants received the morning and evening email reminders at the same time. The majority of my sample were from the Australian Eastern Standard time, which included the locations New South Wales (except Broken Hill), Victoria, Tasmania, and Australian Capital. I did not need to make the same decision for the Scottish participants since there is only one timezone in Scotland. Next, I split both the Australian and Scottish participants into male and female groups. I then randomly selected one participant from the 18-19 years old age group, two from the 20-29 years old age group, two from the 30-39 years old age group, one from the 40+ years old age group. This left me with six male and six female participants with a matching distribution of ages for both the Australian and Scottish groups.

My study was conducted in February 2018, so that participants from Australia were in their summer (brighter environment), and participants from Scotland were in their winter (darker environment). As per my REB approval, all selected participants provided informed consent before taking part. I asked my participants for an email address that they would have the most access to throughout the day to minimise the number of missed submissions. Furthermore, I offered the participants a letter that could be shown at their place of work to explain they were taking part in research for a two week period.

I asked these participants to complete an additional demographics questionnaire that included 12 questions (see Appendix B.11). I asked for the participants' age, gender, country and time zone. I also asked the participants if they would be visiting another country or timezone during the two-week study, their highest attained education, their level of computer literacy, if they mainly work or study outside or inside, if they have any visual impairments, if they wear contacts or glasses, how many mobile devices they own (including the make and model of those devices), and for how many hours each day the devices are used.

Table 3.3 summarises the mean age and standard deviation for both gender (male, female) and location (Australia, Scotland). All 24 participants indicated that they had no plans to visit another country or timezone during the two-week study. The 12 Australian participants were located within the same timezone to ensure that they would receive the self-report and end-of-day emails at the same time of day.

	Male	**Female**	**Australia**	**Scotland**
Mean	30.25	30.67	30.67	30.25
SD	8.50	8.72	8.75	8.47

Table 3.3: Mean and SD for age (years) by gender and location

The highest level of education attained by the participants was "High School" (3 participants), "College" (1) "Undergraduate University" (10), and "Postgraduate University" (10). Eighteen participants reported "Good" computer literacy, and six reported "Excellent". 22 participants mainly work or study inside, and two participants mainly work or study outside. 14 participants wore glasses or contacts[9]. 11 reported no visual impairments, nine had myopia, one had hyperopia, two had myopia and astigmatism, and one had mild astigmatism.

The participants' number of mobile devices ranged from one to five (median=2 devices). Nineteen participants owned at least two devices. Typical daily use was between one to 10 hours (median=4 hours); the younger half (18-28 yrs-old) averaged 5.81 hrs, and the older half (29-46 yrs-old) averaged 4.14 hrs.

[9] SF1 wore glasses to correct a lazy eye rather than for visual acuity.

3.4.4 Results

Twenty-two of my participants (91.67%) indicated that their mobile device usage was typical for both weeks of the study. SM4 indicated that due to illness, his usage was higher over three days on account of not being able to use a computer.

Eighteen participants indicated that they felt their engagement was consistent during the two-week study (SM5 answered so but said there may have been a decrease over three days due to university commitments). Five participants said that their engagement changed. AM2 said that during the last 3-4 days of the study, his responses were not as quick as before, but would still report within half an hour. AF2's engagement decreased during the beginning of week 2. SM1's engagement decreased during the end of the study. SM4's engagement was lower during the week since he was less likely to use a mobile device while working. SM4 increased his phone use over three days when he was away from work. SF6 indicated decreased engagement during week 2 due to work commitments.

SM4 was the only participant not to report any SVIs. When he was asked if he had experienced any SVIs outside of the two-week study, he was able to recall past events where the sun caused an SVI and he would have to manually increase brightness. SM4 also said "*Given the time of year and the weather, I haven't spent much time outside so [the sun has not] been an issue.*" This variability was clear in the data, and not unexpected considering the different seasons of Australia and Scotland, which is something I wanted to observe.

I removed 15 out of 423 submitted reports. I removed seven reports (three self-reports and four end-of-day reports) for not describing SVIs and eight end-of-day reports because they were duplicate submissions. Out of the remaining 408 reports there were 88 self-reports and 29 end-of-day reports that described an SVI event.

Figure 3.3 shows the heatmap distribution of SVIs experienced by the participants. I shifted submitted late reports to include them on the day when my participant experienced the SVI. Two participants indicated that they missed reporting two SVI events, although the end-of-day report allowed them to provide details about one of those events. On day seven, data gathering for the Australian participants was limited to only end-of-day reports due to a technical disruption. There was a decrease in the number of self-reports submitted over two weeks; however, I know from the submitted end-of-day reports that the participants were still engaging with the study. Study 1 did indicate that some people experience SVIs less than once a week and so this new data is likely confirming that SVIs are not experienced by everybody everyday.

			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Australia	Male	AM1		1					1							
		AM2		2	1	1	1	1	1	1			1		1	
		AM3	2		1			1				1				
		AM4						1				1				1
		AM5		1	1					2			1			1
		AM6	1			1					3					
	Female	AF1	1	1	1	1	3	1		2	1	2		1	2	1
		AF2	1		1		1	1		1				1		1
		AF3	1	1	1		1		1							
		AF4		1	1	1	1	1				1			1	
		AF5	1		1					1						
		AF6	2	2	2	2	1	1	1	1		1	1		1	1
Scotland	Male	SM1				1								1		
		SM2		1												
		SM3			1				1							
		SM4														
		SM5	1		1			1	1							
		SM6		1	1		1		1						1	
	Female	SF1			1										1	
		SF2			1											
		SF3		1												
		SF4	1				1									
		SF5	1		1						1		1			
		SF6	1			1	2	2	1			1			1	

Figure 3.3: The total number of SVI events per day across 14 days. White squares indicate 0 and blue, getting darker, indicates 1 to 3 SVI events.

In order to address the larger problem, my research questions from Study 1 now focus on SVIs rather than only BL-SVIs. I used a similar approach to Study 1 to analyse the open-ended questions. I first became familiar with the data. Next, I used the Study 1 codebook to code the data and adjustments were made to the codebook to reflect the broader scope of the new data set (e.g., I did not remove bright screen in dark room SVIs). For the most part, the codebook was appropriate for the data set (I will highlight in the following sections when changes were made). Finally, another researcher familiar with the project and I both independently coded the full data set and did not count mentions that were only providing additional contextual information. I found high agreement for all questions: "Where did this SVI experience take place?" 91.03%, "What were you trying to do?" 93.85%, "What made it difficult?" 81.12%, and "What strategy (or strategies) did you use to overcome the SVI?" 88.58%. We discussed disagreements and re-coded the data, and I refined the codebook to address the disagreements (see Appendix B.12).

RQ1: In what contexts do SVIs occur?

Overall, there were a total of 67 reported SVIs that happened inside (50 for the Australian group and 17 for the Scottish group) and 50 reported SVIs that happened outside (34 for the Australian group and 16 for the Scottish group). There are many different places the SVI event took place: home (36 mentions), in a public space (28 mentions), transport (27 mentions), work or school (23 mentions), while being active (10 mentions), in a shop (three mentions), at an event (one mention), and at the hospital (one mention). Two responses were uncategorisable due to no explicit mention of where the SVI took place: AF1 "*On the way to the shops.*" and SF6 "*Strained eyes when accessing emails in poor light.*".

Similar to Study 1, my participants experienced SVIs during many different tasks, including: "*seeking information*" (47 mentions), "*text-based communication*" (33 mentions), “*creating, consuming, or interacting with media*” (19 mentions), “*navigation and maps*” (eight mentions), “*shopping and payments*” (seven mentions), “*checking notifications*” (seven mentions),“*enacting a system change*” (three mentions), “*setting up device or application*” (three mentions), and “*making and receiving phone calls*” (one mention). There were two “*non-specific*” responses: AM2 “*I was browsing various apps while watching TV.*” and SM3 “*I was trying to see the keys on the phones keyboard.*”. The top three tasks are the same as in Study 1. *Setting up device or application* was a new code and the previous code for shopping was expanded to include mentions of payments with the device.

RQ2: What caused of SVIs?

In Study 1, I identified five themes for causes of BL-SVIs. For Study 2, my data for different types of SVIs continues to support the validity of those themes. However, it was clear from the new data that I needed to consider more deeply the individual within their context, similar to previous research [Sears et al., 2003] and this resulted in acknowledgement of cognitive and physiological effects contributing to SVIs. My themes for Study 2 are: “External Influences”, “Accessory Interference”, “Problematic Hardware Design”, “Operating System and Software Inadequacy”, “Problematic Interface and Content Design”, and “Cognitive and Physiological Effects”.

External Influences: There were 98 mentions of causes that related to the environment. Similar to Study 1, the sun made up the majority of mentions (34). However, since Study 2 broadened my interest to all types of SVIs, I received responses that were more varied. There were 24 mentions of dark environments, 18 mentions of viewing angle, 17 mentions of bright environments, three mentions of moving environment (e.g., AF1: “*The bus kept shaking (more than usual) so it was hard to see the screen.*”), and two mentions of physical obstacles (e.g., dirt on the display of the device). Not surprisingly, there were over twice as many mentions of the sun (24) and bright environment (14) in the

Australian group, compared to the Scottish group (10 and 4, respectively).

Accessory Interference: There were 9 mentions related to human and device accessories. Eight mentions were accessories used by the participants (AM2: "*I didn't have my glasses so reading was more of a strain than normal.*") and one mention of a screen protector making "*...the screen unclear...*" (AF4).

Problematic Hardware Design: There were 85 mentions of the physical design of the mobile devices causing or exacerbating SVI events. Similar to Study 1, 61 mentions suggested that the quality of the display technology is a factor, however, in this case, these were not all examples of BL-SVIs. Some of the SVIs experienced in a dark environment were due to the screen being too bright. It is also possible that in a dark environment the display can still be too dim to view the content (AF6: "*The tablet brightness was low and the lights in the room were also dim making it hard to see the text on the screen.*"). I found 24 mentions of glare and reflections.

Operating System and Software Inadequacy: Data from Study 2 provided me with new information that required me to expand this theme to summarise 27 mentions of general software issues that could be either operating system level problems or application specific. Similar to Study 1, 10 mentions indicated that automated adjustments (e.g., auto-brightness, power saving mode) can factor into SVI events.

There were 15 mentions of using a blue-light screen filter, which is typically used to reduce blue light for better nighttime viewing and improved sleep [Chellappa et al., 2013]. None of the 13 submissions removed from Study 1 for discussing SVIs in a dark environment mentioned the use of a blue-light filter. Blue-light filters can cause a variety of problems (AM2: "*The night-light blue filter made my phone screen too dark, making it difficult to use.*", AM3: "*Trying to play [a game] where you have to match colored dots. [The blue-light filter] made some colours impossible to distinguish.*", and SF3: "*I had the brightness on my phone turned down with a screen filter (blue light) applied, from using my phone in bed* *the night before. I tried to use my phone in the living room and the overhead light was too bright combined with the low brightness of the phone screen.*").

Finally, there were two mentions of apps causing SVI events. The first is an example of the app taking control of system settings, AF4: "*The app makes brightness 100% immediately which was too bright, especially on a Monday morning.*" and the second example was an app not rotating which resulted in the content missing from a website when it is more suited to being viewed in landscape orientation.

Problematic Interface and Content Design: Seventy-six mentions related to the content displayed on a mobile device or the difficulty of seeing what was on the display. Fifty-one of the mentions indicated it was difficult to perceive screen content, whereas 25 mentions provided informative details about aspects of the interface layout or content design that related to the SVI event. Use of colour and colour contrast is important. A challenge is predicting when high-contrast is required (e.g., AF2: "*I was reading a website and their background was black and their text was grey. I had troubles reading the content.*") and low-contrast is required (e.g., SF6: "*The contrasting colours chosen by the bank were very bright.*"). Text size is also important, and so is the rendering of an interface in a different orientation (e.g., SM6: "*...In portrait mode the site I was browsing had missing options at the top of the page and at the side of the page.*"). Furthermore, content that overlays other content on the screen (e.g., Facebook Messenger Chat Heads, adverts) was also problematic (e.g., AM5: "*The content was not well formatted for a mobile screen and an ad kept overlaying the content as well.*", AF2: "*I was trying to make a phone call but [Facebook Messenger] notifications kept popping up making it hard to make the call.*"). Applications can also enable people to adjust colour settings, but this can have unexpected consequences (e.g., AF1: "*This one email had multiple sales for different brands but since I set the background to black, the logos had no contrast.*").

Cognitive and Physiological Effects: Finally there were a total of 19 mentions that did not fit within my previous themes, all of which related to cognitive and physiological effects. I made this one theme since the biological factors were closely related considering the examples given. I found 11 mentions regarding discomfort and pain as a result of the context (e.g., AM2: "*I didn't have my glasses so reading was more of a strain than normal.*", SM5: "*Dark outside, the screen was too bright to look at comfortably.*"). I also found eight mentions of SVI events due to recently waking up (e.g., AM3: "*Screen brightness was way too bright after waking up, usual phone wallpaper is dark but once in the email app [it] has a white background.*", AM5: "*After having had my eyes closed, they were slow to adjust to the brightness of my screen.*").

RQ3: How frustrating are SVIs?

I included a question in Study 2 to measure task importance because Study 1 highlighted that tasks completed on mobile devices range in importance for several reasons. Mobile devices are used to stay connected, for entertainment, and to keep on top of work and school-related tasks.

I used only the self-reports that were submitted after an SVI event (N = 79) to run a Spearman's correlation on the ratings for task importance and frustration. By excluding late self-reports and the end-of-day reports, I minimise any influence that elapsed time may have on the reported task importance and frustration with SVIs. Based on the results of the analysis, I found that as task importance increases so does the amount of frustration experienced during the SVI event ($r_s = .49$, $p < .001$), which confirms my hypothesis formed after reviewing the data from Study 1.

My participants provided several reasons for feeling frustrated: inconvenience by disrupted activities (mentioned by 12 participants), resulting discomfort (mentioned by four participants), experiencing a lack of control (mentioned by eight participants), annoyance (mentioned by two participants), and when the task is important (mentioned by one participant). SF6 said "*my lack of IT knowledge*" referring to not knowing how to resolve SVIs (e.g., adjusting the screen brightness). Five participants mentioned that they were usually not frustrated by SVIs (e.g., due to their typically brief duration).

RQ4: What strategies are used to overcome SVIs?

I received 76 reports demonstrating that a single strategy was used or considered to overcome the SVI event (e.g., SM2: "*Turned up screen brightness.*") and 32 reports demonstrating that more than one strategy was used or considered to overcome the SVI event (e.g., AM2: "*I increased the screen brightness and adjusted the angle of my tablet, but still had some problems with the glare and brightness.*"). Four reports highlighted an unsuccessful or unused strategy (e.g., AM6: attempted to read the time early in the morning but it was "*too bright to see the time clearly*" so he tried holding the device at an angle to minimise the light directly shining in his eyes, but in doing so he could no longer "*read the screen*" because it was tilted away). If a user can address an SVI with different strategies, then one unsuccessful attempt may result in employing another strategy (e.g., AF1: "*I told her to turn the lights off but she didn't so I turned up my brightness.*").

There were 14 reports in which participants were unable to overcome the SVI (e.g., AF3: "*I couldn't really do anything as I was walking outside without shade.*"), even after attempting to address the problem (e.g., AF1: "*I couldn't turn my brightness up because of the low battery so I gave up.*").

Overall, the seven themes identified in Study 1 were sufficient to summarise new data on how people deal with SVIs.

Perseverance: There were a total of 23 mentions. Similar to Study 1, I found evidence of continuing on (three mentions) and completing by memory (two mentions). In the previous study, my participants mentioned squinting (likely to be more common in bright environments). Within Study 2, I found 18 mentions of squinting and other perceptual strategies utilised by the participants (e.g., AF1: "*I had to stop looking at my phone and close my eyes*" because the bus shaking made it difficult to read, and SM5 waited for his "*eyes to adjust*" to the high brightness of the smartphone screen).

Change Tactic: I found 24 mentions that could be summarised as the participant changing tactic. As with Study 1, my participants in Study 2 would also relocate (nine mentions) and switch their approach (four mentions). However, new findings in Study 2 showed that participants would use alternative app features (eight mentions; e.g., AM1 chose to "*listen to gps voice instead of looking at it*"), charge the device (two mentions), and reboot the device (one mention).

Fixing Accessories: Similar to Study 1, adjusting both human and device accessories were solutions when I asked the participants what was contributing to the SVI event. It is interesting that I received three mentions of solutions about removing the human accessory (e.g., AF4 had to "*change to standard glasses*" from the "*prescription sunnies*" she was wearing while trying to set up driving navigation), but there was no evidence of addressing the device accessory causing the SVI. This finding reinforces my Study 1 hypothesis that the solution of altering the device accessory is too inconvenient (e.g., removing a screen protector).

Adjusting Display: There were 52 mentions regarding making adjustments to the display. I found seven mentions of auto-brightness and 32 mentions of manually adjusting the display to resolve the SVI. I also found 13 mentions where a screen filter was adjusted because it was causing the SVI (e.g., AF6: "*I paused the blue light filter on my phone.*").

I asked 12 participants follow-on questions about their experience with auto-brightness based on patterns of behaviour demonstrated in their submitted reports. Seven participants found auto-brightness to not be effective (e.g., it makes the display too dim or too bright), three participants turned it off to save power, while one participant was unaware of the feature prior to the study and one participant likely turned it off by mistake because he typically keeps it on.

Physical Solutions: There were 23 mentions of physical solutions. Similar to Study 1, I found evidence of creating or using local shade (nine mentions), as well as reorienting the body and/or the device (37 mentions). I found two new approaches: removing an obstacle (one mention; SM6 who after opening the case protecting his phone screen discovered "*there was a shopping receipt that had stuck to the phone screen*" and he had to "*flick the paper off*") and adjusting the room lighting (five mentions; e.g., AM3: "*Manually reduced brightness, and turned on bedside lamp to reduce contrast.*", AF1: "*I finally got out of bed, turned off the light, opened the blinds, and resumed using my phone at my desk instead.*").

Waiting: I found nine mentions of waiting for the problem to subside (e.g., SM1: "*Waited until I was inside.*"), but this is not always an option, especially for important tasks.

Not Rely on Device: I counted 10 mentions that suggested the user could not overcome the SVI when using the device. There were also two mentions of speaking to somebody as a method to overcome the SVI (SF6: "*I mentioned to a friend who showed me the brightness setting on my phone.*").

RQ5: How often are SVIs experienced?

When examining week 1, I found 23 participants that experienced at least one SVI – 12 Australian participants reported a total of 53 SVIs and 11 Scottish participants reported a total of 26 SVIs. When examining week 2, I found 15 participants that experienced at least 1 SVI – 10 Australian participants reported a total of 26 SVIs and five Scottish participants reported a total of seven SVIs.

During Study 1 a majority of the participants reported experiencing BL-SVIs at least once per week and using the more suitable methodology of EMA to identify SVI frequency, I can confidently confirm the finding.

3.5 Discussion

The main findings of Study 1 (web-based survey) and Study 2 (EMA study) were:

1. SVIs occur during many different tasks.
2. Factors causing SVIs are: environmental (e.g., lighting, moving surroundings, physical obstacles), device position, human and device accessories, hardware design, software and system settings, content design, and cognitive and physiological effects. Simultaneous factors exacerbate SVIs.
3. SVI frustration has a statistically significant positive correlation with task importance.
4. Many strategies are employed to overcome SVIs, with evidence of combining strategies for more severe SVIs. However, even combined strategies do not always eliminate SVIs.
5. In both studies, SVIs were frequently experienced.

I found that '*not all SVIs are created equal*', echoing previous research [Saulynas et al., 2017]. In general, situational impairments are very complex due to the number of variables that can factor into experiencing the phenomenon. Finding solutions for SVIs is not a simple task and based on my data, different stakeholders need to work together towards mitigating SVIs.

We live in a world that is always connected, and disruptions when using mobile devices are usually unwelcome. Although some SVIs are no more than a mild inconvenience and are unlikely to cause any significant problems for mobile device users, we must recognise that people rely on being connected for many different reasons (e.g., as part of their job, to stay connected to distant family members). While mobile device users can cope with SVIs during less essential tasks, levels of SVI frustration increase for more important tasks. The wide range of SVIs that can occur makes it very challenging to eliminate all SVIs, especially when many factors are involved, and sometimes waiting is the safest solution. However, it is still possible to address some causes of SVIs. Below I outline several design implications and solutions, as well as a new mobile device SVI context model to more comprehensively understand SVI causes.

3.5.1 Implications for Design

The findings of both studies demonstrate that mobile device SVIs are a complex problem. It is evident that a single solution will not address SVIs because multiple factors can cause them and there can be many contributing factors at one time.

Accessory Interference: I found that human and device accessories can create problems for mobile interaction and there is potential for novel ways of designing accessories to minimise SVIs from occurring. For example, sunglasses were identified as a contributor to SVIs in bright environments – the tinted lenses make a mobile display appear darker, and if lenses are polarised then it can further darken the mobile screen. One solution could be 'digital sunglasses' that track the location of the mobile device and overlay a clear "window" that lines up with the device's screen while maintaining a darkened view for anything that is not the device's screen. Using this approach, a person will not need to remove their sunglasses. Workers in hazardous environments required to wear dark or coloured goggles would also benefit from a digital solution.

People protect their devices in cases and use screen covers for peace of mind, yet these could alter user interactions and increase the reflectivity of the display. P81 (Study

1) identified that her screen protector was making the SVI worse; however, she did not mention removing the screen protector as part of her solution. One possibility would be for people to start using matte screen protectors to help reduce reflection SVIs. However, the addition of anti-glare layers on mobile devices for use in bright environments introduces new issues with regards to image quality [Nuijs and Horikx, 1994] and user experience [Becker and Neumeier, 2011].

Problematic Hardware Design: It is essential to carefully consider the design of mobile device hardware in order to minimise the occurrence of SVIs. Reflections and glare were frequent problems experienced by my participants. Manufacturers could introduce the option of having a matte display to reduce reflections and glare, but this could introduce some image degradation [Becker and Neumeier, 2011; Nuijs and Horikx, 1994]. Increasing maximum screen brightness is also an impractical solution because it takes time and effort, it is likely to increase the cost of mobile devices, it needs to be balanced against battery life, and forces all other stakeholders (e.g., end users, designers, developers) to wait for the situation to improve. An alternative approach would be moving the mobile industry towards using transflective displays [Bae et al., 2011], which retain good readability in both bright and dark environments. This may become more popular with displays that switch between transmissive and reflective [Ge et al., 2009].

Battery life can contribute to SVIs. Previous work sought to understand how mobile phone users interact with their device to address the limitation of battery life [Rahmati et al., 2007]. The research is over 10 years old, and the participants of that study demonstrated a lack of knowledge regarding how the battery is used up. My findings suggest people now have a better understanding of battery consumption and how to ensure the device consumes less power. I found examples of participants reducing screen brightness to conserve power. Outwith the user's control, mobile devices employ 'power saving mode' that reduces screen brightness automatically. Fast charging solutions are no help when a power source is unavailable (e.g., when outside). One design consideration to explore would be to allow important parts of the display to remain brighter (e.g., the mobile status bar for notifications), even during power saving mode, although this would be better with OLED displays where each pixel has independent brightness [Geffroy et al., 2006].

Operating System and Software Inadequacy: Automated settings are intended to save the user from having to make changes to system settings manually. However, my participants identified how these could contribute to SVIs.

Auto-brightness could be slow to adjust the screen brightness, or it would settle on a brightness level that was not satisfactory. Previous work has identified issues with the accuracy of adaptive brightness models and has developed new approaches to calculating the appropriate brightness level [Ma et al., 2012; Schuchhardt et al., 2015]. Sometimes auto-brightness is turned off, and the user is forced to attempt to increase the screen brightness manually. One solution to explore would be providing auto-brightness permission to turn itself on when reaching certain thresholds. Alternatively, similar to Trewin's automating accessibility work [Trewin, 2004], if the display brightness is low, then a user's mistyping or inaccurate target selection could be used to inform the system that more light might be required so the user can see what they are doing.

Finally, the Operating System (OS) could help address SVIs caused by power saving mode. One solution would be to allow customisation of what this setting can control, e.g., the user gives power saving mode permission to restrict CPU power but not permission to limit the screen brightness.

On the other hand, one could make use of OS and software level features to help reduce SVIs. For example, built-in AI assistants could warn users about how current usage may affect future mobile interaction. Both of my studies highlight the complexity of SVIs with regards to time, and there is an opportunity to manage this smartly. It became apparent from my participants' reports that the sequence of previous events can lead up to an SVI occurring. For example, your battery runs low while you are inside playing a game under low ambient lighting. Later, you step outside with auto-brightness turned off and it is difficult to see content on the display. You can increase the brightness from memory, but the phone has entered power saving mode, thus capping the maximum brightness). AI assistants can more efficiently manage mobile devices and offer the user with suggestions to mitigate the occurrence of SVIs due to current mobile interaction.

Problematic Interface and Content Design: Creating solutions for improving mobile content design is perhaps the most practical first step towards addressing SVIs because designers have control over the look and functionality of their content. Research has demonstrated that data highlighting interaction issues can be used to inform the exploration of novel interface designs that would overcome previous limitations [Eardley et al., 2018a].

Some SVIs occur in such a way that a person no longer has control (e.g., when caused by content design). In Study 2, when I asked why SVIs are frustrating, three participants discussed content design; AF2 said her frustration with design was a factor because she could not control the design, SM6 had a lower opinion of organisations whose designs factored into experiencing an SVI, and SF4 recommended website designers should consider and plan for SVIs.

One challenge of SVIs is predicting when high-contrast for bright environments and low-contrast for dark environments is required. There is research that has investigated ways to automatically recolour the display for enhanced viewing in bright and dark environments [Yu et al., 2015]. Automatic recolouring is convenient but can add to battery depletion due to increased sensor monitoring, while simultaneously altering the designer's artistic intent. It is worth pursuing how to provide users with active control in content recolouring and supporting designers in being able to add this functionality into mobile app interfaces. One solution may be to support designers in creating alternative colour modes for apps and websites that can be accessed by the user. Another benefit of this approach is that the designer retains control of how their content will look, rather than make the process completely automatic.

3.5.2 Mobile device SVI Context Model

Sears et al. [2003] and Vatavu [2017] previously introduced diagrammatic representations considering situational impairments; however, the first model did not focus on mobile devices and the second extended beyond SVIs to look at all factors affecting visual perception. To address these limitations, I introduce a new mobile device SVI Context Model (Figure 3.4) influenced by the findings present in this chapter.

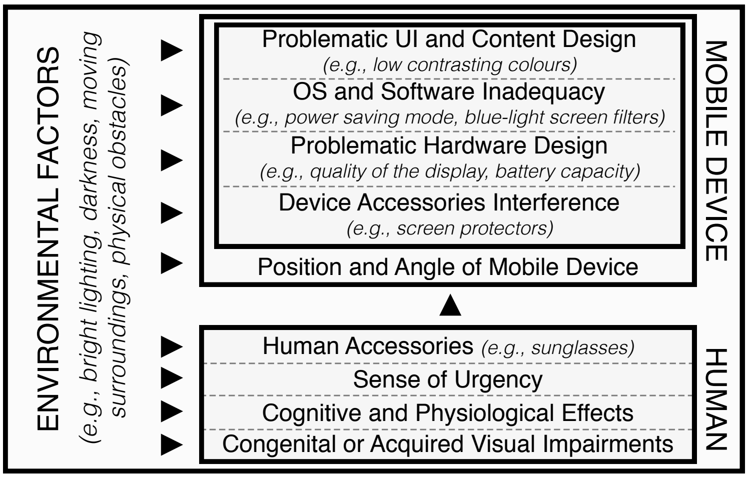


Figure 3.4: My mobile device SVI Context Model considering the layers between the user and the content, all under environmental factors. It concisely provides different stakeholders (e.g., HCI researchers, engineers, manufacturers, designers) with an overview of the complex nature of SVIs.

The ever-changing environment has a continual influence on user interaction, yet previous models do not explicitly show the omnipresence of the environment. To address this, I situate the human and mobile device within the environment and use arrows to emphasise the environment's influence at each level (Figure 3.4). For example, bright sunlight could prompt a person to wear sunglasses, and it could increase the number of reflections on the screen and/or screen protector, it could be brighter than the light emitted from the display and therefore reduce how perceivable content is (particularly content with poorly chosen colours).

My model, agreeing with previous models, recognises that humans have their physical, perceptual, and cognitive limits when interacting with devices. However, I also emphasise the user perception of urgency in completing the task, which can be affected by environmental factors (e.g., calling for help in an emergency). The value of reducing the effects of SVIs increases when the task becomes more critical. Furthermore, the user may wear accessories to counter environmental conditions or for improving activity performance (e.g., tinted goggles when snowboarding), and these can introduce or increase SVIs that may not otherwise have occurred. Therefore, SVI solutions must consider human-worn accessories.

My model is unique in emphasising SVIs imposed by human and device accessories. I replace Sears et al.'s Applications dimension with a four-level representation of the mobile device, indicating each level that could introduce or increase SVIs. I have included the position of the device because this was another important factor. In some cases, the participants could reorient themselves or the device to change how the light fell on the screen; however, this is not always possible if the device is in a fixed position (e.g., placed in an armband or on a car dashboard hands-free mount). First, I highlight the "device accessories" level because people will personalise their devices [Meschtscherjakov et al., 2014], yet my findings suggest protective cases and screen covers can alter user interactions and increase the reflectivity of the display. The next level is "hardware", which involves the physical device and its components, e.g., the maximum brightness of a low-cost tablet could be insufficient, thus having an adverse effect on the user when viewing the screen in direct sunlight. Next the "OS and Software" can introduce or increase SVIs through automated mechanisms (e.g., turning on power saving mode or the blue-light filter). The final level is the "content" being consumed. The on-screen content can introduce or increase SVIs if it is poorly designed (e.g., low-contrast between the text and background).

My model visually represents the findings of my two studies to provide different stakeholders (e.g., HCI researchers, engineers, manufacturers, designers) with a concise overview of the complex nature of SVIs. My model highlights the factors involved, which is especially useful for people who are studying mobile interaction and for people who are unfamiliar with SVIs.

3.6 Conclusion

The problem presented in this thesis is *Situational visual impairments (SVIs) cause usability and accessibility problems for mobile device users, which suggests that current mobile industry practices are insufficient for supporting designers when addressing SVIs.*

In Chapter 2, I identified that no comprehensive study has been conducted with the primary goal of identifying the specific causes of SVIs, how people deal with SVIs (or not), and what people's feelings are towards SVIs. To address this gap, I have presented the methodology and findings of a large online survey and a two-week EMA study that investigated the specific causes of SVIs, how people deal with SVIs (or not), and what people's feelings are towards SVIs. Implications for design are discussed, such as the challenges of addressing problematic hardware design, and as an outcome of the studies conducted, I introduced a mobile device SVI Context Model. The SVI Context Model can be used to help inform better solutions to address SVIs because it conceptualises the complexity of the many factors contributing to the problem and therefore solutions can be designed with a consideration of addressing as many factors as possible.

My findings indicate that creating solutions for improving mobile content design is perhaps the most practical first step towards addressing SVIs. Designers have control over the look and functionality of their content, yet users are frustrated when design causes SVIs and when they are not able to make adjustments to the design to correct the problem. By supporting designers to create content that is less susceptible to SVIs, users can be empowered to complete tasks in a variety of different contexts. In Chapter 4, I will describe two studies conducted to understand what designers are currently doing to address SVIs.

Chapter 4

Identifying Designers' Needs for Addressing Situational Visual Impairments

4.1 Introduction

In Chapter 3, I found several factors that contribute to SVIs, which I grouped into six themes: "External Influences", "Accessory Interference", "Problematic Hardware Design", "Operating System and Software Inadequacy", "Problematic Interface and Content Design", and "Cognitive and Physiological Effects". I focus on addressing SVIs through improving content design for mobile devices because it is a practical first step where I can have the most influence. Many of the hardware limitations of mobile devices (e.g., glossy screens and lower capacity batteries) require manufacturers to make changes to the design of mobile devices, and in many cases, these devices have an already defined production timeline. Researchers have known for years about the issues surrounding display hardware [Gong et al., 2012; Liu et al., 2014; Kim et al., 2007, 2008], yet manufactures likely use glossy displays in consumer products for their richer colours and contrast [Hoffman, 2014], and so these will probably continue to be used.

Furthermore, my investigation within this research area has identified a gap. Much of the related work discussed in Chapter 2 does not recommend ways of improving mobile content design to address situational impairments, and there are currently no solutions to support mobile content designers in addressing SVIs. It was also evident from chapter 3 that users are frustrated when design causes SVIs or when users are unable to make adjustments to the design to correct the problem.

This chapter presents two studies (Study 3 and Study 4) to help understand what designers currently do regarding SVIs, what resources they know of, and what resources are required to support them to best design for SVIs. During Study 3, I surveyed 43 mobile content designers using an online questionnaire to understand current design processes for accessibility and SVIs. During Study 4, I recruited four participants who completed my Study 3 survey to take part in a follow-on semi-structured interview to allow me to: 1) further understand typical design processes, 2) engage in a more in-depth discussion regarding accessibility and SVIs, and 3) to identify effective support for designing to reduce SVIs.

4.2 Study 3: Online Survey

I used an online survey to understand how many mobile content designers consider SVIs and how this compared to accessibility. I was also interested in identifying what support mobile content designers want to help them address SVIs. Distributing the survey online was a quick method of collect data from a large number of participants worldwide, who could complete the survey at their convenience.

4.2.1 Procedure

I distributed my questionnaire (described in section 4.2.2) among Scottish universities and design companies, and for a wider audience used social media (Facebook and Twitter), and Reddit's r/samplesize, r/designthought, and r/UI_Design. I asked for designers who have released mobile content publicly or commercially to take part in the survey. The questionnaire was live from August to December 2016.

As per my department's REB approval, the participants first read through an information page and consented to take part. The questionnaire was expected to take five to ten minutes to complete depending on the responses given. After submitting, the participants were debriefed and could enter into a prize draw for one of four $50 USD (or equivalent) Amazon vouchers.

4.2.2 Materials

My questionnaire (Appendix C.15) comprised 22 close-ended and 16 open-ended questions.

The first section of my questionnaire was for demographic information. Q1, Q2 and Q3 gathered data on the participant's age, gender, and the country in which the participant lived. I asked the participants about their design training (Q4), design career (Q5), the mobile content they design (Q6), and how many years the participants had been designing mobile content that was publicly or commercially released.

The second section of my questionnaire focused on accessibility. I used a definition that said "*products, devices, or services designed for accessibility can be used by people with a disability or impairment*" based on a previous definition [Henry et al., 2014]. I asked the participants if they include accessibility when designing (Q8), and the participants would be asked particular questions depending on the response to Q8. If the participants always include accessibility they were asked to describe the reason(s) for doing this when designing mobile content (Q9). If the participants sometimes include accessibility, I asked the participants to indicate what percentage of projects they included accessibility (Q10), to describe the reason(s) why they do (Q11) and do not (Q12) include accessibility when designing mobile content. For the participants that always and sometimes include accessibility, I also asked what the earliest point in the design process they typically included accessibility was (Q13), in what proportion of projects do they use accessibility guidelines (Q14), to list any accessibility guidelines they use (Q15), in what proportion of projects do they use accessibility design tools (Q16), to list any accessibility design tools they use (Q17), in what proportion of projects do they run evaluations with people who have a disability or impairment (Q18), and finally I asked the participants to describe how they evaluate the design with people who have a disability or impairment (Q19). For the participants who indicated in Q8 that they do not include accessibility when designing, I asked the participants to explain why they do not include accessibility (Q20), and I asked if the participants were aware of either accessibility guidelines, accessibility design tools, and evaluation techniques (Q21).

The third section of my questionnaire focused on situational impairments. I introduced what situational impairments were and provided examples: standing in a noisy crowd while trying to have a phone conversation (situational hearing impairment); carrying shopping bags and trying to compose an SMS on your mobile phone (situational mobility impairment); or wearing glasses with tinted or coloured lenses and trying to accurately determine the colours on a screen (situational visual impairment). I asked the participants how often they design to reduce situational impairments such as providing an alternative input method or providing an alternative output for content so that it can be used by people experiencing a situational impairment (Q22) and in particular if the participants' design to reduce situational visual impairments (Q23).

If the participants always design mobile content to reduce situational visual impairments (SVIs), I asked for the reason(s) for doing this (Q24). If the participants sometimes design to reduce SVIs, I asked the participants to indicate what percentage of projects they design to reduce SVIs (Q25), to describe the reason(s) why they do (Q26) and do not (Q27) include design mobile content that reduces SVIs. For the participants that always and sometimes design to reduce SVIs, I also asked them to list the SVIs they design for (Q28), what the earliest point in the design process they typically design to reduce SVIs was (Q29), in what proportion of projects do they use SVI guidelines (Q30), to list any SVI guidelines they use (Q31), in what proportion of projects do they use SVI design tools (Q32), to list any SVI design tools they use (Q33), in what proportion of projects do they run evaluations with people experiencing SVIs (Q34), to describe how they evaluate the design with people experiencing SVIs (Q35), and finally I asked the participants if they distinguish between visual impairments and SVIs. For the participants who indicated in Q24 that they do not design to reduce SVIs, I asked the participants to explain why they do not (Q37). The final question I asked all participants was what support would best help them design to reduce SVIs (Q38).

4.2.3 Participants

Forty-four participants completed my questionnaire. One participant was removed from the analysis because he did not design any mobile content. The remaining 32 male and 11 female participants were aged 18 to 52 (Mean = 27.15, SD = 7.18; three participants did not respond) and were allocated a participant number (e.g., P1). Twenty-two participants (51.16%) were living in the UK, with 48.84% living outside the UK (11 in the US, three in Canada, two in India, and one each in Senegal, The Netherlands, Turkey, The Philippines, and Australia).

The participants indicated that they had varied design training backgrounds (multiple responses were allowed): 'Undergraduate level university' (23 participants), 'No formal training' (10), 'College' (8), 'Apprenticeship' (8), 'Postgraduate level university' (8), and 'Other' (2: P11 wrote "*personal projects*", P21 wrote "*general assembly (the education startup)*").

I asked my participants what best described their design career: Twenty-four participants said 'Working for a company', followed by 'Self-employed' (8), 'Hobby' (8), 'Other' (3 – "*Design researcher and practising Architect*" (P1), "*Designed as part of coursework*" (P8), "*Company owner*" (P13)). The participants created a range of mobile content (see Table 4.1) and 28 participants designed more than one type of content.

Type of Mobile Content	**No. Participants**
Mobile friendly websites	32
Mobile apps	26
Advertising	12
Games	7
Books	5
Other (including "*data UI/UX*" (P2), "*brand identity*" (P32), "*branding, video graphics, magazines*" (P41), and "*Logo & Branding*" (P43))	4

Table 4.1: Summary of the different types of mobile content created by the participants.

I asked the participants how many years they had publicly or commercially released mobile content and found 42 participants had up to 15 years of experience (M = 3.71, SD = 3.64, Median = 2)[1]. The responses indicate that the participant sample is predominately made up of designers early in their design careers, but also reflects the relatively

[1]Two participants are likely in their 1st year of releasing content.

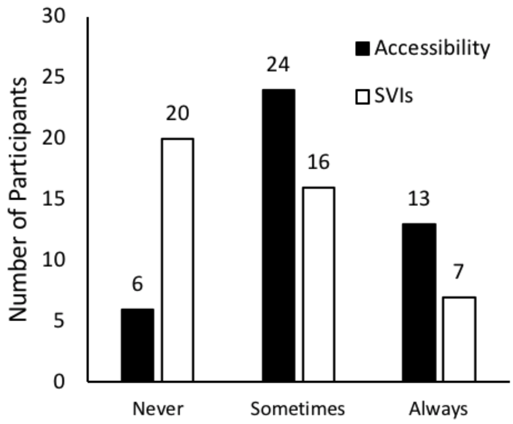


Figure 4.1: Summary of how many participants include accessibility and design to reduce SVIs.

recent growth in mobile content design (e.g., mobile interfaces, mobile-friendly websites) vs traditional desktop applications.

4.2.4 Results

I have adjusted the quotes when appropriate to improve readability and clarity (e.g., adding punctuation, capital letters). I used an open coding approach [Tracy, 2013] with an initial round of first-level coding followed by second-level coding to identify descriptive categories that I then use to summarise the data.

Accessibility

As described in section 4.2.2 (Materials), I first asked questions about accessibility as a way to naturally lead into the questions on SVIs, but to also check that the participant sample is representative of other designers previously reported in the literature that consider accessibility [Tigwell et al., 2017].

I asked the participants if they include accessibility within their design process. The

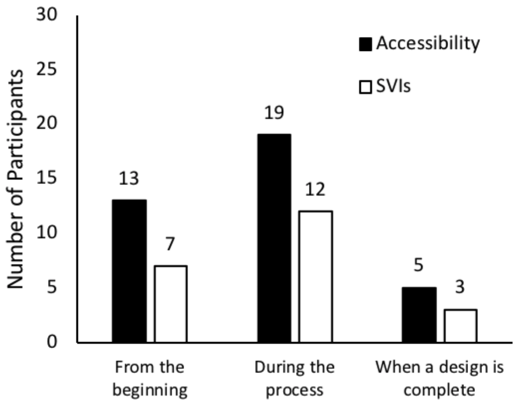


Figure 4.2: A summery of when accessibility and SVIs are part of the design process.

responses were: 'Always' (13), 'Sometimes' (24), and 'Never' (6), as shown in Figure 4.1.

Overall, the proportion of participants who include accessibility in any or all of their designs (~86%) is somewhat higher than in previous research (75%) [Tigwell et al., 2017], which investigated the extent that Web designers and developers include accessibility. The increase might represent some positive shift over time since this current survey is more recent; however, my study is focused on different designers (mobile content designers) and used different recruitment mechanisms.

The participants who 'Always' and 'Sometimes' include accessibility typically do this 'From the beginning' (13 participants) and 'During the process' (19), while a minority incorporated accessibility 'When a design is complete' (5), as shown in Figure 4.2. For the 24 participants who indicated 'Sometimes', two-thirds include accessibility in 40% or fewer projects (see Figure 4.3). I found that 27 participants used guidelines (e.g., WCAG), 19 participants used accessibility-focused design tools (e.g., WAVE[2]), and 14 participants carried out accessibility user evaluations. Among the types of user evaluations reported, there was evidence of evaluating by the designers themselves (e.g., P18: "*Best guess. I do not have people come in to test it*"), recruiting people (e.g., P21: "*User testing with users who are sight-impaired for TTS*"), and evaluating with design tools (e.g.,

[2]https://wave.webaim.org

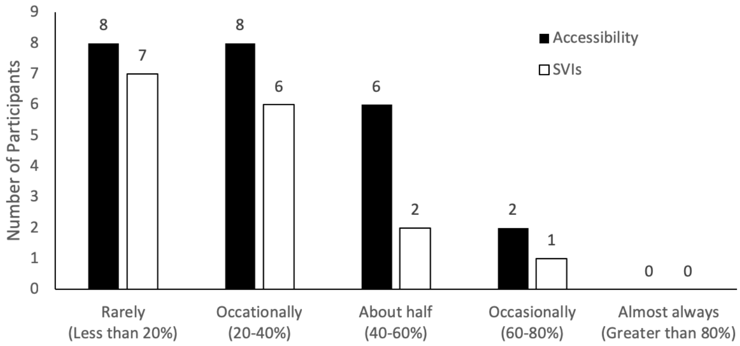


Figure 4.3: A summary of the frequency of projects where participants sometimes include accessibility and sometimes design to reduce SVIs.

P30: "*With the use of sites like colorhexa.com*"). Figure 4.4 shows a breakdown of the proportion of projects the participants use guidelines, design tools, and evaluations for ensuring accessibility. The six participants who never include accessibility were aware of at least one of the following: accessibility guidelines (four participants), accessibility design tools (2), and accessibility evaluation techniques (4).

I was also interested in why designers do or do not include accessibility to identify any overlaps between accessibility and SVIs.

The reasons given **for** including accessibility are combined responses from participants who 'Always' or 'Sometimes' include accessibility. These reasons were: there is a moral obligation (16 participants; e.g., P23 commented "*it's the right thing to do. Content shouldn't be hidden behind an artificial requirement of a certain browser, OS, technology, etc. for the developer's convenience*"), accessibility was a requirement of the project (10 participants; e.g., P41 commented the "*app is targeted at a group who require accessibility options*"), accessibility improves the usability and UX (6 participants; e.g., P35 commented "*to make the product as useful as possible for as many people as possible*"), there is a recognised value in accessibility (3 participants; e.g., P37 commented that it is a "*significant audience*" that need accessible content), accessibility is included due to a legal obligation (2 participants; e.g., P8 commented "*avoid discrimination*"), accessibility is included because

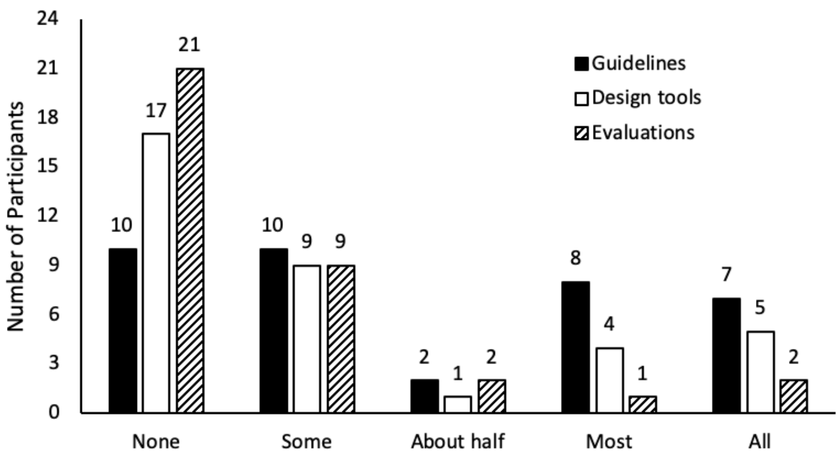


Figure 4.4: A summary of how many participants use guidelines, design tools, and evaluations to ensure accessibility.

time was available (2 participants; e.g., P18 commented "*sometimes we have the time to think about accessibility*"), including accessibility does not require much effort (2 participants; e.g., P13 commented "*often basic accessibility features can be added with little overhead to a project so these are included regardless of client brief*"), and pushing for accessibility will change perceptions (1 participant; P21 commented "*the more we push for it, hopefully there will become a budget for it*").

The reasons given **for not** including accessibility are combined responses from participants who 'Sometimes' or 'Never' include accessibility. These reasons were: limited resources (e.g., time, money) (14 participants; e.g., P9 commented "*there's not always time or budget to add in the extra functionality*"), accessibility was not within the scope of the project (10 participants; e.g., P42 commented accessibility was"*not prioritized by the client*"), accessibility restricts design (2 participants; e.g., P15 commented "*often picking colors is limited*"), achieving 100% is challenging (2 participants; e.g., P14 commented "*in my mind 'including accessibility' is an all-or-nothing process. Especially in a large product, it doesn't help a user if 90% of their flow works, if they can't complete an exit. In this sense, I would say that whilst I do my best to add certain accessibility friendly features to every piece of work I product, I don't do enough to create an end-to-end experience*"), there is disinterest in accessibility (1 participant; P24 commented "*the research for it is extensive and boring*" although he would like to change that because of the "*value in it*"), accessibility can be unpopular with management (1 participant; P17 commented "*it is not usually considered a priority due to the [percentage] of people it would affect*"), and finally personal preference in not including accessibility (1 participant; P20 commented it was his "*preference*").

Situational Impairments

I provided the participants with the definition "*situational impairments are usually caused by environment conditions that negatively affect a person's ability to complete a task when they would otherwise not have a problem*" so that the participants had a consistent understanding. I provided the participants with three examples: 1) standing in a noisy crowd on the phone (situational hearing impairment), 2) carrying shopping bags and trying to compose an SMS (situational mobility impairment), and 3) wearing glasses with coloured lenses, while trying to identify colours on a screen (situational visual impairment). I only provided a few examples to help reduce biasing participants.

I recognise that the above definition of SVIs differs slightly from the definition I provide in the introduction (see Section 1). The primary reason is that I was considering the non-academic audience I was surveying. People immediately consider environmental factors causing situational impairments more so than other factors, as highlighted by the shift in thinking of the problem in the academic literature from ordinary people in extra-ordinary environments [Newell, 1995] to considering a wider context [Sears et al., 2003]. I did not want to overcomplicate the questionnaire by discussing the intricacies of factors involved when a person is situationally impaired. Furthermore, I provided the participants with several examples, and for the SVI example, I mentioned coloured lenses rather than environmental lighting.

I asked the participants if they ever design to reduce the occurrence of situational

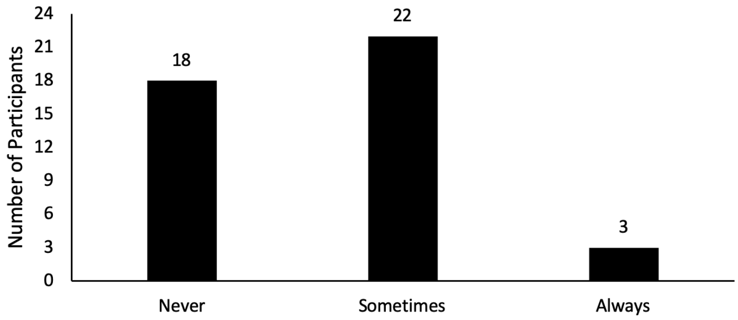


Figure 4.5: Summary of how many participants design to reduce situational impairments.

impairments before focusing on a specific type of situational impairment – SVIs. All forty-three participants responded to this question. Three participants indicated "Always", 22 participants indicated "Sometimes", and 18 participants indicated "Never" (see Figure 4.5). The remainder of the questionnaire then focused on SVIs. I had previously given the participants an example of SVIs and how it differed from other situational impairments.

Situational Visual Impairment

I first asked the participants if they design to reduce SVIs. All forty-three participants responded to this question with 'Always' (7), 'Sometimes' (16), and 'Never' (20). There is a noticeable change (see Figure 4.1) in distribution compared to the counterpart accessibility question – the majority of the participants do not consider SVIs. A McNemar-Bowker test indicates a significant difference ($p = .007$) between the distributions. Bonferroni corrected post-hoc tests identified a significant difference between 'Never' and 'Sometimes' ($p = .024$). Twenty-two participants reported the earliest point at which they design for SVIs: 'From the beginning' (7 participants), 'During the process' (12), and 'When a design is complete' (3). This distribution is similar to the counterpart accessibility question (see Figure 4.2). Most participants consider accessibility and SVI 'during the process', suggesting a fluid design approach rather than focusing on all details from the outset.

For the 16 participants who sometimes design to reduce SVIs, I also asked how often this occurs in their design projects. Responses were: 'Rarely (Less than 20%)' (7 participants), 'Occasionally (20-40%)' (6), 'About half (40-60%)' (2), and 'Often (60-80%)' (1). A similar decreasing trend (see Figure 4.3) was also present in the counterpart accessibility question.

I asked the participants what types of SVIs they try to reduce through design. Sixteen participants responded, but only six participants listed genuine causes for SVIs such as reading at night, unusual interior/exterior lighting, bright situations, wearing tinted glasses, being far from a screen, being in a moving vehicle. The remaining 10 participants listed typical accessibility challenges (e.g., P43: "color blind and poor vision"), or responses that did not provide enough clarification (e.g., P19: "visual, audio"). Some designers appear not to understand SVIs very well.

Twenty-two participants reported what proportion of projects used SVI guidelines: 'None' (7 participants), 'Some' (7), 'About half' (3), 'Most' (2), and 'All' (3) (see Figure 4.6). Out of seven responses to the follow-on question there were no mentions of guidelines that highlight the issue of SVIs (such as "Shared Web Experiences" [Yesilada et al., 2013] and Mobile Accessibility [Patch et al., 2015]) – P19 said "*can't find any*", while P4 and P41 mentioned colour vision deficiency (CVD), thus providing further evidence that designers misunderstand SVIs. P29 responded "*clear and large fonts*", which is likely to be easier to see when in a bright environment, however, it is not clear from what guideline this idea originates or if the designer has determined this approach on their own.

Twenty participants reported what proportion of projects used SVI design tools: 'None' (9 participants), 'Some' (3), 'About half' (3), 'Most' (1), and 'All' (4) (see Figure 4.6). Out of the five responses listing tools, there were three mentions of tools for CVD. Either

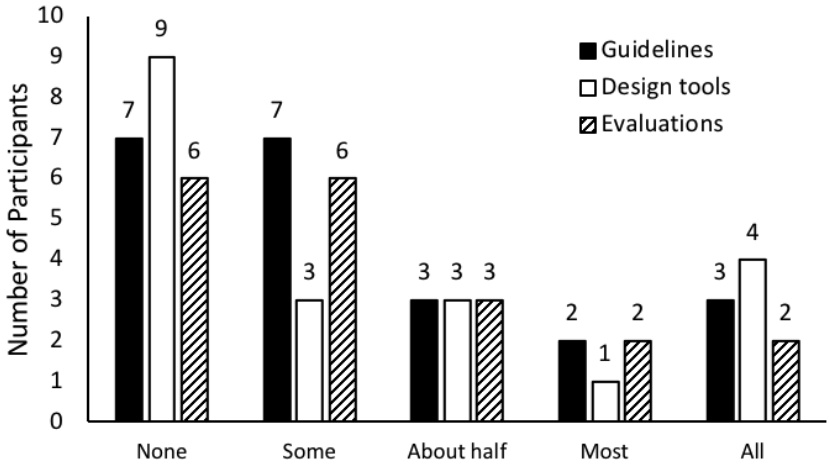


Figure 4.6: A summary of how many participants use guidelines, design tools, and evaluations to reduce SVIs from occurring.

this is a misunderstanding, or they are using CVD tools because no alternatives exist. One comment was "*N/A*" (P40), and the other was "*Color contrast buttons*" (P6), which likely refers to existing Web content accessibility guidelines.

Nineteen participants reported what proportion of projects ran evaluations with people experiencing SVIs. 'None' (6 participants), 'Some' (6), 'About half' (3), 'Most' (2), and 'All' (2) (see Figure 4.6). Out of 12 follow-on requests to list evaluation techniques, there was a range of approaches. I found four mentions of self-testing, four mentions of in-house testing, two mentions of external testing, one mention of simulating the environment, and three other mentions related to: 'user testing environments', 'usability test', and 'direct observation'.

What reasons were given ***for*** *designing to reduce situational visual impairments?* I combined responses from the participants who said they 'Always' or 'Sometimes' design to reduce SVIs. The reasons given were: benefits everybody (8 participants; e.g., P35 commented "*it benefits everyone to have a good type size, good tap targets and well thought out interfaces for various situations and input methods*"), for improved accessibility (3 participants; e.g., P33 commented "*because it is an extension of designing accessibly*"), project requirement

(2 participants; e.g., P42 commented "*it depends on whether it has been identified as a risk factor/priority with the client*"), sufficient budget and time (2 participants; e.g., P32 commented "*budget and time*"), for completeness (1 participant; P37 commented "*for completeness*"), and moral obligation (1 participant; P19 commented "*because as a designer, you should be*"). I found that there are some similarities and differences between designing to reduce SVIs and including accessibility. Moral obligation, a requirement of the project, and having time were present in both. Having a sufficient budget was mentioned as a reason for designing to reduce SVIs, but the participants did not mention a sufficient budget as a reason for including accessibility, although the participants mention insufficient budget as a reason for not including accessibility. There was no mention of a legal obligation, but, this is unsurprising since I am unaware of any "situational impairment" laws. Discussion of designing to reduce SVIs benefiting everybody, for completeness, and improving accessibility are similar to the 'improving usability and UX' reasons given for why designers include accessibility. Interestingly, while one participant said that pushing for accessibility will change perception, this did not occur for SVIs and is likely due to situational impairments not being widely discussed or understood. The fact that almost everyone is affected by SVIs at some point could be used to change perceptions in a positive way.

What reasons were given ***for not*** *designing to reduce situational visual impairments?* I combined responses from the participants who said they 'Sometimes' or 'Never' design to reduce SVIs: it is not in the design scope or their current practice (13 participants; e.g., P19 commented "*clients not paying for the extra design and test time required*"), limited resources (e.g., time, tools, money) (13 participants; e.g., P27 commented "*time and limited tools*"), the participants are unaware of or had not considered SVIs (5 participants; e.g., P28 commented "*never considered it before*"), and the participants viewed SVIs as a minor issue (4 participants; e.g., P20 commented there was "*not a demand as yet*"). Again, there are some similarities and differences between not designing to reduce SVIs and not including accessibility. Not within the project scope and limited resources were present in both. However, the responses for not designing to reduce SVIs also point towards it not being a part of current practice, which means support for process change needs to be considered when looking to support designers designing for SVIs. Differences in responses further highlight the uncertainty about SVIs and situational impairments in general. SVIs being viewed as a minor issue echo some of the opinions presented about accessibility (P17: "*It is not usually considered a priority due to the [percentage] of people it would affect*"), however, this is not the case with accessibility when considered on a global scale, and with the increase in mobile device use, SVIs are increasingly prevalent. Several participants stated they were unaware of or had not previously considered SVIs, highlighting the need to investigate whether education discusses SVIs. The remaining responses for not including accessibility could all equally apply to SVIs: challenges (e.g., it restricts design), disinterest in accessibility, and the personal preference of not including accessibility. I asked the participants if they distinguish between a visual impairment and a situational visual impairment and seven participants indicated '*Yes*', five indicated '*No*', and P19 responded "*yes and no*", thus further underlining the perceived similarities and differences between accessibility and SVIs.

Finally, I wanted to know what would best help designers create content less susceptible to SVIs. All the participants responded and were allowed to indicate more than one response. In order of most requested: 30 participants wanted 'Guidelines', followed by 'Education' (25), 'Digital design tools' (20), 'Support service' (13), 'Physical design tools' (9), and P42 said: "*Understanding the context of use. That is always the biggest hurdle. After that, design becomes a lot easier*."

4.2.5 Summary

My findings from Study 3 illustrate similarities and differences between accessibility and SVIs. SVI design has not progressed as much as accessibility design: designing to reduce SVIs is often not in the design scope or part of the designer's current practice, there are limited resources available (e.g., time, money, tools) to design for SVIs, some designers are unaware of or have not considered SVIs before, and in many cases designers view SVIs as a minor issue. However, accessibility and SVI design were both perceived to be of benefit for a broader set of users than the target audience, and the participants recognised that designing for one often resulted in at least partial inclusion of the other. These findings are integral for providing insights into current mobile design practices, and the type of support mobile designers want. After Study 3, I next conducted follow-on semi-structured interviews to: 1) further understand typical design processes, 2) have a more in-depth discussion regarding accessibility and SVIs, and 3) identify how to effectively integrate SVI support into design processes so that mobile designers can reduce SVIs.

4.3 Study 4: Interviews

While the use of an online survey in Study 3 was beneficial in identifying how many mobile content designers are considering SVIs, some insights (e.g., the design process followed by the participants) are missed because of the structured design of surveys [Tracy, 2013]. Interviews are a valuable qualitative research methodology that facilitate the collection of data in a way which allows the interviewer to react to the interviewees' responses, and adapt the conversation so as to fully answer the research questions of interest Tracy [2013]. Therefore, follow-on semi-structured interviews were conducted with four participants from Study 3 who agreed to take part and this allowed me to: 1) further understand typical design processes, 2) have a more in-depth discussion regarding accessibility and SVIs, and 3) identify how to effectively integrate SVI support into design processes so that mobile designers can reduce SVIs.

4.3.1 Materials and Procedure

I decided on semi-structured interviews as the appropriate method for Study 4 to allow for some flexibility when talking with the participants. To ensure the interviews followed a similar structure, I wrote up an interview guide (Appendix C.16) and used it as an aid during the sessions.

There were five main parts to the semi-structured interviews to ensure that I covered topics that would allow me to understand the design process and how it differed between designers, to better understand designers thoughts on accessibility and SVIs, and to understand how to offer effective SVI support.

I first began the semi-structured interviews with simple demographic questions to find out the participants' age, gender, and how long they had been designing mobile content that had publicly or commercially been released. Beginning with simple and easy to answer questions was important so I could build up a rapport with the participants.

Next, I was interested in understanding the participants' design history and their current career. In particular, I wanted to know what their design training involved (e.g., if they had attained a degree) and what design process they typically followed.

For the third section of the interview, I was interested in further understanding more specific design practices the participants may be aware of and use. This discussion included an assessment of their awareness of accessibility, whether it did or did not feature during their training, what they thought of accessibility, and where their views fit within the wider design communities attitudes towards accessibility.

Next, the semi-structured interview focused on situational visual impairments. I wanted to understand their personal experience of SVIs before discussing whether it was something they thought about addressing when designing. It was important that I also checked whether the participants had changed their perception of – and design approach towards – SVIs, and if they were aware of specific guidelines or tools to support designing to reduce SVIs.

For the final part of the semi-structured interview, I discussed the four themes identified from the results of my Study 3 survey. I used this opportunity to ask the participants to reflect on their design experiences related to these themes. For example, I asked the participants' if there was a time which they could recall working on a design and the design brief or client requirements were missing something. I was able to then identify their process for handling this situation and ask for their opinions on avoiding these issues when looking to improve designing for SVIs. Finally, I discussed with the participants their experience of, and opinions on, guidelines, education, and digital design tools.

Two out of the four interviews occurred over Skype, and the other two interviews were in person. All interviews were audio recorded for later transcription. The shortest interview was 38 minutes, and the longest interview was 1 hour (Mean = 50 minutes). The participants were reimbursed with a £10 GBP (or equivalent) Amazon voucher.

4.3.2 Participants

Twenty participants from the Study 3 questionnaire provided their contact details to be invited to a follow-on study. When contacted, only four participants consented to take part in an interview (Table 4.2 summarises their backgrounds).

Despite the small number of participants, this sample still gives reasonable spread and

ID	Age	Gender	Experience and Education
Jo (P3)	23	F	*Jo has been releasing mobile content for 1.5 years.* She has an Environmental Engineering undergraduate degree. She is currently undertaking a Masters degree and has taken part in workshops run by app developers and utilises self-study (e.g., using Coursera).
Max (P17)	28	M	*Max has been releasing mobile content for 2-3 years.* He has an Applied Computing undergraduate degree and is a games designer with no formal training – he describes it as a "*learn as I go*" job. The company creates their own games and perceives the customer as the client. Although there are not many new games being created, the company is focused on continually updating their existing games.
Ann (P19)	26	F	*Ann has been releasing mobile content for 2.5 years.* She has an Applied Computing undergraduate degree and an MSc in User Experience Design. She is employed as a mobile designer making native apps and hybrid apps (i.e., applications built with Web technologies to run on multiple platforms).
Ron (P30)	19	M	*Ron has been releasing mobile content for 3 years.* He had previously attended a design school and at the time of the interview had a few weeks left of his degree at a different school in the Netherlands. He was also working at a company as an intern designer.

Table 4.2: Participant demographics with descriptions of education, training, and work experiences. Each participant has been assigned a pseudonym.

diversity. All of the participants reported experiencing SVIs. However, when it comes to designing to reduce SVIs, Max does not usually consider SVIs, Jo sometimes considers SVIs (especially if time permits), while Ron is always considering SVIs, and Ann has worked on a project in which her team actually implemented an SVI feature. As participating in the survey (Study 3) may have changed the participants' views or design process regarding SVIs, I checked to see if this was the case to help ensure that the Study 4 participants were indeed representative. However, since taking part in the questionnaire, no participants reported changes in considering SVIs during their design process.

4.3.3 Phases of Thematic Analysis

I conducted a thematic analysis to fully understand, interpret, and report patterns identified within the detailed qualitative data. A thematic analysis is a popular qualitative analytic method that offers researchers flexibility when analysing and reporting qualitative data [Braun and Clarke, 2006].

In particular, I carefully followed the phases of thematic analysis as outlined by Braun and Clarke [2006], which provides clear guidelines on conducting and reporting a thematic analysis. This section reports the first five phases and the sixth phase entails producing a report of the analysis with the inclusion of data extracts that support the analysis and relate to the research questions. I present my report in the results section (see Section 4.3.4).

Phase 1: Getting familiar with my data

First, I listened to the audio recordings before transcribing anything. I then used the audio recordings to create transcripts for each interview. I anonymised any mention of names and locations within the transcripts. Finally, I read through each transcript while listening to the audio recordings to ensure accuracy.

Phase 2: Generating initial codes

I highlighted segments of text on printouts of the transcripts, and I made notes of initial ideas for possible codes. I then loaded the transcripts into RQDA[3], a qualitative

[3]http://rqda.r-forge.r-project.org

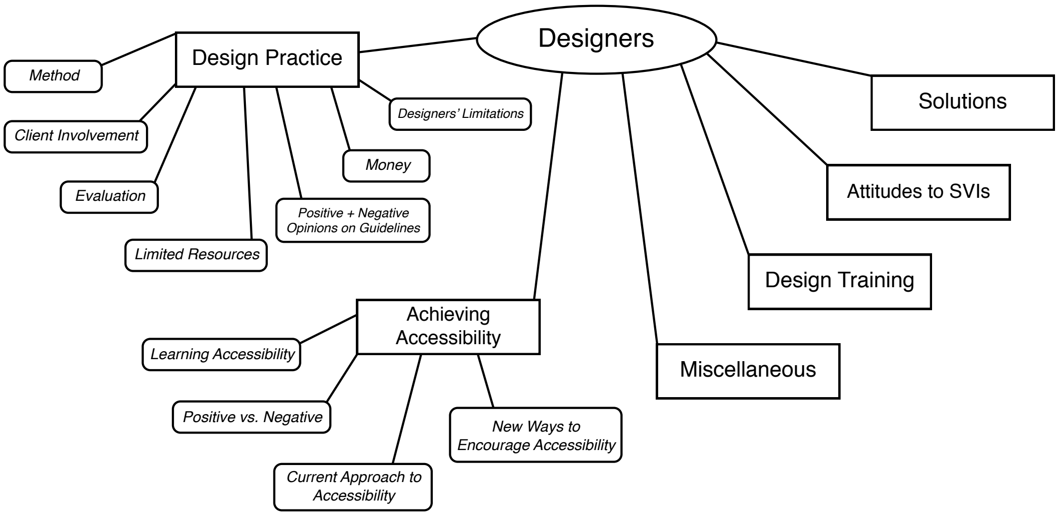


Figure 4.7: The initial thematic map showing the six themes and eleven sub-themes.

data analysis package for R. I used the initial highlights as a guide when coding the transcripts. I then reviewed and refined the codes.

Phase 3: Searching for themes

I gave each code a definition and, where necessary, an example of the content that would fall under this code. I used strips of paper containing the codes and the definitions to facilitate the process of searching for potential themes. I produced an initial thematic map after sorting each code into piles of possible themes (Figure 4.7).

Phase 4: Reviewing themes

I refined the thematic map to better reflect my aims for this study. I conducted a Level 1 analysis, where each code was discussed in relation to the thematic map by myself and another researcher familiar with the project, followed by a Level 2 analysis, which involved checking that the themes suit the entire data set. I achieved this by re-reading the transcribed interviews and making final modifications to the thematic

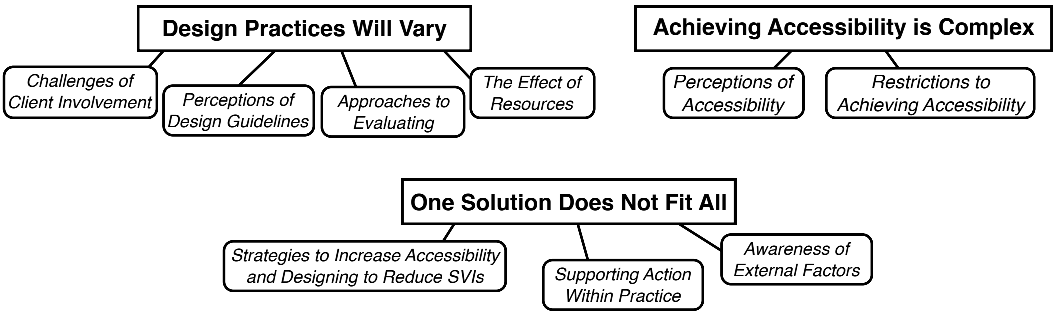


Figure 4.8: The thematic map with the final themes (*Design Practices Will Vary*, *Achieving Accessibility is Complex*, and *One Solution Does Not Fit All*).

map as necessary.

Phase 5: Defining and naming themes

The last part of the thematic analysis involved writing a description for the themes and sub-themes while assigning appropriate names that capture the essence of their associated coded extracts. To refine the specifics of each theme, I re-read the coded extracts to ensure I was telling a coherent story. I present the complete thematic map in Figure 4.8.

4.3.4 Results

Discussion on accessibility is prominent because SVIs are not something some of the participants often include when designing. I allowed the participants to reflect on accessibility to understand how to best support their practice. Although it is important to reiterate that SVIs can be an accessibility concern. I found three themes (with nine sub-themes): *Design Practices Will Vary*, *Achieving Accessibility is Complex*, and *One Solution Does Not Fit All*.

Design Practices Will Vary

The participants discussed their general design practices and, predictably, design does not have a one-size-fits-all approach; although there were some similarities, there were also substantial differences in the participants' approaches to designing. The reported design approaches can be adaptive, iterative, and unstructured. Some treat guidelines as suggestions rather than following them precisely. Being able to work quickly and efficiently is vital to all participants, who recognised that involving more people in a design process can be detrimental. It is also important to recognise that changing an individual designer's design process can take time. Within this main theme, there were four dominant sub-themes.

Challenges of Client Involvement I highlight several different challenges across participants with regards to dealing with clients throughout the design process. Client involvement can be a positive thing, and participants viewed it as important; however, it was evident that there are negative experiences too.

> Ron: "*I've spent hours [with] clients [who] have just pointed...'I want that to move one pixel to the right, I want it to move one pixel.' It was really one pixel!*"

> Ann: "*[laughs] you get some clients that are very very heavily involved and it's a good thing and you get some that are very very heavily involved and it's a bad thing.*"

In general, the challenges faced were often because the design brief was incorrect (e.g., not making requirements clear).

> Ron: "*That's most of the time I think [the design brief] is missing something.*"

Clients can also have a negative attitude towards accessibility, often not requesting the inclusion of accessibility.

Ann: "*A lot of clients think that [accessibility] takes longer for us to do and no one is going to use it.*"

Clients may have brand colours that are problematic from an accessibility point of view. When designers raise accessibility concerns, the client can become distrustful and overbearing, often needing convincing about why specific requests are not suitable for the product. However, when the client lacks knowledge about something they can learn through working with the designer. When designers want to design to reduce SVIs, clients may react similarly, but unlike when focusing on disability, designers can make a persuasive argument reasoning that *all* users can experience SVIs.

Perceptions of Design Guidelines The participants discussed various positive and negative opinions regarding design guidelines. In general, guidelines help designers as a starting point for good design. Recent design guidelines, such as Google's Material Design and Apple's iOS design guidelines are perceived as being well suited. There is also trust in guidelines because they are understood to be vetted by others over time:

Jo: "*I think that nowadays there are the guidelines when designing and you should follow them because [the guidelines are] something proven.*"

Guidelines associated with a well-known or large company (e.g., Apple) are used to discourage clients' poor or inaccessible design suggestions. Such guidelines are also appealing because they are often written using less technical language compared to other guidelines (e.g., WCAG). However, designers can sometimes view guidelines as a negative resource. Guidelines can contain far too much content that the designer does not want to read. At a minimum, designers want to find the key points quickly:

Ann: "*Have you seen the meme of...the big JavaScript book? And then it's like JavaScript the good parts...the guidelines need that!*"

There is also the risk of distrust towards guidelines when the wording is not written in a way that is expected by designers:

> Ann: "*I don't link anyone to WCAG because it doesn't look…trustable. They need to be completely rewritten, not like changed but just, there's so much needless text!*"

Approaches to Evaluating The participants discussed their opinions of feedback on design and their different evaluation approaches.

Two designers (Max and Ann) recognised the importance of evaluating a design early, with Max elaborating that user feedback is useful because it is possible to identify usability issues early. Since Max does not currently work with clients, he explained that changes to a game's design would be dropped depending on the feedback given by the customers through their community team; therefore, evaluations are happening after release. Also, Jo spoke about the importance of evaluating with a diverse group of people.

Evaluating with people is viewed as important, but sometimes the people used for those evaluations are not the target audience. Participants mentioned evaluating with the intended user group (Max), but also staff (Max) and students (Jo).

Running evaluations for SVIs is also possible, but sometimes designers are unable to evaluate under real-world conditions and so need to get creative. Jo and Ann discussed altering the environment to conduct evaluations:

> Jo: "*I changed the parameters like [room] lighting, and stuff like that.*"

> Ann: "*[We] tested it by shining [flashlights] on the phone to see if it worked because it wasn't sunny outside so – (Ann laughs) – there wasn't a lot I could do.*"

It is commendable that Jo and Ann actively evaluate the appropriateness of their designs under different conditions to assess the occurrence of SVIs. However, designers may not have access to the appropriate environment to evaluate in such a way (e.g., during winter on a cloudy day when the designer wants to assess the design for use on a bright summer day). A more systematic approach such as through the use of SVI design tools would provide the designer with the necessary support in evaluating their designs while working in a controlled office environment.

The Effect of Resources The participants also discussed how available resources (e.g., guidelines, time, money) can affect design, and how these resources are perceived.

Limited resources hinder designers from addressing problems:

> Ron: "*Yeah, well this happened a lot when I was first starting to get clients. How did I resolve it? I didn't resolve it. It was just one big mess [laughs].*"

Sometimes the participants will use design tools, and they are positive towards these. For example, using a design tool that simulates colour vision deficiency helps show why designers need to consider colour more carefully (Ron). A design tool that runs SVI simulations would support the designer, while increasing awareness of any nuances SVIs have in a similar way that there are different types of colour vision deficiency [Sharpe et al., 1999].

There was evidence that the participants trust particular types of resources. For example, academic research findings that inform good design practice and default designs from major OS platforms (e.g., fonts) were trusted because they have been sufficiently verified therefore saving the designer time. Furthermore, 3rd party tools that assist in the process of gathering user feedback are also resources that designers will trust in improving their designs.

There was uncertainty among all four participants as to the existence of guidelines for SVIs and Ron was unsure of the content of the accessibility section in Google's Material Design documentation. Guidelines that highlight SVIs do exist (e.g., "Shared Web Experiences" [Yesilada et al., 2013] and Mobile Accessibility [Patch et al., 2015]), but the participants not mentioning these (or others) suggests a need to promote specific guidelines more. However, based on Ron's point it is also essential that guidelines be designed in a way for more rapid comprehension as discussed in the *Perceptions of Design Guidelines* sub-theme (Section 4.3.4).

Finally, a lack of resources (e.g., time, budget) affected all of my participants. Jo mentioned facing a lack of resources and explained that "*One perception was to do it for free or not do it at all, so I preferred not to do it at all.*" In game development, Max said that a game never truly ships in a finished state because there is "*always more stuff*" to do.

Achieving Accessibility is Complex

Jo, Ann, and Ron all include or have included accessibility in their design process. All the participants were familiar with accessibility, but the amount of focus given to accessibility varied. Max and Ann had similar, quite extensive exposure to accessibility through their undergraduate degrees. However, while Ann includes accessibility during work, Max does not, highlighting how different industries can dictate accessibility adoption. Max does believe it "*would be nice to do*".

Perceptions of Accessibility There are similar and contrasting perceptions that the participants presented toward accessibility, as well as their positive and negative attitudes towards accessibility.

The perceptions of accessibility range from negative to positive. During the discussions with Ann and Ron, there was a sense that accessibility is an afterthought for some designers. The negative perceptions toward accessibility that participants offered as reasons for it not being pursued was that it took time to implement and it only benefits a small number of people – suggesting great effort required (in time and money) for little reward. Furthermore, the requirements for implementing accessibility were seen as a compromise to design. The positive perceptions of accessibility were that it was not only important for people with disabilities but for all users because they benefit from accessibility (Jo and Ann). Ann also commented that because accessibility improves usability and user experience, it would increase the likelihood of people returning to a product.

Similar contrasting views were present when commenting on SVIs. Jo said, "*No, it's not a small issue at all. [Using] an application [on] my mobile phone…you're not at home [in a controlled environment]…you go everywhere.*" However, Max did not consider it to be an important problem.

Restrictions to Achieving Accessibility The participants emphasised several reasons for designers not including accessibility when designing, which can provide insights into issues for promoting the consideration of SVIs. Part of the interview discussion with Max highlighted that the exclusion of accessibility can be a conscious decision of the designer rather than due to inadequate education and training. For example, the function of a product can determine whether designers include accessibility:

> Max: "*…I imagine like the guys at Niantic when they were making Pokemon Go, were probably thinking a lot about like…is the game visible when outdoors, like having a night mode kind of thing, [the designers] probably thought a lot more about it because that game has to be played outdoors, and you're always be looking at the screen under sunlight or whatever. Uh, with our games it's not as big of an issue…in the wider sort of applications I think [accessibility is] becoming more important, in, within games not so much I don't think.*"

Max identifies that the nature of some games will require consideration of situational impairment and accessibility, such as Pokemon Go, which is a mobile game that requires players to navigate the real-world to play in the game-world. However, for the games his company makes, he does not believe there is a requirement and "*trying to ac-*

commodate a lot of accessibility options in games kind of compromises, well it can compromise the actual gameplay" (Max).

The introduction and discussion of accessibility can also vary within education. Two of my participants (Max and Ann) found there was a major focus on accessibility within their education (they both took the same undergraduate degree but at different times), while Ron said accessibility was only given a minor focus, if any at all. Jo was introduced to accessibility, but it is unclear how much focus her course gave to accessibility. Restrictions to achieving accessibility may be due to designers themselves having a lack of awareness, and therefore do not think about the implications of poor design, particularly if they are early in their design career and therefore are unsure how to go about designing accessible content. Their lack of knowledge means it does not get done:

> Ann: "*They've come from being a pure graphics designer and moved in, and there's a lot of considerations that they just don't have.*"

Limited exposure to accessibility is not only due to the coverage formal education offers. There was evidence that online courses, for example, online UX courses "*barely mention accessibility*" (Ann), and so the issue of informing designers about accessibility is present in other educational resources.

Max suggested that his company would include accessibility if it was requested by the game players, thus reasoning his games do not require accessibility because there is no demand. However, by offering an inaccessible gaming experience, the players that require accessibility are likely looking elsewhere. Estimates in the US alone suggest 6.2 million people are unable to play games due to a disability [Yuan et al., 2011]. Inaccessible games exclude a large potential player base, and this practice goes against the 2010 UK Equality Act[4] because there has been no attempt at demonstrating a desire to try to make the game accessible. Max also suggested that the function of a product

[4] http://www.legislation.gov.uk/ukpga/2010/15/contents

can determine if accessibility should be considered, believing that "*accommodat[ing] a lot of accessibility options in games kind of compromises, well it can compromise the actual gameplay.*"

There is also the problem that current accessibility solutions are not adequate to support accessible design:

> Ann: "*I think a lot of the limitations of them is that they're terribly designed – (Ann laughs). Like, um, you know the colour contrast analyser from the Paciello Group? There's one you install [on] your desktop [that] looks like it was made for windows 98. It is really difficult [to] use. It's not interactive, it's not a plugin for Sketch!*"

The point raised by Ann is an important one. Designers will not want to use poorly designed tools, and one way to avoid this issue is by involving the designer into the creation of such tools. Involving mobile designers within the creation process of an SVI design tool would increase the likelihood that the tool better fits within the design process. Furthermore, Ann spoke about Sketch as a tool that her company uses, and the potential benefits of targeting tools already used by the designers:

> Ann: "*A Sketch plugin, that'd be amazing, because obviously you can test it all, [we] wouldn't have to go and bother to make our jumbo sheet, we could just run it and it brings it up*"

If the support can be built into tools already used by the designers then it would be better than offering something that appears disconnected.

One Solution Does Not Fit All

There are a variety of ways to increase the inclusion of accessibility and designing to reduce SVIs. Next, I report on support that was deemed to be helpful, as well as the need to raise awareness about other factors that contribute to SVIs.

Strategies to Increase Accessibility and Designing to Reduce SVIs The participants also discussed ways to increase awareness and understanding of accessibility and SVIs. There are a variety of ways to help provide designers with knowledge about accessibility and SVIs. First, it is clear that talking about these problems is not enough:

> Jo: "*There is no point of talking and talking about an issue without doing anything, [give designers] something because designers want to have something.*"

However, it is important that there is an effort among the design community to create a dialogue discussing SVIs and accessibility in general:

> Jo: "*I think that I should, actually, all of us, I should try and make [designers] understand.*"

One approach to increase awareness and understanding would be through education. Although Max equates education as similar to what guidelines are doing, educational settings can be used to scaffold the learning process of why guidelines are important and how to use guidelines. Since SVIs were "*never mentioned*" (Ron) within some formal education course, an alternative approach is to target education and run tutorials or workshops, because learning extends beyond formal education. At one point Max indicated that his company will adapt their design process based on what topics are discussed at the Game Developer Conference (GDC):

> Max: "*...this stuff with like, you know, red and green and placing of buttons and things, [are] practices [that] have been introduced very slowly. So it's the sort of*

thing [the] bosses will go off to GDC and uh, and they'll come back and say like oh Supercell did a talk and said that...placing the buttons in this way [gets] a much more positive response, so now that's going to be part of our practices. So we kind of sort of pick up practices as we go."

An even stronger tactic would be building design tools that educate and support designing for SVIs since regardless of the educational path taken by designers, design tools will be an integral part of a designers job.

It is also important to disseminate research outside of academia to increase awareness and understanding (e.g., Ron suggested a marketing campaign), and increase presence on popular websites used by designers. Ann felt that inclusion of a case study would be helpful. A recommendation was to use the influence of major OS platforms on designers to push for designing to reduce SVIs. Max mentioned that one way to increase accessibility within the games industry is for the app store companies (i.e., Apple and Google) to "*push for [accessibility]*" by saying a game can only be featured or promoted if it is accessible.

Furthermore, time was a recurring theme; designers require strategies that will save them time by supporting quick accessibility design because designers "*...don't have a lot of time, [they're] under deadlines*" (Ann). Furthermore, considering the budget constraints faced by designers, any solution must be affordable (preferably free):

> Max: "*...everything we ever make in our games is always about like costs, cost versus reward*"

Finally, for some designers, they may only be willing to rely on automated solutions handed by the mobile device. Max spoke positively about "*[Getting] saved a lot by the OS you know, like that colourblind mode and things like that.*" In this case, designers can forgo implementing accessibility into their designs. However, this relies on the accuracy of those automated solutions and also places the responsibility onto the user to fix accessibility issues, which should not be the expected outcome.

Supporting Action Within Practice There are several factors to consider when looking to help designers implement accessibility and, in particular, design to reduce SVIs. First, evaluations with the target audience are important, however, recruiting participants can be difficult. Jo suggests using incentives for getting people to take part, although this can become costly. Second, it is important that any solutions are *easy to understand and use* by the designer, but also for the client because designers can leverage these resources to dissuade a client who is adamant about a poor design request. Alternatively, the current guidelines provided by OS creators, rather than WCAG, could be extended to provide greater detail regarding situational impairments and SVIs. However, it is important that the solutions offered do not restrict designing too much, in this example, Max was referring to guidelines:

> Max: "*As long as they weren't too restrictive then we'd probably be quite happy to just do that all the time.*"

Although guidelines can be useful, offering SVI design tools would reduce the reliance on reading guidelines and could provide interactive support. Max and Ann both felt that simulations would be useful to enhance the designer's understanding of SVIs, and simulations can be incorporated into design tools. However, a design tool must fit within the design process, which is a challenge since I know that all designers do not follow the same design process, and even for an individual designer, approaches can vary according to the project requirements:

> Ann: "*I think that a lot of [the accessibility tools] are very much designed for specific use cases...but as part of a design flow, it sits by itself and it's very isolated.*"

Ann also called attention to an interesting challenge where there is a need for adaptable accessibility and SVI design tools that meet the needs of many different designers and their projects.

Finally, various techniques were discussed by the participants throughout the interview, either when discussing accessibility for visual impairments or SVIs, and these can be used to improve content visibility overall: increase brightness, increase contrast, increase font size or zoom in to the content, increase line thickness and weight of an element. It would be possible to have in-built support within an SVI design tool that informs the designer the appropriateness for different contrast ratios and font sizes for different SVIs. Jo suggested that applications should adapt to the environment and it would be easier to do this if designers had a sense of what alternative designers for mobile content could be.

Awareness of External Factors There are also external factors that designers should be considering so that alternative modes of interaction can be implemented. One participant raised the point that external factors contribute to situational impairments:

> Ann: "*If [a user is] outside, there's a couple more things I need to be looking at, things like: Can they actually see it? Are they gonna be wearing gloves? [Will they] be touching the screen?*"

Using resources such as the Haptimap Context Cards [Magnusson, 2011] are a good starting point for prompting designers to think about the different contexts a person may use a mobile device, although the context cards do not readily lend themselves to a practical solution in the same way an SVI design tool would.

4.4 Discussion

Through surveying designers, I found that there are striking similarities between the challenges faced when designing for accessibility and for SVIs – particularly when considering past issues surrounding accessibility. In particular, I found evidence that wider extrinsic factors can result in barriers to ensuring accessibility needs are met, which supports previous work [Ross et al., 2017].

SVI design seems not to be as prominent as accessibility design: designing to reduce SVIs is often not in the design scope or part of the designer's current practice, there are limited resources available (e.g., time, money, tools) to design for SVIs, some designers are unaware of or have not considered SVIs before, and in many cases designers view SVIs as a minor issue. However, the participants also reported positive connections between accessibility and SVI design. Both were perceived to be of benefit for a broader set of users than the target audience, and they recognised that designing for one often resulted in at least partial inclusion of the other.

I also found a particular affinity between accessibility and SVI design. The participants reported a *legal* obligation to incorporate accessibility in their designs (a negative consequence of not including accessibility), whereas this was not evident when discussing SVIs. Instead, motivation can come from *financial* gain through increased market share by considering SVIs because people are more likely to return to apps with increased usability in different contexts. Furthermore, the participants also incorporate accessibility due to moral convictions, suggesting a sense of *sympathy* for users with disabilities and arguing it is unethical to exclude accessibility. Previous work on impairment simulations can help designers empathise and build an understanding of the importance of accessibility both in education [Youngblood, 2013] and a broader context [MacAlpine and Flatla, 2016], but simulations can be difficult, expensive, or time-consuming to prepare. In contrast, consideration of SVIs is likely coming from a feeling of *empathy* because designers, often having directly experienced SVIs, can relate more easily. The 'empathic' understanding designers have of SVIs (because they have experienced SVIs themselves) can be leveraged to enhance awareness of the importance for both SVIs and accessibility, which should help to increase the inclusiveness of design. In my recommendations for education (see Section 4.5 – Education), I further discuss increasing inclusivity and accessibility through designing to reduce SVIs in the context of related literature.

Overall, there were fewer designers considering SVIs than accessibility. In addition, some participant responses showed a misunderstanding of what SVIs are, likely artificially inflating the numbers of designers who reported that they feel they are designing to reduce SVIs. The participants requested support in the form of 'Guidelines', 'Education', and 'Digital Design Tools' and I ran follow-up interviews to identify the best way to integrate this support within current design processes. From my interviews, I identified three themes that provide greater insights into supporting designers in designing to reduce SVIs. The themes were *design practices will vary*, *achieving accessibility is complex*, and *one solution does not fit all*. In light of my findings, I next discuss and make recommendations on how to extend Guidelines, Education, and Digital Design Tools.

4.5 Improving Avenues of Support

Guidelines – I recommend that existing accessibility guidelines be extended to include SVIs. Industry guidelines (e.g., Android Material Design[5] and WCAG 2.0 [Caldwell et al., 2008]) should be extended to help designers to increase luminance contrast for reduced screen brightness (e.g., due to low-battery) or bright sunlight situations. Huang et al. [2017] have made progress in outlining mobile interface guidelines for comfort-

[5]https://material.io/guidelines

able reading; however, their study was run in a controlled indoor environment with ambient illumination levels much lower than those expected outside [Ander, 2003], so further research is required. It is important to revise contrast ratios with data gathered on a large scale from typical real-world conditions, in a similar approach to Reinecke et al. [2016]. and investigate guidelines for design elements such as font type, style, size, and weight, as well as icon designs.

Through discussion during the interviews, it became clear that there are both positive and negative attitudes towards guidelines. Criticism about accessibility guidelines (e.g., WCAG) being too verbose and dense is not new [Brys and Vanderbauwhede, 2006; Swallow et al., 2014], however I did discover that there are also positive attitudes towards guidelines (e.g., using them to support an argument against a client's design request, trusting the content designed will be of a high standard, recognising the value of 'simplified' industry guidelines (e.g., Android Material Design)). Ultimately, when researching new guidelines they should be easy to understand and allow for a degree of flexibility (Ann: "*...a number but with a tolerance level...*"), so creativity is not restricted. Allowing for flexibility is important: P15 (questionnaire) reported "*often picking colors is limited*", and during the interview, Ann discussed the challenge of having to use company brand colours (echoing previous research [Tigwell et al., 2017]).

Education – During the interviews, Ron explicitly said SVIs were not part of his education, and the other three participants discussed ways of increasing awareness and understanding of SVIs without mentioning their education.

Youngblood et al. [2017] argue that the ethical reasons for implementing accessibility are not effective, and so more should be done to emphasise the legal implications of not creating accessible content. However, as I found in my study, legality does not factor into designing to reduce SVIs at all because the law does not require it. Instead, I could potentially further increase the motivation to include accessibility by arguing that the population affected by SVIs is much larger and broader. This approach is not new; both Universal Design [Bergman et al., 1996] and Universal Usability [Vanderheiden, 2000] promote designing for a broad range of users and situations. This idea persists in the academic community – a panel discussion led by Gavin Lew suggested that addressing accessibility for people with a disability will lead to designs that are universally beneficial [Lew et al., 2015]. Petrie et al. [2015] and Yesilada et al. [2015] also support this opinion. A more appropriate perspective for designers to take would be ability-based design, which focuses on what a person can do rather what they cannot do [Wobbrock et al., 2011, 2018]. Yet, regardless of the approach designers should be following, based on the results of my study, it seems that these perspectives are not being passed on to designers.

There has been research on the teaching of accessibility in computer science programs [Lewthwaite and Sloan, 2016], and suggestions on how to instil best practice in higher education classrooms [Putnam et al., 2016; Youngblood et al., 2017]. However, in addition to formal education, other methods of design training were discussed such as using online courses and learning best practice approaches promoted at conferences. The participants discussed a range of resources available for people to learn from (e.g., online courses such as Coursera[6] and Udemy[7], case studies on Medium[8], blogs). In addition to formal education, targeting design websites (e.g. Dribbble[9]) and online self-learning courses to address SVIs can further raise awareness and help to forge an inclusive design culture.

SVIs provide the benefit of helping designers to *empathise* first, rather than be *sympathetic*. Leveraging the conceptual and practical overlap between accessibility and SVIs, this empathy can potentially increase accessible design. However, I know from my

[6]https://www.coursera.org
[7]https://www.udemy.com
[8]https://medium.com
[9]https://dribbble.com

findings in Study 1 and Study 2 that situational impairments are a temporary experience; therefore we must be careful not to equate situational impairments with congenital and acquired disabilities as they are fundamentally different [Henry et al., 2014]. People who have a disability require specific consideration to address their needs and must remain the primary focus of accessibility.

Digital Design Tools – Digital design tools are one method of supporting action in practice, and this was the third most requested solution to support designing to reduce SVIs. It is suggested that an insufficient understanding of guidelines or a lack of tool support is one reason for inaccessible website [Power et al., 2012]. A design support tool can serve as a platform for understanding how best to design for SVIs, and the tool can incorporate the extended guidelines I suggest above.

Max discussed being more willing to rely on automated accessibility options provided by the mobile device's OS, thereby reducing the responsibility of the designer to create accessible content. Jo discussed applications that can adapt to the environment. Adapting content under variable lighting has been researched before [Lee et al., 2007; Yu et al., 2015; Ward et al., 2017]. However, this passes the responsibility to either the user to install an app or the manufacturer and OS creators to implement the setting on the device. By automating the feature, there is additional processing power (resulting in lower battery life) and, more importantly, the designer no longer has control over their design's look.

During my interviews, Ann explained that accessibility design tools tend to be inadequate by not fitting within the designer's design process or only being functioning when the designer has finished a design, thereby making accessibility checking more of an afterthought. In previous work, I also found similar issues with online tools for supporting designers to choose accessible colours for people with colour vision deficiency, yet demonstrated that by including designers in the creation of such tools, it is possible to focus on designing with accessibility in mind, rather than restricting creativity for accessibility [Tigwell et al., 2017]. It is important to develop SVI design tools with a user-centred design approach as they would likely fit better into the design process, and therefore the tool would be used more, increasing the accessibility of mobile content.

The participants discussed increasing contrast to reduce SVIs caused by bright environments. In particular, Ann discussed implementing a high-contrast version of an interface; however, this addition was late in the design process, and her design team only implemented the alternative mode because of extended project time. Considering that common issues reported by the participants were *working towards a deadline* and *not having enough time*, the design tool should support rapid designing, and be implemented to fit within the designer's typical work environment. The benefit of this approach is that the designer has control over the look and feel of the high-contrast design. Furthermore, it would be beneficial if the design tool allowed designers to interact with the interface layout to alter other design elements (icons, font, etc.).

4.6 Conclusion

My findings from Study 1 and Study 2 (reported in Chapter 3) highlighted that content design is one factor that causes SVIs, and users were frustrated by this. It was evident from my review of the related work in Chapter 2 that solutions addressing situational impairments when using mobile devices further do not focus on supporting mobile content designers.

In this chapter, I report two studies (Study 3 and Study 4) I conducted to understand what designers currently do regarding SVIs, what resources they know of, and what is required to best support them in designing to reduce SVIs. I surveyed 43 mobile content designers (Study 3) and ran four follow-on interviews (Study 4) to identify how often mobile designers consider SVIs and how I can provide adequate support. I found key similarities and differences between accessibility and designing to reduce SVIs. The participants in Study 3 requested guidelines, education, and digital design tools for improved SVI design support, which I discussed in more detail with mobile designers in Study 4. Consequently, I make the following recommendations to help shape the future of mobile design: (1) Current guidelines need to be extended to include validated SVI guidelines, (2) Formal education and online popular professional development resources must include information about SVIs, (3) New SVI design tools should be developed with designer input to fit within their design process.

A new SVI design tool can have an immediate positive influence on supporting designers, and it can drive the demand for education, as well as make any guidelines developed immediately accessible. For this reason, I will focus on identifying the necessary features and implementation for designers to begin using an SVI design tool. In the next chapter, I will describe two studies conducted in order to meet the needs of mobile app designers so that they can design mobile content with alternative modes to empower mobile device users within different contexts.

Chapter 5

Supporting Designers in Reducing Situational Visual Impairments

5.1 Introduction

In Chapter 4, I reported two studies (Study 3 and Study 4) that help to understand what mobile content designers currently do regarding SVIs, what resources they know of, and what is required to support them best to design for SVIs. The top three requests by mobile content designers were guidelines, education, and digital design tools.

Although digital design tools were the third most popular request, this is my focus for reasons of practicality and maximising impact. There is generally a negative view towards accessibility guidelines [Swallow et al., 2014], and there are already many different guidelines online that introducing another set is likely going to have limited influence. A benefit of focusing on design tools is that it is possible to absorb guidelines into the design tool, and this removes a step the designer is expected to follow (i.e., the designer is expected to know of, understand, and use the guidelines). Extending education would be useful, but the challenge is making sure to expose designers to educational content that discusses SVIs. Since all designers of digital content are likely to use digital design tools, then the instruction about SVIs can be included within the design tool itself, and it doubles as an educational resource.

Prior work has explored the creation of design software that supports designers in quickly producing editable vector images from interface screenshots [Swearngin et al., 2018a] and exploring variations with interface design layouts [Swearngin et al., 2018b]. These solutions demonstrate the possibility of software saving the design time and effort, however, this work was not focused on supporting designers in addressing SVIs.

I wanted to focus on the design of the mobile app interface since this is a significant part of how users interact with apps and the aesthetic design choices can often lead to SVIs. With this in mind, I can offer recommendations to the companies of popular design software to explain what features need to be incorporated to help support addressing SVIs. Although previous work [Tigwell et al., 2017] and evidence from Study 4 (see Section 4.3) suggest that the design community does not always accept accessibility design tools, this is usually due to the tools not meeting the needs of the designer and not fitting within their design process. To address this concern, I planned my final two studies to get input from mobile app designers at different points of the development process using a user-centred and participatory design approach [Lowdermilk, 2013; Spinuzzi, 2005].

In this chapter, I will present two studies (Study 5 and Study 6) that I ran to identify recommendations on how an SVI design tool should function to maximise the likelihood that the tool supports mobile app designers and reduces the risk that it would be abandoned because it does not meet their needs. During Study 5, I surveyed 50 mobile app designers using an online questionnaire to understand how they design mobile app interfaces. In particular, I was interested in learning more about the tools that mobile app designers use (e.g., paper vs software), what software mobile app designers use and when, and how mobile app designers explore multiple design ideas. During Study 6, I ran two design workshops. The goal of the first design workshop was to use paper-based prototyping to design a digital design tool for SVIs that fits within a designers' typical workflow. I then developed high-fidelity concepts based on ideas generated in the first design workshop. I created prototypes that were to be used within the Sketch software[1] environment. I chose Sketch, a popular design software with tools that support designers in creating the user interface of mobile apps, because participants at different stages of my research commented on using it. The goal of the second design workshop was to identify the necessary refinements to the high-fidelity concepts.

5.2 Study 5: Online Survey

Currently, research has yet to identify the range of tools and practices of mobile app interface designers. I used an online survey to understand the approach and tools used when designing mobile app interfaces, including how often designers are including alternative modes. I designed the online survey to understanding these aspects of the design process because I would then have a more informed understanding of mobile app interface design, since Study 3 & 4 (see Chapter 4) were not specifically focused on this aspect of mobile design, and the interface elements of an app are a significant part of what we interact with when looking at and using our devices.

[1]https://www.sketchapp.com

5.2.1 Material and Procedure

For the online survey, I used a questionnaire (Appendix D.17) comprised of 13 close-ended and 12 open-ended questions. Twenty-four of the questions were compulsory[2] to collect a complete data set; however, I made this clear to the participants, and they could withdraw at any time without penalty.

The questionnaire gathered the following data.

- Demographic information. **Q1-7**
- If a participant works on paper. **Q8**
  - If yes, I asked how often they did this, when in their design process they did this, and why. **Q9-11**
- What software and tools participants used for mobile app design. **Q12**
- If a participant worked on multiple design ideas for a mobile app interface. **Q13**
  - If yes, I asked how often the participant did this, when in their design process, how it is approached, and how the final design is chosen. **Q14-17**
- If a participant considered alternative modes or themes for mobile app interfaces (e.g., a dark mode for nighttime use). **Q18**
  - If yes, I asked how often the participant did this, when in their design process, how it is approached, how the final versions are chosen, and whether designing alternative modes or themes presents challenges. **Q19-23**
- I asked when the participants typically consider the mobile app interface colour

[2] The final question was an optional open-ended question for participants to leave any further comments not covered by the previous questions

scheme. **Q24**

- I included an optional question at the end that allowed participants to leave any further comments about their design process and experiences when designing a mobile app interface that they think are important but were not covered by the previous questions. **Q25**

The survey was expected to take five to ten minutes to complete depending on the responses given. I distributed the questionnaire among 5 universities (Dundee, Guelph, New Brunswick, Saskatchewan, Washington), and to broaden my audience I also publicly posted onto social media (e.g., Facebook, Twitter), and Reddit to research and design focused groups (e.g., r/samplesize, r/UI_Design). As per my department's REB approval, participants first read through an information page and consented to take part. The online survey was active for one week in June 2018.

5.2.2 Participants

Fifty participants completed my questionnaire, 38 Male and 12 Female, aged between 18 and 55 years old (Mean: 28.78 years old). I gave each participant a participant ID (e.g., P1). Fifteen participants were from the USA (30%), 12 from Canada (24%), 10 from the UK (20%), two participants were from each of Australia, India, and Sweden, while there was one participant from each of the following: Chile, Cyprus, Czech Republic, Germany, Netherlands, South Africa, and Thailand.

The participants indicated that they had varied design training backgrounds (multiple responses were allowed): 'Undergraduate level university' (24 participants), 'No formal training' (16), 'Postgraduate level university' (14), 'College' (7), 'Apprenticeship' (3), and 'Other' (4; e.g., taking online courses).

I asked the participants what best described their design career; 26 participants said

'Working for a company', followed by 'Self-employed' (10), 'Hobby' (7), 'Other' (7 - four students, two academics, and one participant who responded "*Working on developing a mobile application for a project, so interface design is a part.*", which I could not categorise).

The participants have been designing mobile app interfaces for up to 12 years (Mean: 3.94; Median: 3; Mode 2) and for various platforms (multiple responses were allowed). Thirty-six participants (72%) design for Android, thirty-seven participants design for iOS (74%), four participants (8%) design for Ultimate Windows Platform and six participants (12%) indicated other (e.g., Web, React Native).

5.2.3 Results

I analysed the qualitative data of the survey using an open coding approach [Tracy, 2013]. I first read through the data files to ensure I was familiar with the data set. I then began by defining specific codes (first-level coding approach), which were then grouped into descriptive categories (second-level coding). For example, reasons for using paper included the codes "easier to focus" and "easy to collaborate" , which were then grouped into the category "ease of use".

Working on Paper

Since apps are a digital service and are made using computers, it is easy to focus too much on this aspect of the design process. Working on paper is a recognised and useful prototyping approach [Wong, 1992] and I was interested in identifying how many mobile app designers continue to do this, and their reasons why, considering that there is an increasingly digital work environment with many different digital tools to support their practice.

Forty-four participants (88%) will work on paper during some point of the design process compared to 6 participants (12%) who do not work on paper. Seven participants (15.91%) always work on paper, 10 participants (22.73%) almost always work on paper, five participants (11.36%) often work on paper, six participants (13.64%) work on paper about half of the time, seven participants (15.91%) occasionally work on paper, and nine participants (20.45%) rarely work on paper.

The participants use paper at many points in the design process (e.g., at the early stages of the design project, throughout the process, during meetings with clients). Twenty-four participants specifically mentioned that paper was used early on in the design process.

The participants provided many reasons for using paper in the design process. The reasons for using paper broadly related to several key ideas: the ease of use (e.g., quick edits, fewer distractions, collaboration, work in front of client, discard ideas), determining the fundamental interface design problems (e.g., interaction, dimensions), fosters creativity, and paper's availability and low cost.

Although paper is found to be part of the design process, the participants are mainly using paper to record and explore initial ideas quickly (e.g., interface layout) rather than to make fully realised or highly detailed interfaces (e.g., precise font sizes and colour).

Design Software and Tools

In total, the participants listed 30 different design tools highlighting the range of design tools available to designers. The design tools range from physical (e.g., pen and paper, whiteboards) to digital (e.g., Adobe Illustrator). Furthermore, the digital tools mentioned served a variety of purposes such as graphics editors (e.g., Adobe Photoshop, CorelDRAW), prototyping software (e.g., Axure RP, InVision), visual effects software (e.g., Adobe After Effects), supported coding environments (e.g., Android Studio, Unity), supported collaboration software (e.g., Lucid Chart, Zeplin), and feedback and guidance software (e.g., Pendo). It is clear that designers will use whatever is available and what best meets their needs, which was evident from the range of sophistication among the software used (e.g., PowerPoint vs Figma). The top five design tools were: Sketch (mentioned by 18 participants), Adobe Photoshop (14 participants), Adobe Illustrator (9 participants), Pen and Paper (7 participants), and InVision (6 participants). Both P38 and P40 did not use any design tools. P38 explained that the reason he did not use design tools was that he managed a design team instead of designing directly.

Sketch was a tool that Ann from Study 4 used (see section 4.3). Ann spoke about the benefits of having SVI support built into Sketch. Since Sketch is the most popular choice from the participant sample of my online questionnaire, it is a strong candidate to use when exploring how a digital design tool can support designing to reduce SVIs.

Multiple Designs:

The next section of my questionnaire was used to understand whether the designers consider multiple designs of an interface. I was interested in exploring this because confirming that mobile app designers typically try out more than one design idea would mean that the SVI design tool likely needs to support a method for quickly exploring design ideas.

Forty-nine participants (98%) have considered multiple design ideas during at least one project when designing a mobile app interface, and only 1 participant said they did not do this. Seven participants (14.29%) always consider multiple designs, 7 participants (14.29%) almost always consider multiple designs, 12 participants (24.49%) often consider multiple designs, 17 participants (34.69%) consider multiple designs about half of the time, five participants (10.20%) occasionally consider multiple designs, and one participant (2.04%) rarely considers multiple designs.

The participants' responses also highlighted that consideration of multiple designs happens at many points in the design process (e.g., at the early stages of the design project, throughout the process, at the request of stakeholders).

The participants also provided insights into the range of approaches that they adopt when exploring multiple designs (e.g., determine a colour palette first, lots of paper prototypes, teams working on multiple ideas, involve stakeholders, draw on ideas from other apps, place ideas side by side, work on I/O criteria first).

I also asked the participants how they approach choosing a final mobile app interface. I grouped the approaches into four categories: the chosen design is most suited for the project (e.g., time available, cost), the chosen design offers the best experience (e.g., easy to read, aesthetically pleasing), the chosen design wins by feedback (e.g., testing, voting, team decision, client/user input), and the chosen design is preferred by the designer.

Alternative Modes

Leading on from the section that asked about the participants' general consideration of multiple designs, I asked the participants whether they consider alternative modes or themes. The difference between the two is that when considering multiple designs, the designer ultimately chooses one final design for an app, whereas when considering alternative modes or themes the designer is choosing many final designs each with a specific purpose: an alternative mode example would be a "dark mode" for nighttime viewing; an example of a theme would be an aesthetic "skin" for user customisation. While alternative modes closely relate to situational impairments, I did not want to discount participants who create themes for their apps since they will probably utilise similar design principles and approaches, even though those themes may not serve a practical purpose beyond customisation.

Overall, 15 participants (30%) indicated that they include an alternative mode or theme that the user can enable. No participant always includes an alternative mode or theme. Two participants (13.33%) almost always include an alternative mode or theme, one participant (6.67%) often includes an alternative mode or theme, one participant (6.67%) includes an alternative mode or theme about half of the time, six participants (40.00%) occasionally include an alternative mode or theme, and five participants (33.33%) rarely include an alternative mode or theme.

I found the participants consider alternative modes or themes at different points in the design process (e.g., in the beginning, after the primary design, after the UX is determined, after development, late into the project). These findings illustrate the variation between how different designers work and affirm what I found in Study 3 and Study 4 (see Chapter 4).

I asked the participants how they approach working on alternative modes or themes for mobile app interfaces and found that there is a mixture of approaches (e.g., make it look aesthetically pleasing, considering different light conditions, begin by inverting things, spend time working out new colours, understand context and environment). A prominent feature within the responses to this question was the problem-solving aspect of design, for example:

> P17: "*It depends. One app was simply a matter of offering a variety of colors to use as background and toolbar colors. For another app, where I added a dark mode, I went back into Sketch and spent time selecting new colors to use for each interface element.*"

It appears that mobile app designers try to identify what works for different conditions and why a user may want to choose different options.

I asked the participants how they decide on the final version(s) of alternative modes or themes. The participants mentioned various ways in which they would approach choosing the alternative modes or themes (e.g., through testing, the client makes the decision, add all features but make them user enabled, what the designer prefers, when tired of adding variations), thus demonstrating the complexity of the design process.

As a final question to this section of the questionnaire, I was interested in knowing whether there were any challenges that participants face when designing alternative modes or themes. The participants reported several challenges they face when designing alternative modes or themes, for example:

> P21: "*Branding guidelines don't always accommodate for light and dark so sometimes branding guidelines must be bent or broken.*"

Overall the 15 participants comments covered the issues of time and effort (4 participants), the challenge of using colours (4), accessibility and guidelines (3), problematic graphics elements (2), the challenge of satisfying all user preferences (1), the difficulty in replicating the environment (1), and convincing app developers (1).

Exploring Colour:

When considering how to address SVIs through design a large part of the solution relates to colour. Low contrasting colours are less taxing to view in low light situations but will be very difficult if not impossible to make out on a bright sunny day. Likewise, higher contrasting colours are more accessible in bright ambient lighting conditions, but too severe in low ambient light.

I asked participants at what point during the design process they explore the mobile app interface colour scheme. The responses show that there is no single approach to choosing colour schemes, and mobile app designers consider colour throughout various stages of the design process, including from the beginning (e.g., P45: "*From the start, the color scheme is one of the most important parts of any app. An app with a bad color scheme is a bad app.*"), during the design process (e.g., P26: "*When moving from wireframes to high fidelity comps. But this is flexible and may be changed at any time before the project is finished.*"), and at the end of the design process (e.g., P47: "*At the end of implementation, editing the placeholder schemes.*"). It is also worth noting that six participants mentioned having to use client brand colours.

This suggests that mobile app designers take different approaches to explore colour, and in many instances, there are other factors (sometimes uncontrollable, such as client specified colours) that influence the design process. It is essential that SVI design tool recommendations are flexible and sensitive to this variation.

Additional Comments

Seventeen participants left additional comments (with some providing multiple comments) about their design process and experiences that were not covered by other survey questions. Six participants praised software that supports practice and Sketch was specifically mentioned by three participants. Four participants commented on the importance of following good work practices such as seeking out expert help, considering the app's usability and accessibility, working with developers, and gathering requirements. Three participants highlighted design challenges such as designing for many different devices (e.g., varying screen sizes), new technologies (e.g., VR/AR), and the time-consuming issue of representing all app states for developers to build. Two participants suggested improvements to software (e.g., saving time with improved exporting of designs to functional XML, provide interactive demos for clients). Two participants mentioned the challenges of working with clients who do not know what they want or change their mind, and designers must recognise a client's perception of the users can mismatch with the actual users. Two participants commented that it was important to educate clients (e.g., why designers are important and not relying on a developer to design app interfaces). One participant explained that it was challenging to evaluating apps. One participant was appreciative of Google's Material Design guidelines. One participant suggested I ask about out the design principles designers follow, which I did not because Study 3 and Study 4 (see Chapter 4) indicated how varied that was. P36 stated he was designing "*out of need more than love*".

5.2.4 Summary

This study reported on design practices of mobile app interface designers. I have identified that there are varied practices, including the consideration of multiple design options. The majority of participants like to work on paper, and many different physical and digital design tools are used to support the designing of a mobile app interface. Sketch[3] was the most popular tool listed by the participants. Mobile app designers typically take the time to consider different design ideas rather than committing to one design, and this can occur at various points of the design process. However, only 30% of the participants create alternative modes or themes, even though most are typically in the habit of considering multiple designs. The participants also raised issues with regards to creating alternative modes and themes that covered insufficient time and increased effort, the challenges related to colour, accessibility and guidelines, problematic graphics elements, the difficulty of satisfying all user preferences, the challenge when replicating the environment, and convincing app developers it is worth doing.

[3]Sketch is a popular design software with tools to support designers creating mobile app user interfaces https://www.sketchapp.com

This will impact on the accessibility potential of apps, especially when considering the common SVIs experienced when using mobile devices. The exploration of colour can occur at different points of the design process; however, clients will sometimes require the use of a branded colour scheme, which restricts the designer's freedom, especially if the designer wants to create an alternative mode for improved accessibility.

It was clear from these finding that the majority of designers are not creating alternative modes or theme, which would help to reduce the occurrence of SVIs because the app design would be more suitable for the context of use. I used these new findings with the findings of my previous four studies to plan a couple of design workshops in which solutions would be prototyped and refined.

5.3 Study 6: Design Workshops to Prototype SVI Design Tools

During Study 3 & 4, I was interested in understanding mobile content designers (not specifically those who design mobile app interfaces) and what considerations there were for accessibility and SVIs during the design process. Study 5 provided me with a deeper understanding of how mobile app interface designers work and the tools that they use, which was necessary before I focused on exploring prototypes for SVI design tools.

My research approach has followed the British Design Council's Double Diamond model (Figure 5.1), which maps out how designers across different disciplines approach their creative process.[4] The Double Diamond model is a well known approach to Design Thinking, which supports the development process of new ideas [Tschimmel, 2012]. The Double Diamond model can be adjusted for software products and services [Schneider,

[4]https://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond

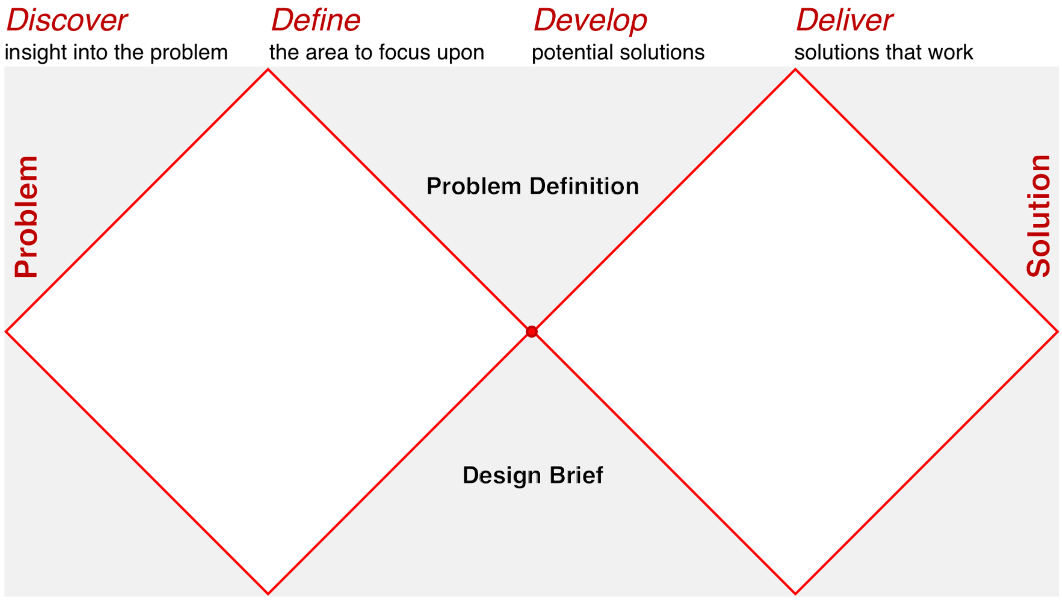


Figure 5.1: The Double Diamond model created by the British Design Council.

2015]. Studies 1 and 2 were about discovering the problem and Studies 3 to 5 allowed me to focus on a particular aspect of the problem and define it. Using this knowledge I was able to construct a design brief (discussed in Section 5.3.2) to guide the participants taking part in the design workshops. Therefore, I completed the first half of the Double Diamond model.

The second half of the model required exploring and iteratively creating solutions. I planned design workshops with mobile app interface designers to explore ideas for recommendations on how to incorporate support for designing to reduce SVIs. I utilised a participatory design approach [Spinuzzi, 2005] because I wanted to actively involve the end users (i.e., mobile app interface designers) in the process of designing solutions. The users would know what they need and how they want to achieve success using a system, and their insights into how they work will contribute to the success of the system [Olsson, 2004]. It was important that I first conduct a pilot study to identify any challenges in running a participatory design session because my research had shown that designers do not often design to reduce SVIs. The pilot study (Section 5.3.1) highlighted that I needed to begin with more discussion on SVIs and design before moving to the prototyping stage. After running the first workshop, I planned to take those initial ideas and build high-fidelity prototypes. I would then get feedback for those prototypes in a second workshop, which would give me ideas on how to refine those prototypes.

5.3.1 Pilot Design Workshop

The goal of the pilot design workshop was to prepare for the main design workshops. I would be able to assess the quality of my workshop material and to identify if the time dedicated to each task was sufficient.

Pilot Participants

Four participants took part in the pilot design workshop. I recruited two male and two female participants aged between 23 and 39 years-old (Mean = 28.25; SD = 7.37).

Two participants had attained a university degree at an undergraduate level, and two participants had postgraduate degrees.

The participants had varying degrees of experience with designing mobile app interfaces, UI design, Website or Web interface design. P1 had experience with all four, P2 had some experience (prototyping and photoshop work), P3 only responded "yes", and P4 left the response blank.

I asked the participants to indicate if they had experience with using various design software and tools. The options were selected based upon the analysed responses from the online survey (see Section 5.2.3). All four participants had experience with graphic editors and physical tools. Three participants (P1, P2, P3) had experience with prototyping software and coding environments. P1 and P3 had experience with supported collaboration software, and P3 had experience with visual effects software.

Pilot Material and Procedure

I set up the HCI Experimentation Lab in the Queen Mother Building at the University of Dundee so that the participants would each have sufficient space to complete the tasks (see Figure 5.2).

The introduction part of the pilot took 10 minutes. The participants were instructed to read over the information sheet (Appendix D.18) before completing the consent form (Appendix D.19) and image release forms (Appendix D.20). I then instructed the participants to complete the demographics form (Appendix D.21). I used presentation slides to provide the participants with an overview of the structure of the pilot study (introduction, sketching session, discussion session, feedback opportunity – discussed in detail below).

I explained that the purpose of the pilot design workshop was to prototype an SVI design tool to support designing for situational visual impairments. I provided the participants with a brief background on SVIs and why design is relevant, by giving each participant with the SVI explanation sheet I created for Study 2 (Appendix B.10).

I explained that the sketching session would take 50 minutes, and I asked the participants to follow the five design-sheet (FdS) methodology [Roberts et al., 2016]. I gave the following brief overview of the FdS methodology during the introduction: "The FdS methodology is used to support people in being creative and structuring information visualisation interfaces through sketching. Although designed to support the creation of information visualisation interfaces, it is suitable for other interface designs so long as there is a focus on a visual interface [Roberts et al., 2016]." I then provided

Figure 5.2: The pilot workshop setup showing all the materials provided for each participant.

each participant with:

1. The five sheets of A3 sized paper required for the FsD methodology[5].

2. A selection of pens with limited colour choices to discourage spending time on making fully realised and detailed sketches, which was not the purpose for the initial workshop.

3. A "Design Brief Worksheet" (Appendix D.22) that outlined the task that the participants were being asked to complete, important considerations that the participants make when sketching their solutions, and a list of questions based on findings from my previous work to assist in the generation of ideas.

In the final part of the introduction, I reminded the participants of five rules to ensure the pilot design workshop ran smoothly: 1) there are no judgements, 2) encourage wild and creative ideas, 3) stay on topic, 4) only one person speaks at a time during discussions, 5) quantity over quality is best.

I also included seven "Support Cards", which were laminated sheets of A4 paper with screenshots of popular Android and iOS mobile apps that included alternative modes and themes (two shown in Figure 5.3 and Figure 5.4). The cards covered a broad cross-section of apps: one calendar app, one map app, one messaging app, one social media app, one weather app, and two games. One game had a specific night mode, and another game changed the visual design when it was nighttime within the game world. The Support Cards (see Appendix D.23 for all seven cards) allowed the participants to reflect on how current apps use alternative modes, including the well-executed and poorly-executed elements in these designs. The participants could use the cards to help imagine the steps a mobile app designer would need to go through from a default UI mode to an alternative mode; helping them think about necessary features for an SVI

[5]The structured outline for each sheet can be found here: http://fds.design/index.php/resources-and-publications/

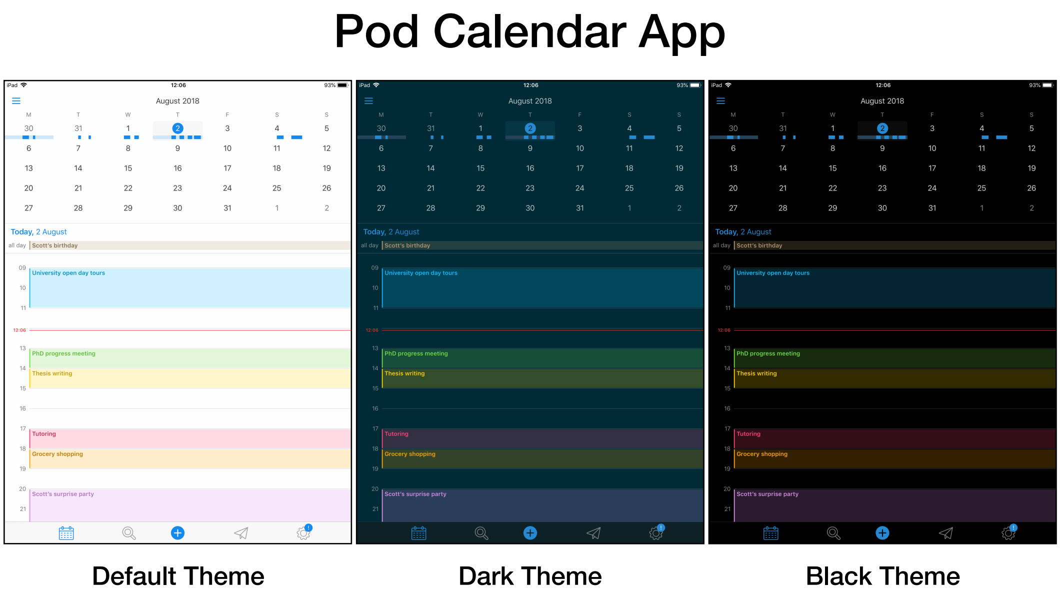


Figure 5.3: Example of a "Support Card" – The Pod Calendar App for iOS in its default, dark, and black theme.

design tool.

I divided the 50-minutes sketching session into three parts. The participants were first given 20 minutes to explore their initial ideas on Sheet 1. A countdown was added to the presentation screen so that the participants could keep an eye on the time. The participants were then encouraged to move onto the next step and given 20 more minutes to use sheets 2-4 to explore three alternative designs. At the end of this step, the participants were given a final 10 minutes to use Sheet 5 to create their final design.

After the sketching session, I led a discussion with the participants that lasted 25 minutes. The participants were each given 2 minutes to talk through their final design. I used the remaining time to encourage the participants to talk about what they thought about alternative modes and to reflect on their usefulness from the perspective of design.

Before the session ended, the participants were each given a feedback sheet to complete so that I had clear suggestions on how to improve the workshop structure (Ap-

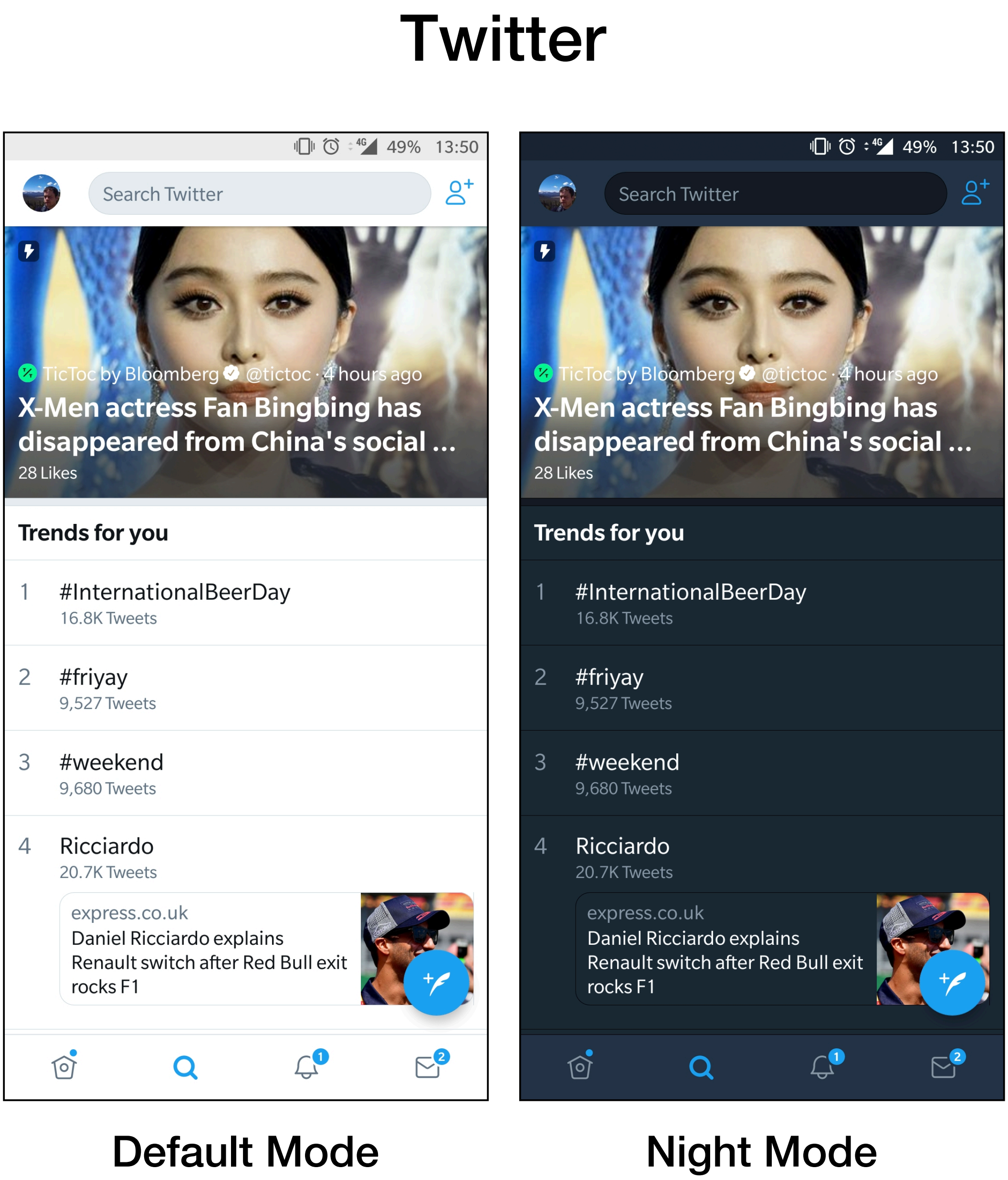


Figure 5.4: Example of a "Support Card" – The Twitter app for Android in its default and night mode.

pendix D.24). I reimbursed the participants with a £10 Amazon voucher.

Pilot Observations and Findings

There were several observations that I made during the pilot study that helped improve the design of the main workshops:

1. It was clear from the start that the participants were uncertain of what was expected of them, suggesting that I had made the introduction too short.

2. The participants were hesitant to use the material in front of them (e.g., the support cards).

3. The participants did not explore many ideas, which suggests I should have made it more apparent that the goal of using the FsD methodology was to support rapid and extensive idea generation (10 or more concepts at the start). P1, P2, and P3 only completed Sheets 1, 2, and 5, highlighting the problem of time. P4 used all 5 sheets but it was clear that Sheets 3 and 4 were less detailed than Sheet 2.

4. I had the participants working individually to increase the number of ideas for the discussion; however, the room was very quiet, which likely made for a less creative atmosphere.

5. I expected the participants to retain a lot of information from the introduction, and although there were support materials on the table, it was likely overwhelming.

6. I set the final sketching stage to 10 minutes because less time should be required, however, the previous two stages were both 20 minutes long, and so the participants were used to having twice as long for sketching.

7. During the discussion it was clear that the table setup made it difficult to encourage the participants to get close for the discussion. There was a good discussion, but no audio recording; I could not write down everything while fully engaging with the participants.

All four participants completed their feedback sheet. Three participants (P1, P2, P3) wrote that time was an issue and the workshop would benefit from dedicating more time to the tasks e.g., P1 explained that the five design-sheet method was a new concept and required reading; however, P4 felt that the time was suitable because she likes "working fast".

I found mixed options with regards to the material used during the design workshop. P1 found the materials and, in particular, the design brief worksheet as useful. P2 found the material confusing but argued this was due to a lack of familiarity. P3 felt the materials used to support the workshop were strong and appropriate, but "challenging for rusty designers". Finally, P4 found the FdS methodology to be interesting but difficult to understand at first. P4 also requested more design tools (e.g., colour, post-its, scissors); however, since the goal of the first design workshop is to focus on rapid idea generation, increasing the number of tools is likely to increase the required time.

I received several suggestions on what I could have explained in more detail. P1 said to "*stress the fact that it is for a design tool, not another dark mode*". P2 and P3 felt the FdS methodology needed to be explained more, with P2 recommending I ask participants to look up the FdS methodology before the workshop. P4 requested more information with the task at hand and suggested the "*design brief worksheet could have been explained out loud*" followed by a discussion with everybody at the beginning. P4 suggested that the discussion could focus on the participants' experience with design and apps with day/night mode and their experience as users.

All four participants also made some final comments. P1 found the methodology a challenge for a "*non-creative*" personality. Both P2 and P4 felt that working in groups would have been better to support creativity. P3 found the workshop to be a good pilot "*well thought-through and prepared with glitches that you are now aware of*".

Pilot Conclusion

My pilot study provided useful insights, and I decided to make three key changes to the design workshop structure. After the introduction, I added a discussion with participants about their experiences with SVIs, using alternative modes, and designing alternative modes. I decided to remove the FsD methodology because I would be working with mobile app designers who likely sketch on paper as part of their job and are accustomed to generating ideas. The mobile app designers are also unlikely to know of the FsD methodology, and dedicating sufficient time to explain the FsD process would take up too much of the limited workshop runtime. I also decided to group participants during the sketching stage to encourage discussion and aid in the creative process.

5.3.2 Design Workshop 1: Material and Procedure

The goal of the first design workshop was to generate SVI design tool ideas on paper, which I would then use to build high-fidelity prototypes. The study took place in a meeting space in the Spinks Addition building at the University of Saskatchewan, Sasakatoon, Canada (see Figure 5.5). The room included a large table suitable for the participants to gather around at one end and work comfortably in their pairs. The room also included a large display, which I used to aid in providing an introduction to the session. The workshop took one and a half hours to complete.

I first asked the participants to read over the information sheet (Appendix D.25) before completing the consent form (Appendix D.26) and image and audio release form

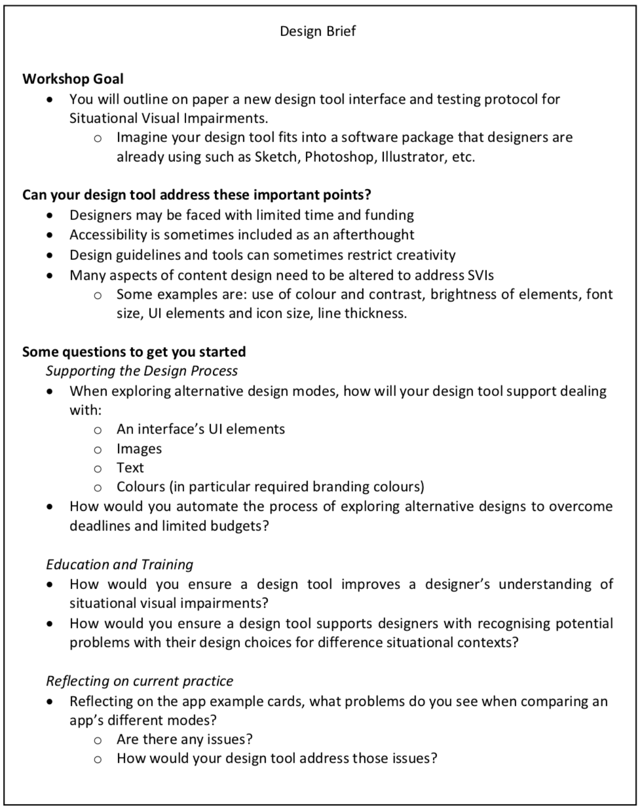
Figure 5.5: The room layout for the first design workshop with all materials laid out for the participants.

(Appendix D.27). The session was audio recorded so that I could transcribe the conversations at a later date allowing me to focus on leading the workshop.

I next asked the participants to complete a demographic form (Appendix D.28) to establish the participants' age, gender, level of education, number of years of experience designing, number of years of experience designing either Mobile App Interfaces, Mobile UI elements, or Mobile Web interfaces, and experience with using various design software and tools that were presented in categories based upon the analysed responses from the online survey (see Section 5.2.3).

I presented the participants with an outline of the design workshop (short introduction, discussion on mobile design, prototyping session, group discussion) so that they knew what to expect. I then explained that the purpose of the design workshop was to prototype design tools for SVIs, and therefore the participants were required to design something they saw as being useful. I also provided the participants with an overview of SVIs, and the link between design and SVIs, which we would discuss in more detail after the introduction. I gave the participants the same five rules from the pilot to ensure the design workshop ran smoothly, and I provided each participant with an SVI explanation sheet (the same from Study 2), which they could consult at any point during the workshop. It was important that the participants strive for quantity over quality at this early stage so that there were many different ideas to work with. The first workshop was only the initial part of the iterative process I was following, and I would gather further feedback in the second workshop to further refine and improve the prototypes.

During the first 20 minutes of the design workshop, I led a discussion with the participants to identify their personal experiences with SVIs, as well as to identify whether any of the participants had used alternative app modes for different situations (e.g., a dark mode for nighttime use). I focused on the participants' design experiences and


Design Brief

Workshop Goal
- You will outline on paper a new design tool interface and testing protocol for Situational Visual Impairments.
    - Imagine your design tool fits into a software package that designers are already using such as Sketch, Photoshop, Illustrator, etc.

Can your design tool address these important points?
- Designers may be faced with limited time and funding
- Accessibility is sometimes included as an afterthought
- Design guidelines and tools can sometimes restrict creativity
- Many aspects of content design need to be altered to address SVIs
    - Some examples are: use of colour and contrast, brightness of elements, font size, UI elements and icon size, line thickness.

Some questions to get you started
Supporting the Design Process
- When exploring alternative design modes, how will your design tool support dealing with:
    - An interface's UI elements
    - Images
    - Text
    - Colours (in particular required branding colours)
- How would you automate the process of exploring alternative designs to overcome deadlines and limited budgets?

Education and Training
- How would you ensure a design tool improves a designer's understanding of situational visual impairments?
- How would you ensure a design tool supports designers with recognising potential problems with their design choices for difference situational contexts?

Reflecting on current practice
- Reflecting on the app example cards, what problems do you see when comparing an app's different modes?
    - Are there any issues?
    - How would your design tool address those issues?

Figure 5.6: Study 6 Design Brief Worksheet.

whether they addressed SVIs through design. I distributed the same seven "Support Cards" from the pilot (e.g., seen in Figure 5.3 and Figure 5.4) to help the participants imagine the steps a mobile app designer would need to go through from a default UI mode to an alternative mode and what would be challenging when designing. The participants could then begin thinking about what features would be necessary for an SVI design tool. I explained that I was focused on exploring design tools because it was a highly requested solution in Study 3, there is often criticism towards the structure and usefulness of guidelines, and that design tools could include the functionality to guide and educate designers. I emphasised that no design tool would fit within every designers workflow, and therefore the participants should aim to make their ideas flexible.

Finally, I went through an updated "Design Brief" (Figure 5.6) to ensure the participants were clear about what I required them to do during the sketching session. The "Design

Brief" outlined the goal of the workshop. The design brief provided some key points that the participants ideas should address (e.g., designer may be faced with limited time and funding). I discussed these points and highlighted the important point that "design guidelines and tools can sometimes restrict creativity". I explained that from my previous work with designers it was clear when looking at accessibility design tools, if the tool does not support the designer in achieving what they need to, or it does not fit within their design process, then the designers will not use the design tool and it becomes abandoned. The design brief also offered some questions based on findings from my previous work to assist in the generation of ideas. For example, education and training was included so that the participants would remember to think of ways that their solution ideas could focus attention on the prevalence of SVIs and support designers in recognising design problems that would cause SVIs.

After the discussion, I provided pens, highlighters, coloured pencils, and A3 sheets of blank paper to the participants for their 40 minutes sketching session, and the participants were instructed to follow the design brief I had provided earlier. The session was fast paced for two reasons. First, the assigned time was used to encourage the participants to generate as many ideas as possible. Second, the participants all had their own commitments (e.g., jobs during the day) and it was therefore challenging to find a time that suited everybody. I asked that the participants work together in pairs to encourage further discussion and create a more stimulating environment. I told the participants when half of their time was gone and when five minutes were remaining so that they could complete their low-fidelity prototype sketches.

The workshop ended with a 20-minute group discussion about the ideas each pair explored. Each pair discussed their ideas first, followed by a whole group discussion each other's ideas.

I reimbursed each participant with a CAD$15 Amazon voucher.

5.3.3 Design Workshop 1: Participants

Four participants (three male, one female) took part in the first design workshop. The participants were aged between 19 and 33 years-old (Mean = 25.50; SD = 7.05).

Two participants had attained postgraduate university degrees, one participant had a college degree, and one participant had finished high school.

The participants had varying degrees of design experience. The participants had an average of 2.25 years of design experience (Range: 0-6 years; Median = 1.50 years; SD 2.60 years). With regards to designing for either app interfaces, mobile UI elements, or mobile Web interfaces, the participants had an average of 2.13 years of design experience (Range: 0-6 years; Median = 1.25 years; SD 2.66 years).

In terms of design software and tools used, all four participants had experience with physical tools, three participants (P1, P2, P4) had experience with graphics editors, two participants (P1, P2) had experience with visual effects software, two participants (P3, P4) had experience with coding environments, P3 had experience using prototyping software, and P1 had experience using supported collaboration software.

5.3.4 Design Workshop 1: Observations and Findings

I primarily used an audio recorder to capture the discussion during the design workshop. I also took observational notes and photos of the work the participants did. In this section, I highlight key moments during the design workshop and use quotes from the participants as evidence to support these observations.

Discussion on SVIs and Design

All four participants related to having experienced a situational visual impairment. P3 shared one SVI experience that he had:

> P3: "*So I have these sunglasses that are polarised...I can't see the dashboard of my car. So I have to look underneath my sunglasses... these are prescription sunglasses and my phone was the same way... cause it's polarised, everything is super blurry when you look through it, so I have to look at my phone underneath my glasses.*"

P3's account of an SVI highlights the risk that SVIs pose. P3 is unable to take off the sunglasses because they are prescription and it is likely to be a regular experience on account of not frequently changing his glasses, phone or car dashboard.

P4 provided an example that is a situational impairment but not an SVI:

> P4: "*It's not convenient. One thing that's quite common [is] when you are using [a] touch screen and you wear gloves, then that's a problem.*"

I was able to use this as an opportunity to clarify the specifics of SVIs to ensure the designers had a clear understanding.

When discussing alternative modes, P1 and P2 both used dark modes:

> P1: "*I have that extension that makes YouTube dark skinned.*"

> P2: "*Like I said, I use it all the time.*"

P3 inadvertently used alternative modes:

> P3: "*I don't do it on purpose but my Car Play does it. Sometimes it is black and sometimes it is white. It's not something that I intentionally do.*"

I asked the participants if they had any criticisms of alternative modes, but the group was uncertain. To help, I added the Support Cards to the discussion and asked the participants to now think as designers rather than as users.

> P3: "*I've never built theming or dark modes.*"

Since P3 had "*never built theming or dark modes*", I asked if he had considered the contexts that users would be using his apps, e.g., outside in bright sunlight or the middle of the night:

> P3: "*For sure. So instead of having the theming I typically try to make high contrast designs that would work across various environments. I've also designed a few apps for seniors so that was like really huge fonts and high contrast, bolded, no light fonts, that kind of stuff.*"

It was excellent that P3 considers context; however, the approach he described does not allow for user control. Within a different context, a high contrast design may be unsuitable. The other participants also clarified their experience with designing for SVIs:

> P4: "*I had [a] feature you could change font size but yeah not much working with contrast.*"

> P2: "*I feel like the closest I've got to is using white text over black. Just because you can see it in any light and over any screen, that's mainly video not an app per se.*"

> P1: "*I think it's already been mentioned, the font size.*"

P1, P2, and P4 all consider the implications of their design choices to some extent (e.g., high contrasting text is easier to read). However, they did not set out to design for a full range of contexts (e.g., various environmental conditions) and alter all aspects of an interface for those contexts (e.g., colour, font size, icon size). Interestingly, P3 raised a concern about design decisions clashing with the accessibility settings:

> P3: "*I always worry about colliding with the system level accessibility items. So all the OSs have like font size defaults so when my fonts are 'this' big by default and then somebody has that setting on then it makes it like 3x the size. So my design choices collide with the system level support. So I always worry about that part of it.*"

I found that P3's concern touched on an interesting point because if users are allowed to make adjustments to mobile app interfaces (such as changing contrast and increasing font size), then those changes may clash with any accessibility settings that the device has enabled. It may be helpful to inform designers about the way in which designs would change with enabled accessibility settings.

While the participants were reflecting over the support cards used to demonstrate different alternative mode, I asked them to think about how they would go from Design A to Design B, what support they would need to make the process as easy as possible. The participants also reviewed the support cards and highlighted several issues with the designs:

1. Photos as a background can affect text readability.
2. Use of colour (e.g., changing colour can result in a mismatch with colour associations).
3. Contrast (e.g., too low to read comfortably).
4. Amount of content (e.g., night mode should display less content).
5. Font size.

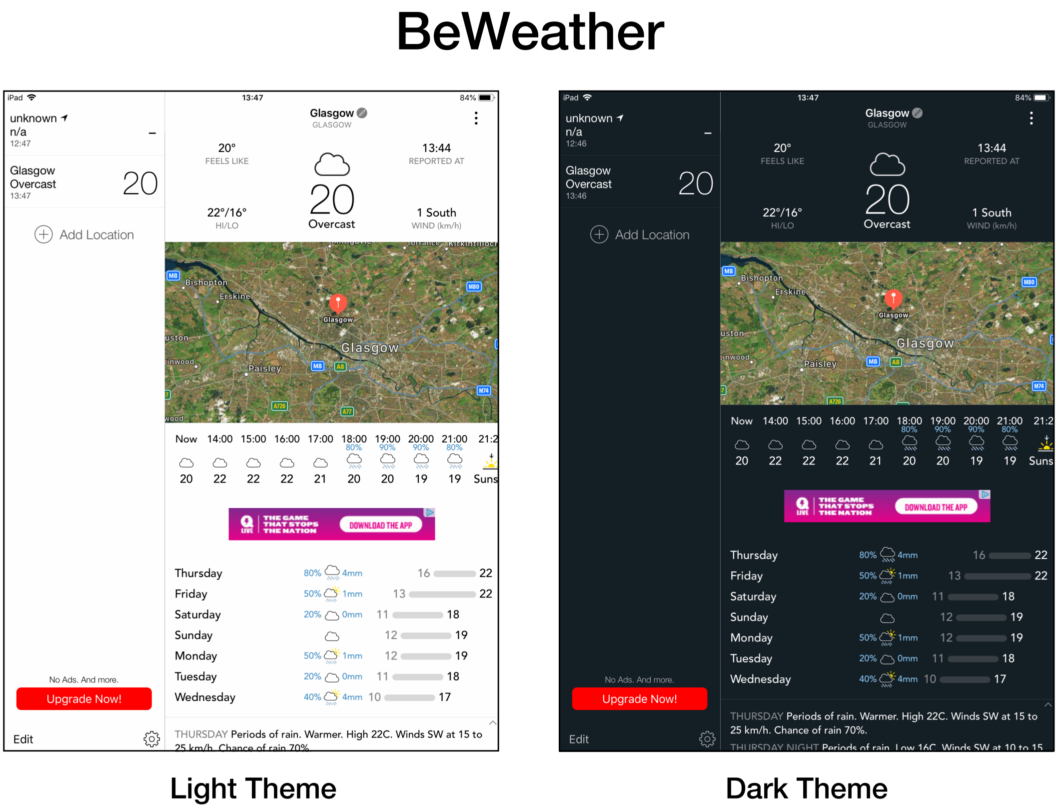


Figure 5.7: Example of a "Support Card" – The light and dark themes of the iOS BeWeather app.

In addition, I also highlighted that for some apps there is content the designer will not have control over, such as images posted on Twitter (Figure 5.4) or the advertisements in the BeWeather App (Figure 5.7), that there can be many of elements that a designer is responsible for (e.g., in the Pod Calendar App, Figure 5.3), and that some of the alternative modes appear to only be half complete (e.g., the Twitter App, Figure 5.4, and Signal app, Figure 5.8, both have unaltered elements that could be better designed).

Sketching Session and Discussion

I paired P1 and P2 together and P3 and P4 together. There was a noticeable improvement in how the participants began the task when compared with the pilot study. Dur-

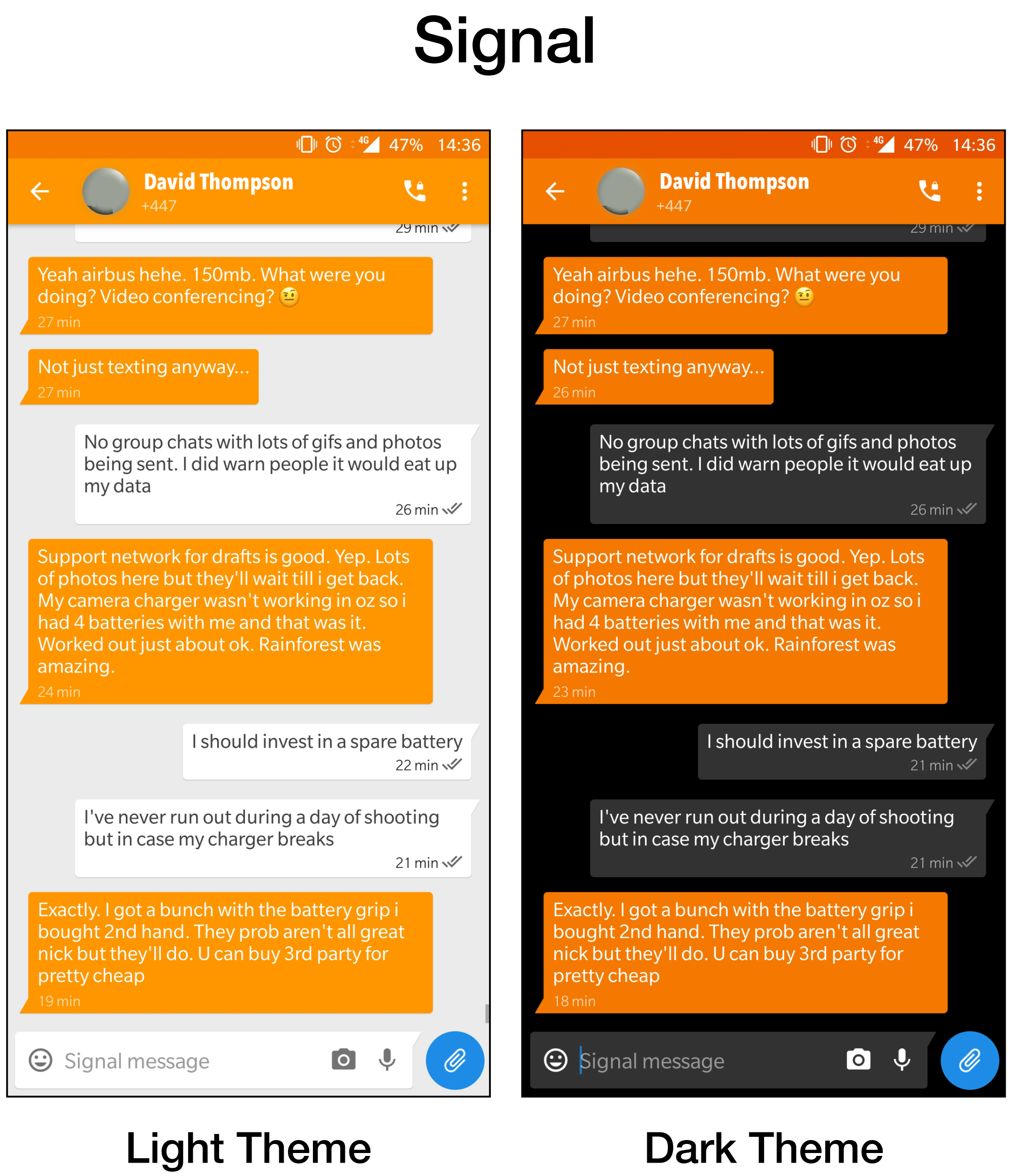


Figure 5.8: Example of a "Support Card" – The light and dark themes of the Android messaging app Signal.

ing this part of the workshop, the participants were sketching and talking quietly, and the audio was difficult to make out. However, I intentionally dedicated time towards the end of the workshop to discuss the low-fidelity prototypes for SVI design tools that the participants had sketched. There were moments when pairs came together to have a larger discussion. Figure 5.9 shows an example of the sketches that the participants produced in this part of the workshop (see Appendix D.29 for more).

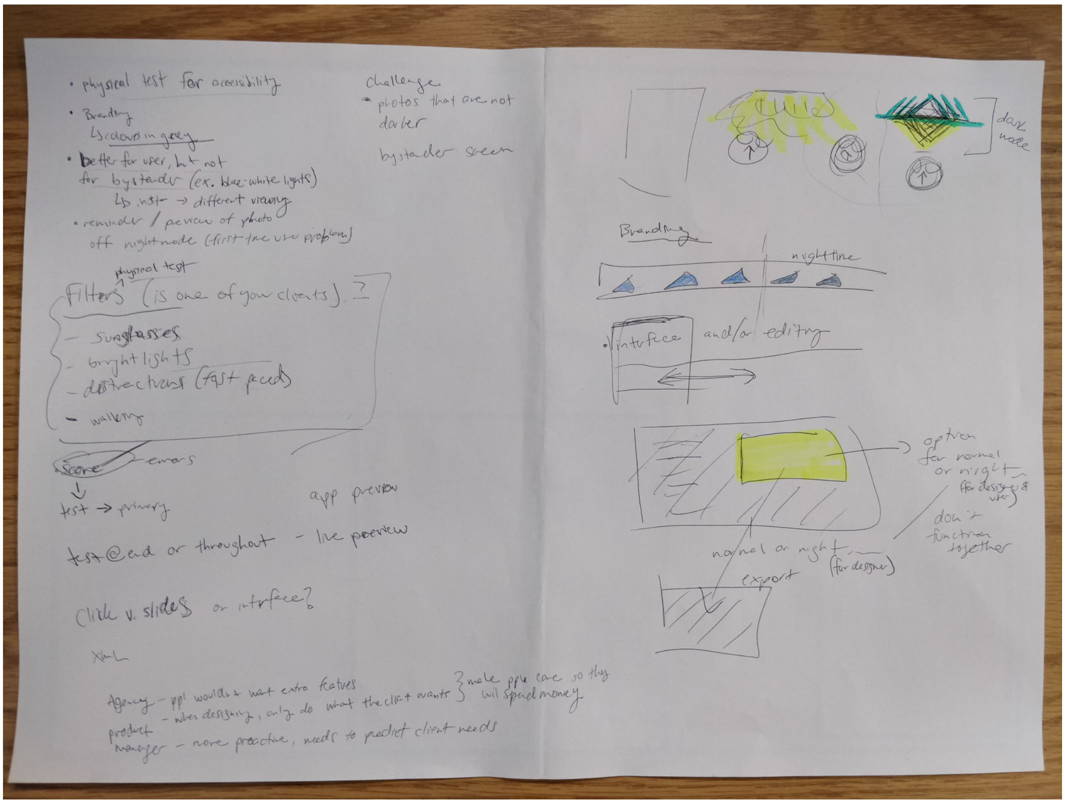


Figure 5.9: An example of the sketches produced by the participants in Workshop 1.

I have summarised the ideas from the participants in Table 5.1. I used these ideas to create high-fidelity prototypes in order to facilitate a discussion in the second workshop.

	Participant Ideas for SVI Design Tool Approaches
1	**Notification of issues:** e.g., pop-up error messages during design or after export.

2 **SVI simulation assessment:** e.g., simulations of different SVIs, e.g., sunglasses, bright lighting, walking.

3 **Real-time (live) demonstration of app:** e.g., short 5-10s video clips. The system "*doesn't have to assess it just shows or demonstrates*" after selecting an SVI context card.

4 **System conflict simulation:** e.g., simulation for demonstrating conflicts with system level adjustments (e.g., power saving, night mode, accessibility settings).

5 **Auto generate alternative mode:** e.g., a live preview of the alternate mode is shown when designing. The system asks for alternate logos/icons, colours, etc., and it would reject dark mode if branding colours are inappropriate.

6 **Suggestion sidebar:** e.g., use a sidebar to inform a designer of issues (e.g., when adding low contrast text the sidebar will indicate a problem).

7 **Adaptive design interface:** e.g., the system interface will change, such as displaying different tools in the toolbar for addressing different SVIs, and the designer can see the product in multiple situations.

8 **Pre-select alternative modes:** e.g., the system uses a start screen for the design to indicate the modes to be designed for (e.g., dark mode). When selecting assets (e.g., logos, buttons) in one mode, the system asks for assets for the other modes, and it can make recommendations.

9 **Guidelines:** e.g., the designer is provided with guidelines to avoid exporting a design they think will be usable when in fact for others (or on other devices) it will appear differently.

10 **Export review:** e.g., generate a report when a design is exported. The report can provide "*did you know tips*"; user-generated image warnings (placeholders from Google Images/Getty can be used); statistics about issues (e.g., 10% of people would not use your app because it does not work in low light).

11 **Working in greyscale:** e.g., to deal with branding limitations by having the designer work in greyscale to find tones that suit different situations.

12 **Impaired bystander:** e.g., the system supports designing so that a bystander is not impaired (e.g., distracting a partner in bed with light from the device). The tool would support the creation of a design that means the light is not focused on the other person).

13 **Running physical tests:** e.g., support the designer in being able to test their designs away from a screen such as going outside to evaluate a design in a bright environment.

14 **Compliance badges:** e.g., can be used to convince designers to address SVIs. The badges will indicate the different parts of an app that are good (e.g., there is sufficient colour contrast). These will be displayed on the App Store and will give peace of mind to the users.

Table 5.1: A summary of the core ideas generated by the participants in Workshop 1.

After the workshop, I grouped the participants' ideas into six categories that I could work with (ordered from what is expected to happen near the beginning of the design process to the end; see Table 5.2)[6].

Category Name	Participants' Idea(s)
Interface adaption	7 & 8
Notification of issues (*e.g., pop-ups, sidebar*)	1 & 6
SVI simulations (*e.g., live demo, conflicts with system changes such as night mode and accessibility font changes*)	2, 3, & 4
Auto-generated alternative modes	5
Review on export	10
Compliance badges	14.

Table 5.2: The participants' ideas grouped into six categories.

[6] ideas 9, 11, 12, & 13 are not included, and I provide an explanation in Section 5.3.5

5.3.5 Developing High-Fidelity Prototypes

I next spent two weeks developing high-fidelity prototypes based on the ideas generated by the participants in the first workshop. I created the high-fidelity prototype using HTML, CSS, JavaScript, Photoshop, Sketch, and Video Editing. I recorded concise videos of the high-fidelity prototypes in use – the shortest video was 7 seconds, and the longest video was 40 seconds (Mean = 24.33s; Median = 24.00s; SD = 10.19). In total, I developed 18 different high-fidelity prototype[7].

The high-fidelity prototypes I created cover different points (beginning, middle, end) in the design process. I divided the videos showcasing parts of the design process into the following categories.

1. *Beginning of design process*
   (a) Two videos: "Interface Adaption" (Figure 5.10) and "Pre-select Alternative Modes" (Figure 5.11)
2. *During/Mid design process*
   (a) Thirteen videos: "Forced Warning Notification" (Figure 5.12), "Controlled Warning Notification" (Figure 5.13), "Text-based Sidebar Warning Notification" (Figure 5.14), "Simulation-based Sidebar Warning Notication" (Figure 5.15), "Notification of Problematic Areas" (Figure 5.16), "Sunlight Simulation" (Figure 5.17), "Night Mode Simulation" (Figure 5.18), "In Situ Simulation" (Figure 5.19), "System Conflict Simulation" (Figure 5.20), "Free Exploration" (Figure 5.21), "Constrained Exploration" (Figure 5.22), "Simultaneous Real-time Alternative Mode" (Figure 5.23), and "Auto-generate Alternative Mode" (Figure 5.24)

[7] Videos are available here: https://www.dropbox.com/sh/meo0g8opbjisrsq/AABqJ8ZH_9uGlY9AJGVzM2m_a?dl=0

3. *End of design process*

   (a) One video: "Review on Export" (Figure 5.25)

Two additional high-fidelity prototypes were created based on the first workshop discussion but these did not fall within the design process. The first of the two videos demonstrated compliance badges as seen by the user when downloading an app ("Compliance Badges" Figure 5.26) and the second video demonstrated how the user could interact with images when "dark mode" is enabled ("Overcoming Dark Mode Limitations" Figure 5.27).

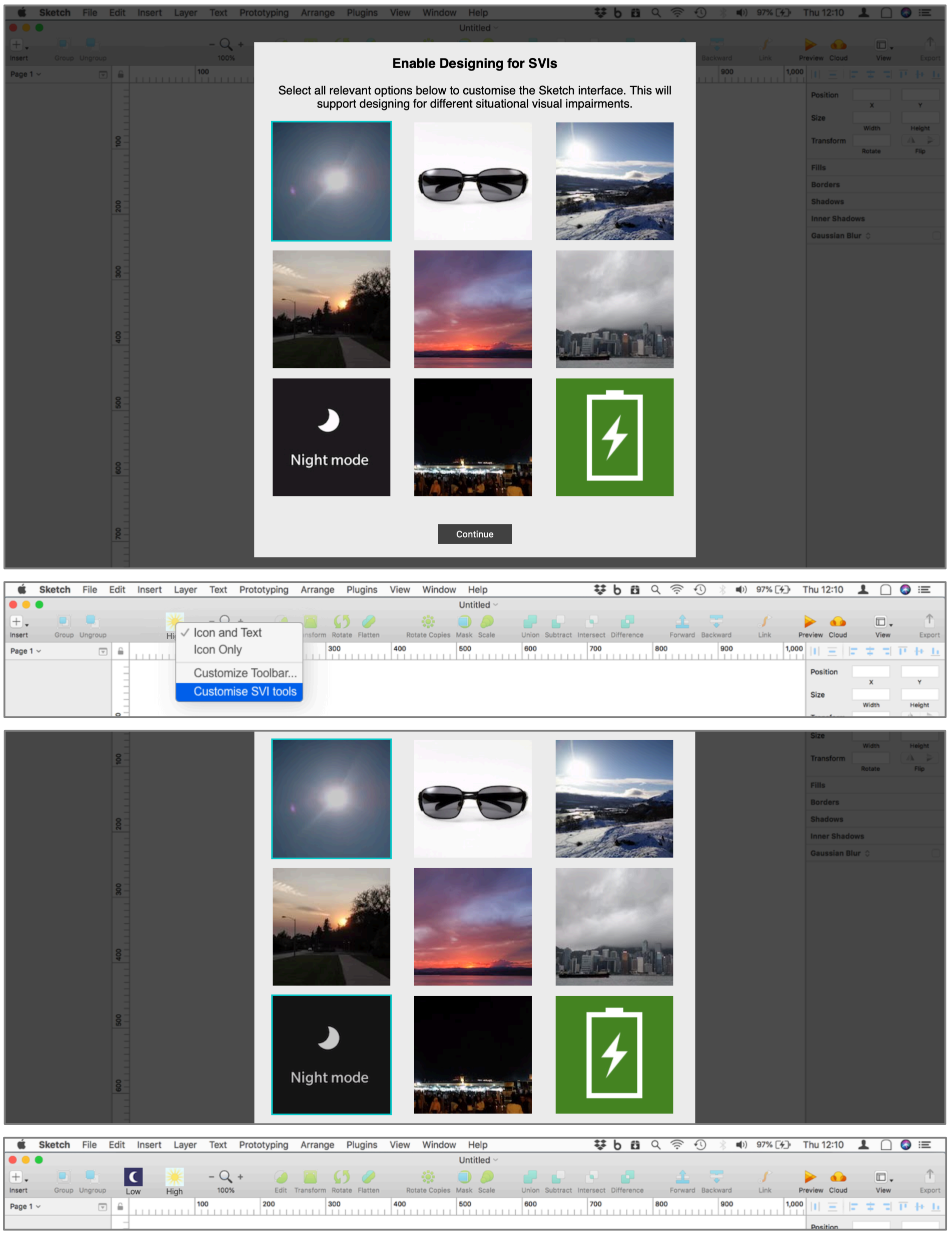


Figure 5.10: "Interface Adaption": When the designer opens Sketch a menu fades into view (top image). There are nine contexts (e.g., bright sunlight, low power. nighttime) the designer can select. When a selection is confirmed the Sketch toolbar includes tools specific for those contexts (second image from top). The designer can right-click the SVI tool icon to return to the previous nine contexts (second image from bottom), and the designer can choose to enable or disable those contexts, resulting in a change within the Sketch toolbar (bottom image).

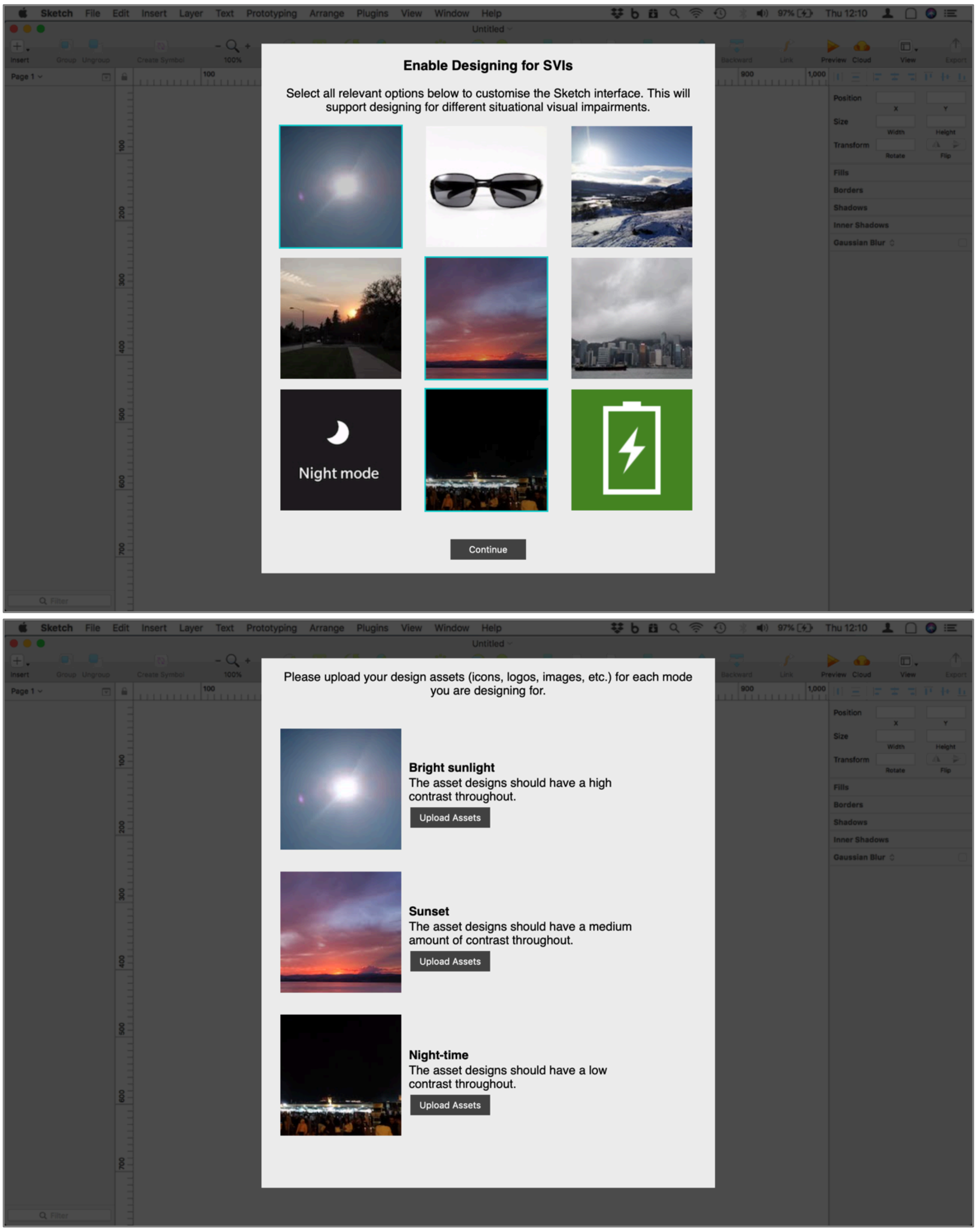


Figure 5.11: "Pre-select Alternative Modes": When the designer opens Sketch a menu fades into view (top image). There are nine contexts (e.g., bright environment, sunset. night-time) the designer can select. When the designer selects 'continue' a second screen is displayed (bottom image). The designer is advised on the design of the assets that need to be uploaded. For example, the sunset context suggests assets (e.g., icons, colour palettes) should have a medium amount of contrast, whereas the contrast should be low for the night-time context and high for the bright sunlight context.

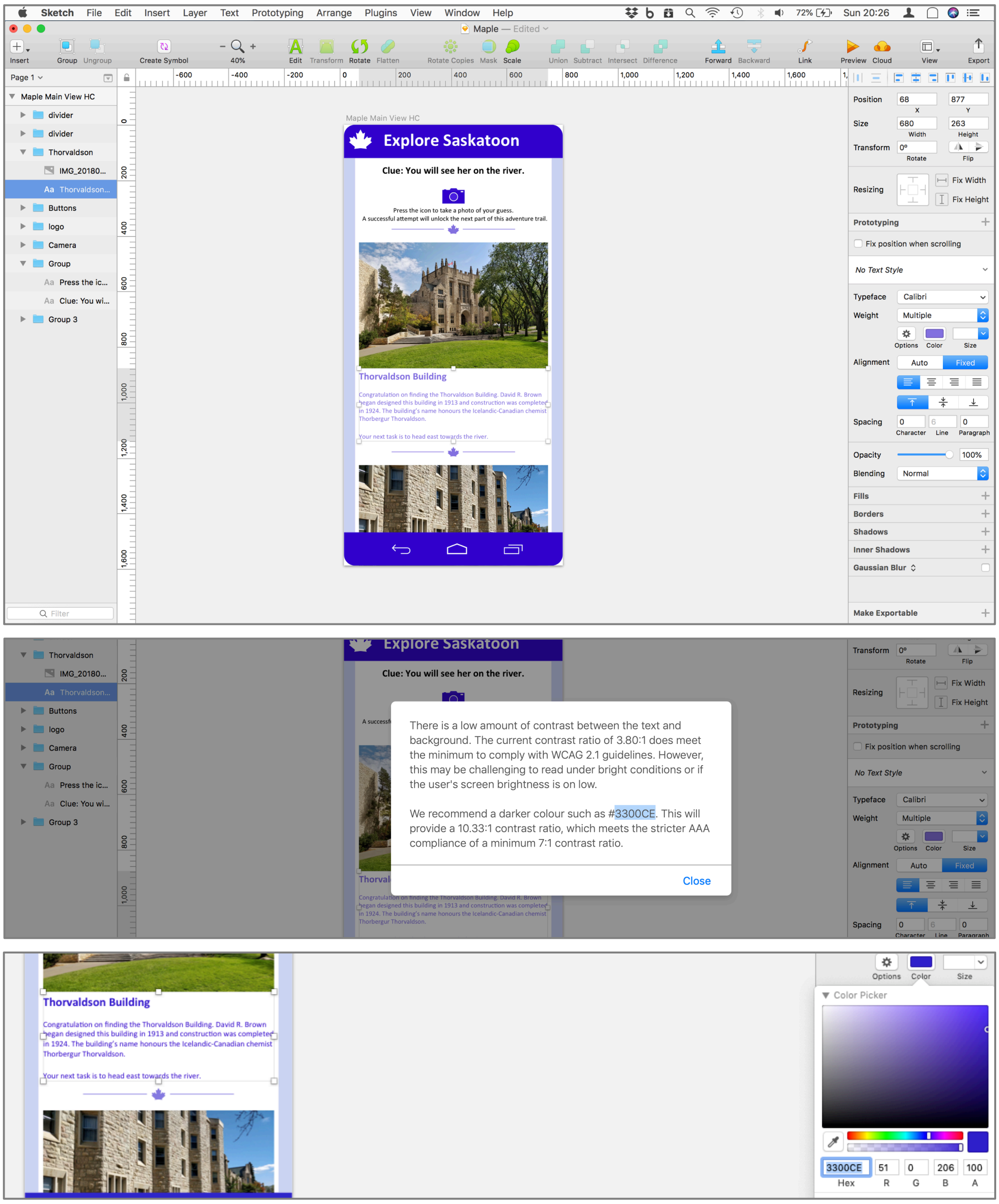


Figure 5.12: "Forced Warning Notification": While the designer is creating an interface, Sketch is analysing for potential errors. In this example, the designer has finished typing some text (top image). Sketch recognises that the font colour results in a low contrast due to the white background, which will cause problems because the designer indicated they are designing a high contrast mode. A warning message appears (middle image). The warning provides some information about the issue and the designer can copy the improved hex value suggested by Sketch. The designer can then easily paste the value into the colour picker to quickly change the text (bottom image).

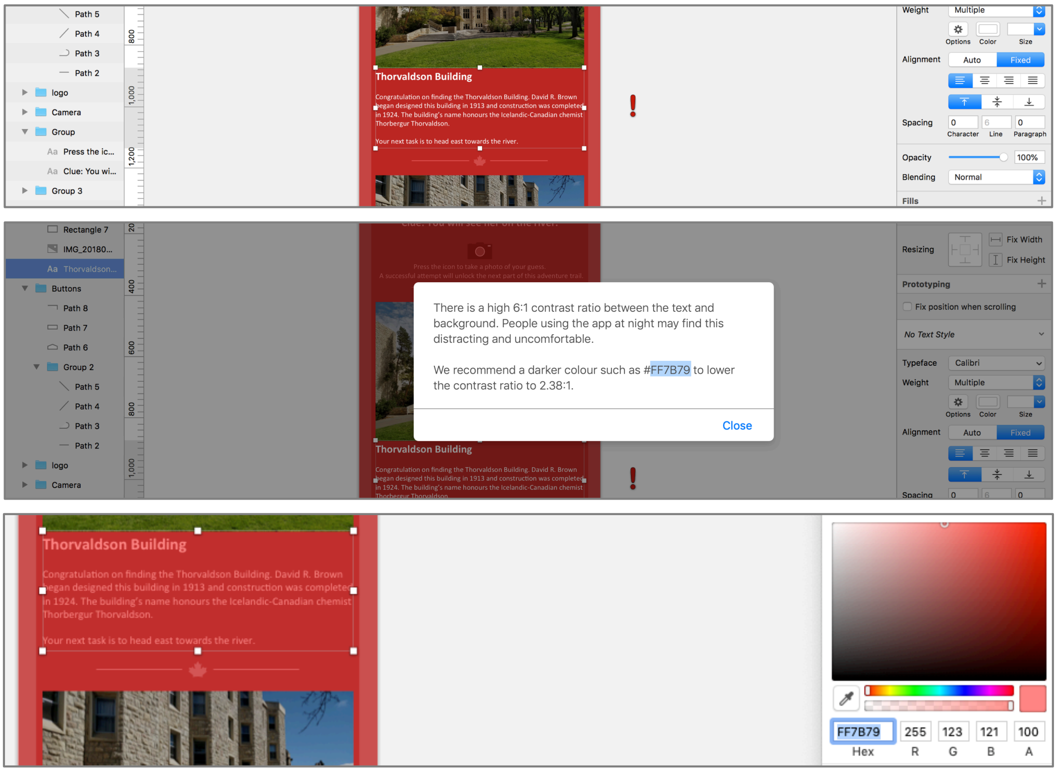


Figure 5.13: "Controlled Warning Notification": While the designer is creating an interface, Sketch is analysing for potential errors. In this example, the designer has finished typing some text (top image). Sketch recognises that the font colour results in a high contrast due to the red background, which will cause problems because the designer indicated they are designing a low contrast mode. A warning exclamation mark appears next to the area of the design that a problem has been detected (middle image). The warning provides some information about the issue and the designer can copy the improved hex value suggested by Sketch. The designer can then easily paste the value into the colour picker to quickly change the text (bottom image).

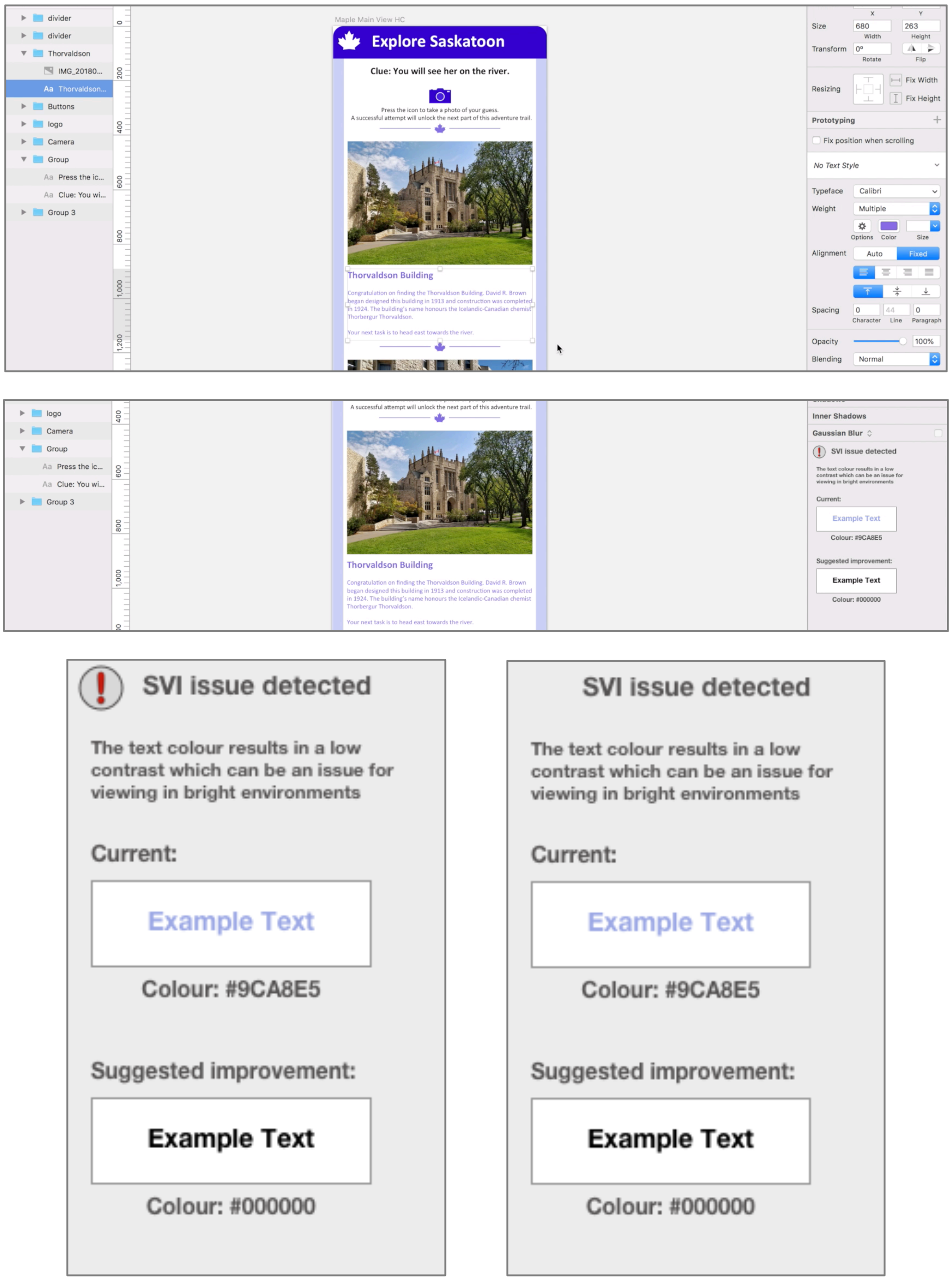


Figure 5.14: "Text-based Sidebar Warning Notification": While the designer is creating an interface, Sketch is analysing for potential errors. In this example, the designer has finished typing some text (top image). Sketch recognises that the font colour results in a low contrast to the white background, which will cause problems because the designer indicated they are designing a high contrast mode. A warning message appears in the sidebar (middle image), while providing some information about the issue and a solution. A notification icon flashes on (bottom left image) and off (bottom right image) to draw attention to the warning.

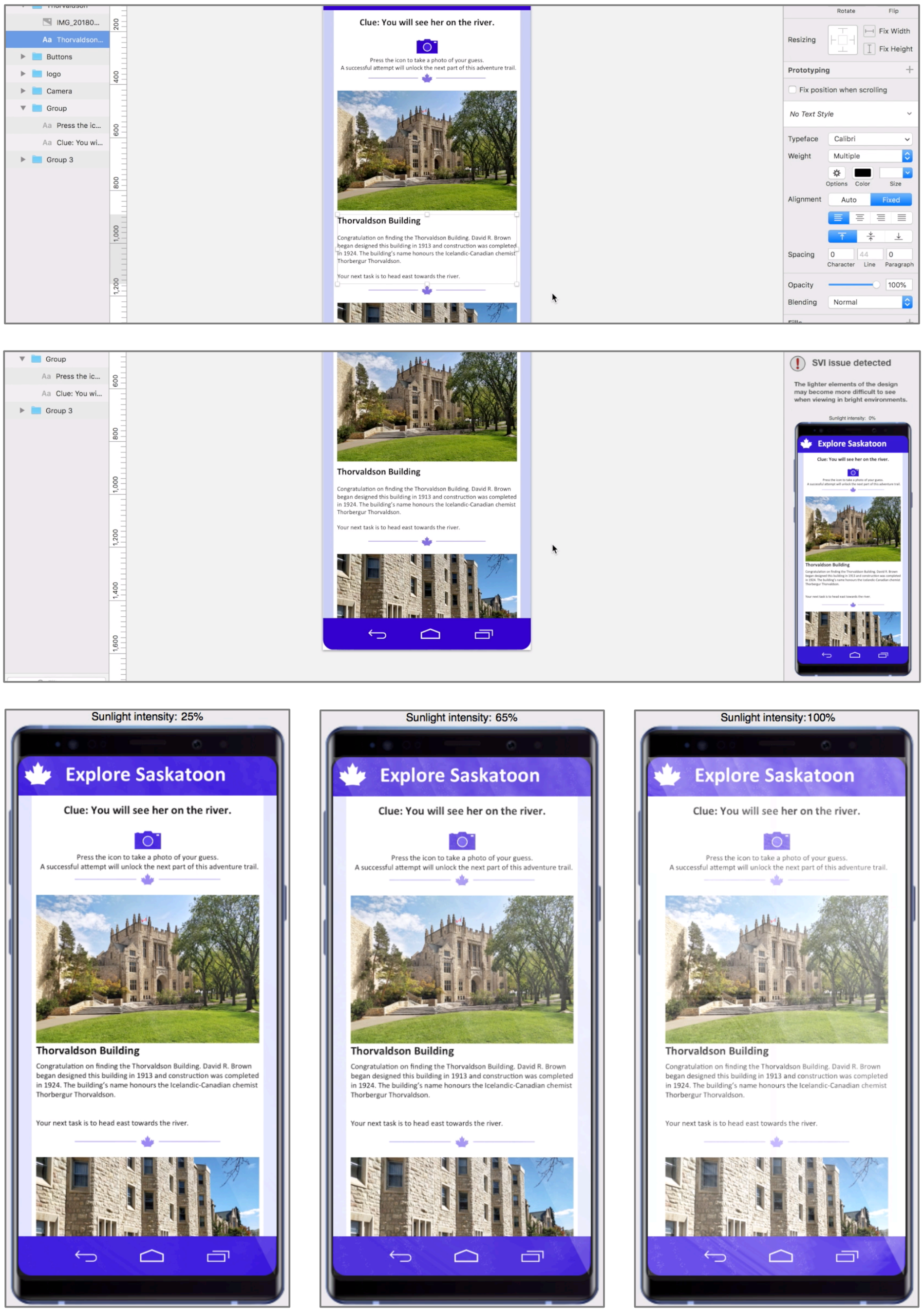


Figure 5.15: "Simulation-based Sidebar Warning Notification": While the designer is creating an interface, Sketch is analysing for potential errors. In this example, the designer has finished typing some text (top image). Sketch recognises that some of the elements will be difficult to view under strong sunlight. A simulation appears in the sidebar (middle image). The sunlight intensity simulation cycles through 0% to 100% (demonstrated by the bottom images).

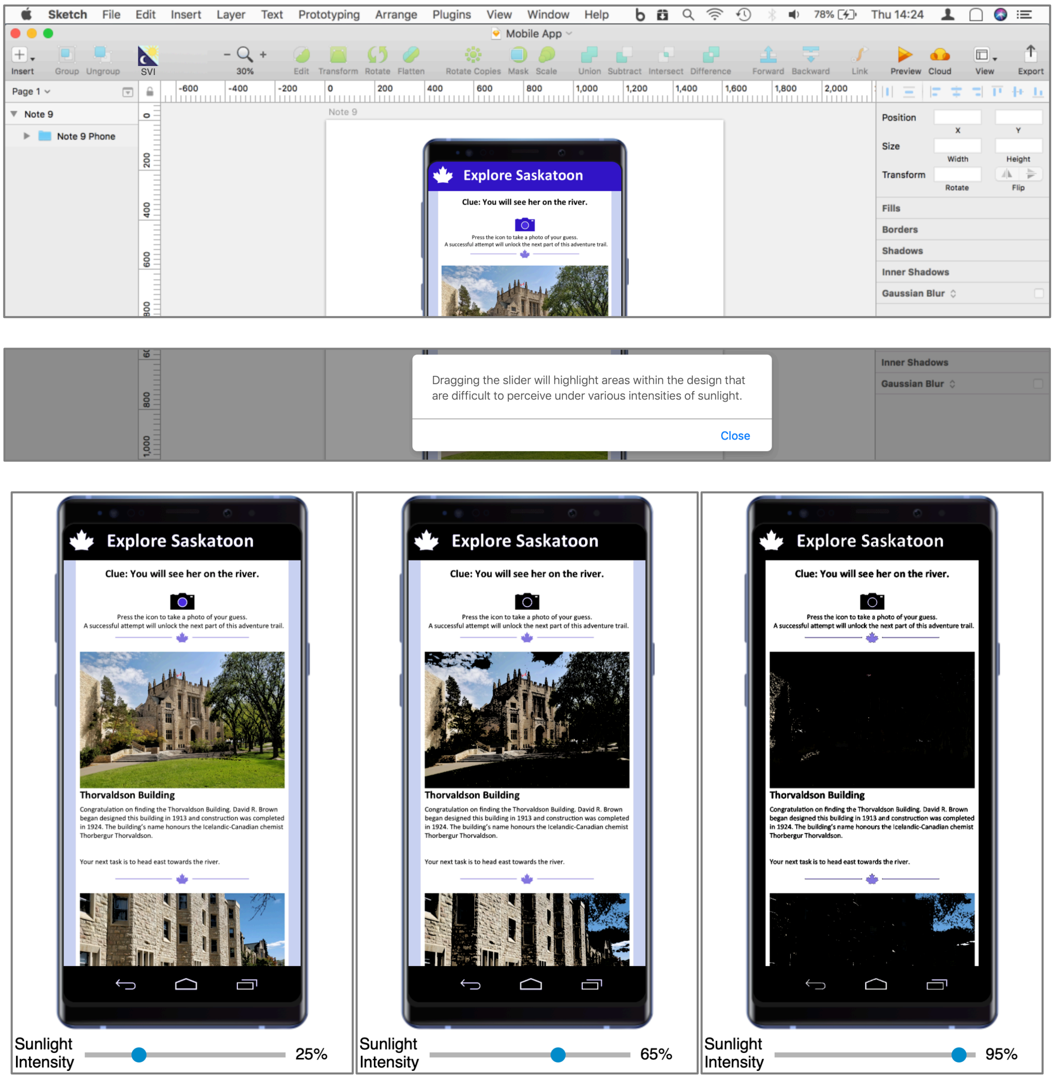


Figure 5.16: "Notification of Problematic Areas": When the designer is designing for a specific context (e.g., sunlight), they can select an SVI tool icon (top image), which runs an analysis of the design. A pop up informs the designer they can identify problem areas of a design (middle image). The sunlight intensity simulation cycles through 0% to 100% and recolours the areas of a design that will be difficult to distinguish under that particular intensity of sunlight (demonstrated by the bottom images).

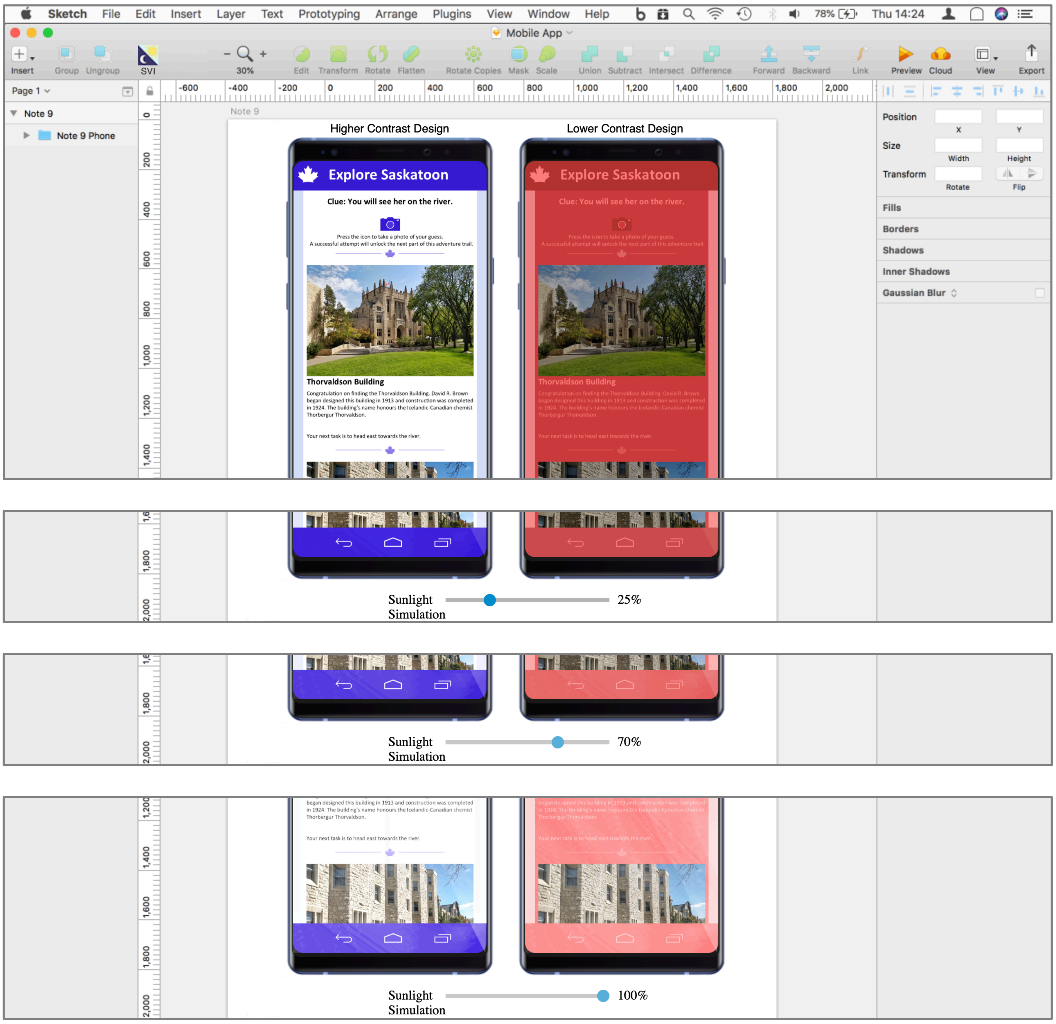


Figure 5.17: "Sunlight Simulation": The designer can run a simulation on their designs by selecting an SVI icon in the toolbar (top image). In this example, the designer is looking at comparing both a high contrast and low contrast design as if the user was using their device outside. The designer has control over the intensity of the simulation, which cycles through 0% to 100% (demonstrated by the three remaining images).

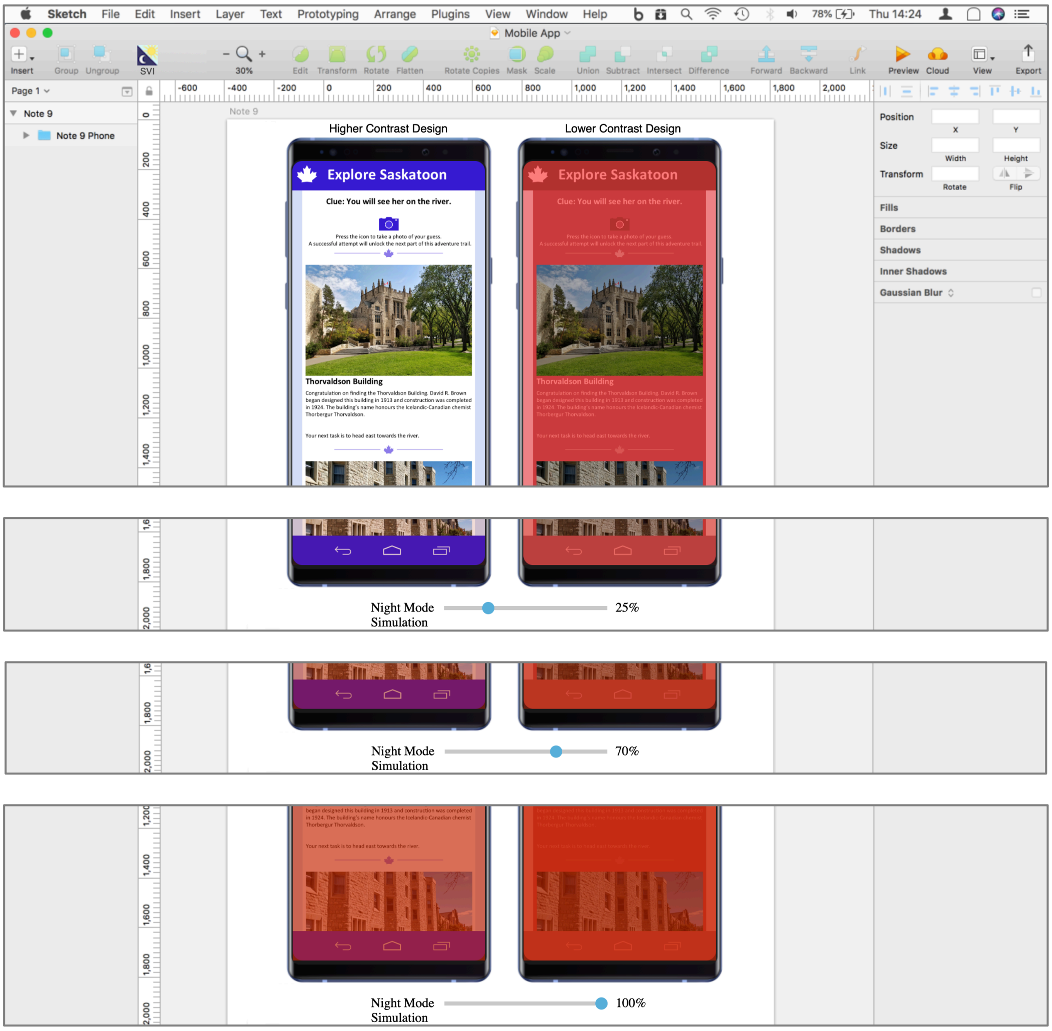


Figure 5.18: “Night Mode Simulation”: The designer can run a simulation on their designs by selecting an SVI icon in the toolbar (top image). In this example, the designer is looking at comparing both a high contrast and low contrast design as if the user had enabled night mode (which includes an adjustable blue-light filter). The designer has control over the intensity of the simulation, which cycles through 0% to 100% (demonstrated by the three remaining images).

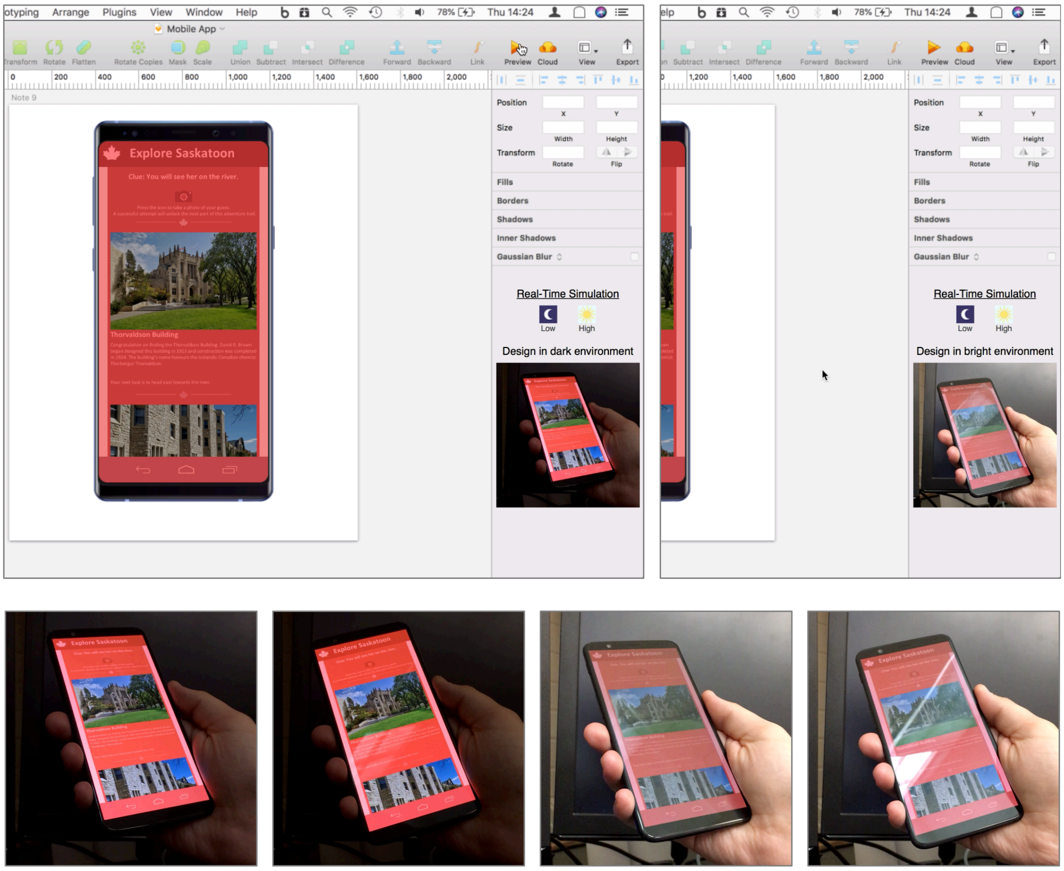


Figure 5.19: "In Situ Simulation": When the designer selects a preview button, a simulation is displayed in the sidebar that shows a rendered video of a mobile device with the design displayed on the screen (top left image). The designer can switch between a low and a high ambient illumination context (top right image). The video shows the device being used at different angles which will highlight any problems. Reflections are less prominent in the low ambient illumination simulation (bottom left images) compared to the high ambient illumination simulation (bottom right images).

Figure 5.20: "System Conflict Simulation": The designer can choose to identify potential system conflicts that could arise with their design. The option can be selected from the toolbar (top image). A window pops up, enabling the designer to switch between different modes, such as default vs large text and icons (middle images). The designer can view a solution to the problem with the ability to save the improved design (bottom images).

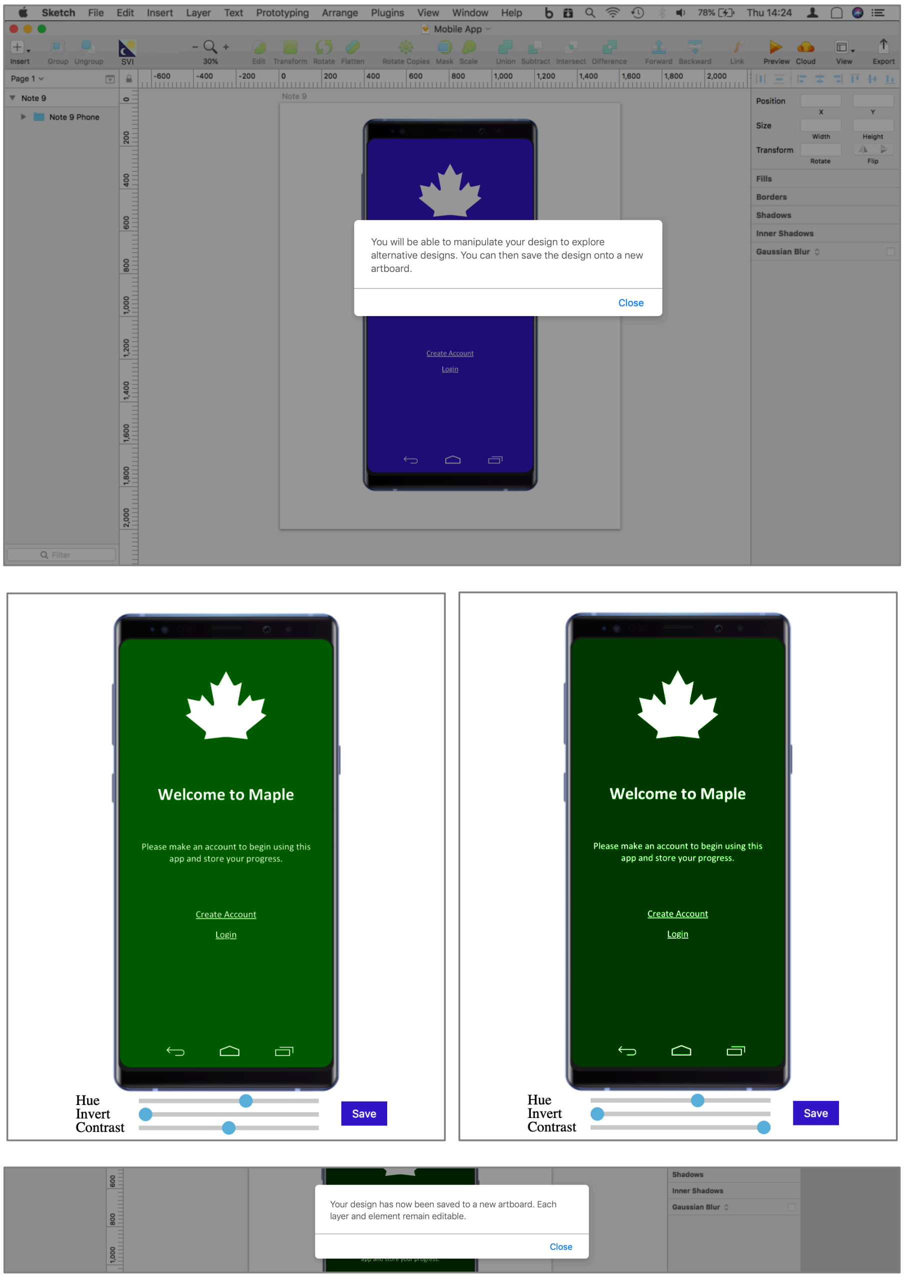


Figure 5.21: "Free Exploration": After the designer selects the free exploration icon in the toolbar, a message appears explaining that the designer will be able to manipulate the design and save their alterations to a new artboard (top image). The designer can quickly drag sliders for hue, invert, and contrast to alter the look of the design, such as making a higher contrast interface (middle images). When the designer saves their alterations, a message confirms the design has been saved and includes fully editable layers and elements (bottom image). This was one of the two ideas I had, which I wanted to show the second workshop participants.

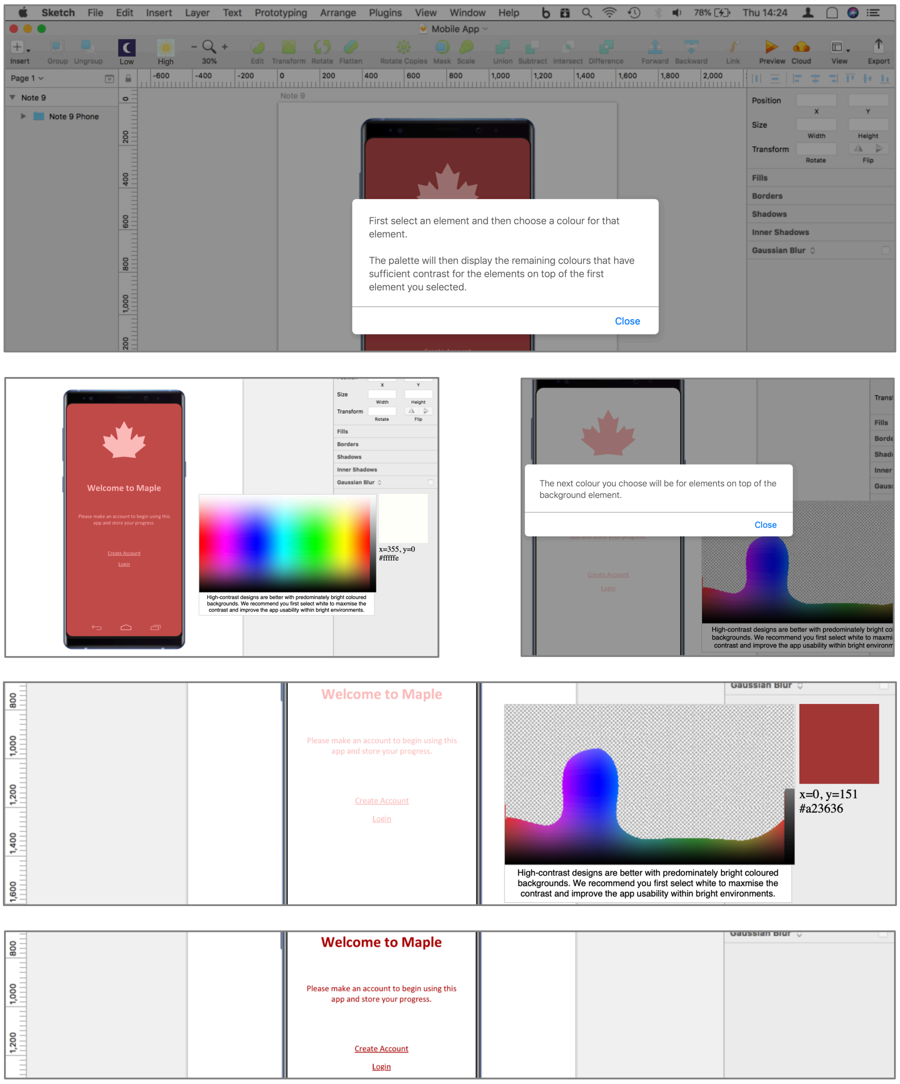


Figure 5.22: "Constrained Exploration": After the designer selects whether they want to create a low or high contrast design using the constrained exploration icon in the toolbar, a message appears asking the designer to select an element on the artboard (top image). When the message disappears the designer can see a colour picker with advice for the alternative design they chose to create, such as a higher contrast interface (left image, second from top). The designer is notified whether they select a foreground or background element, and then the designer must select a colour. The designer has chosen a bright colour and told to choose a colour for background elements (right image, second from top). The design is updated, and the colour picker now displays a subset of colours that would provide a suitable level of contrast (second image from bottom). This provides freedom within a constrained environment. Finally, when the second colour is chosen an update is made to the design (bottom image). This was one of the two ideas I had, which I wanted to show the second workshop participants.

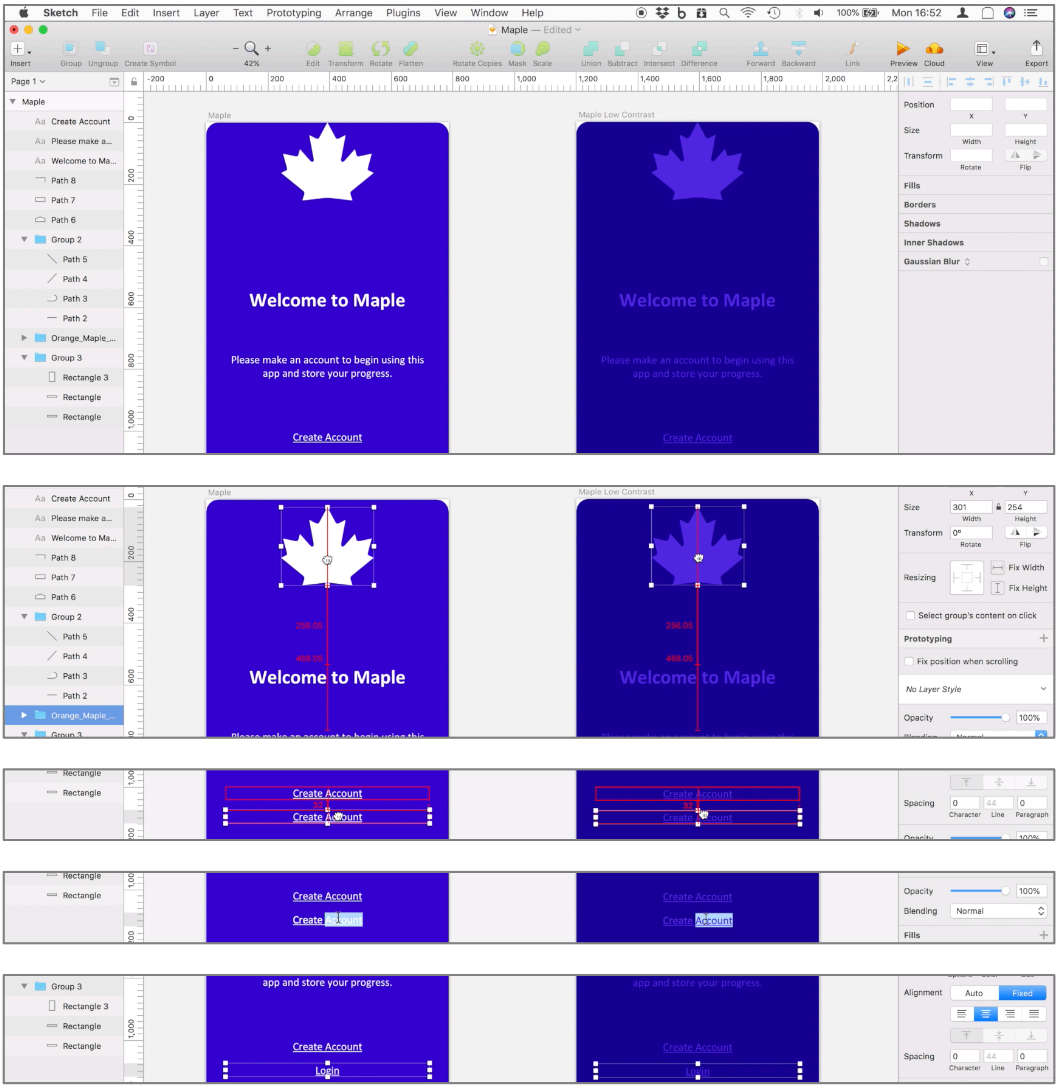


Figure 5.23: "Simultaneous Real-time Alternative Mode": When Sketch is put into this mode, the designer can select what alternative design they want to produce, such as a dark mode, and this is created in an artboard (top image). When the designer manipulates the default design, such as moving icons or editing text, the changes are observed on the alternative design simultaneously (as demonstrated by the remaining images).

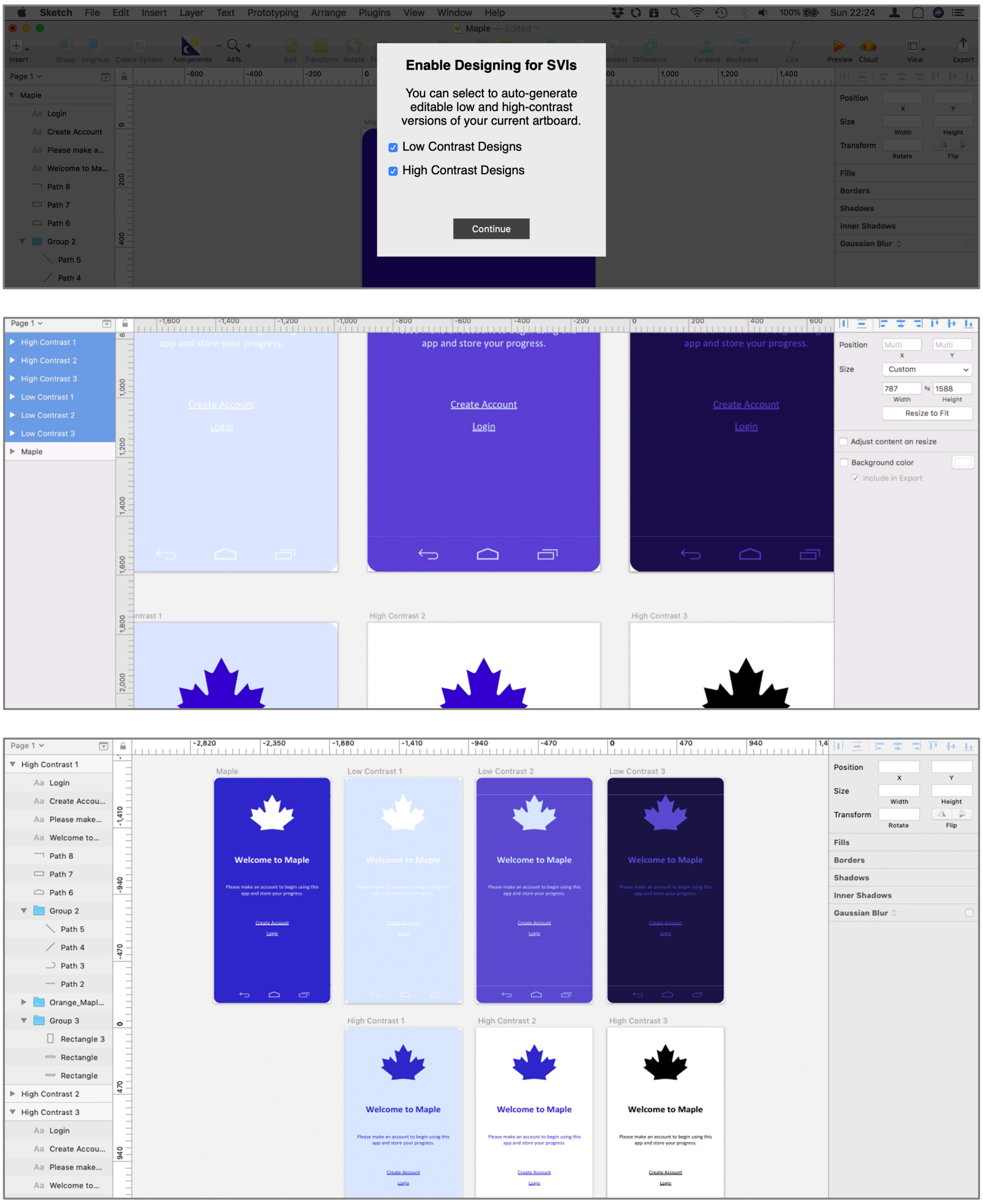


Figure 5.24: "Auto-generate Alternative Mode": The designer can access this feature from the toolbar. A menu pops up to ask the designer which alternative modes they want to create (top image). When the designer confirms the selection, Sketch creates several alternative designs using the original design (middle image). The alternative designs retain all editable layers (bottom image).

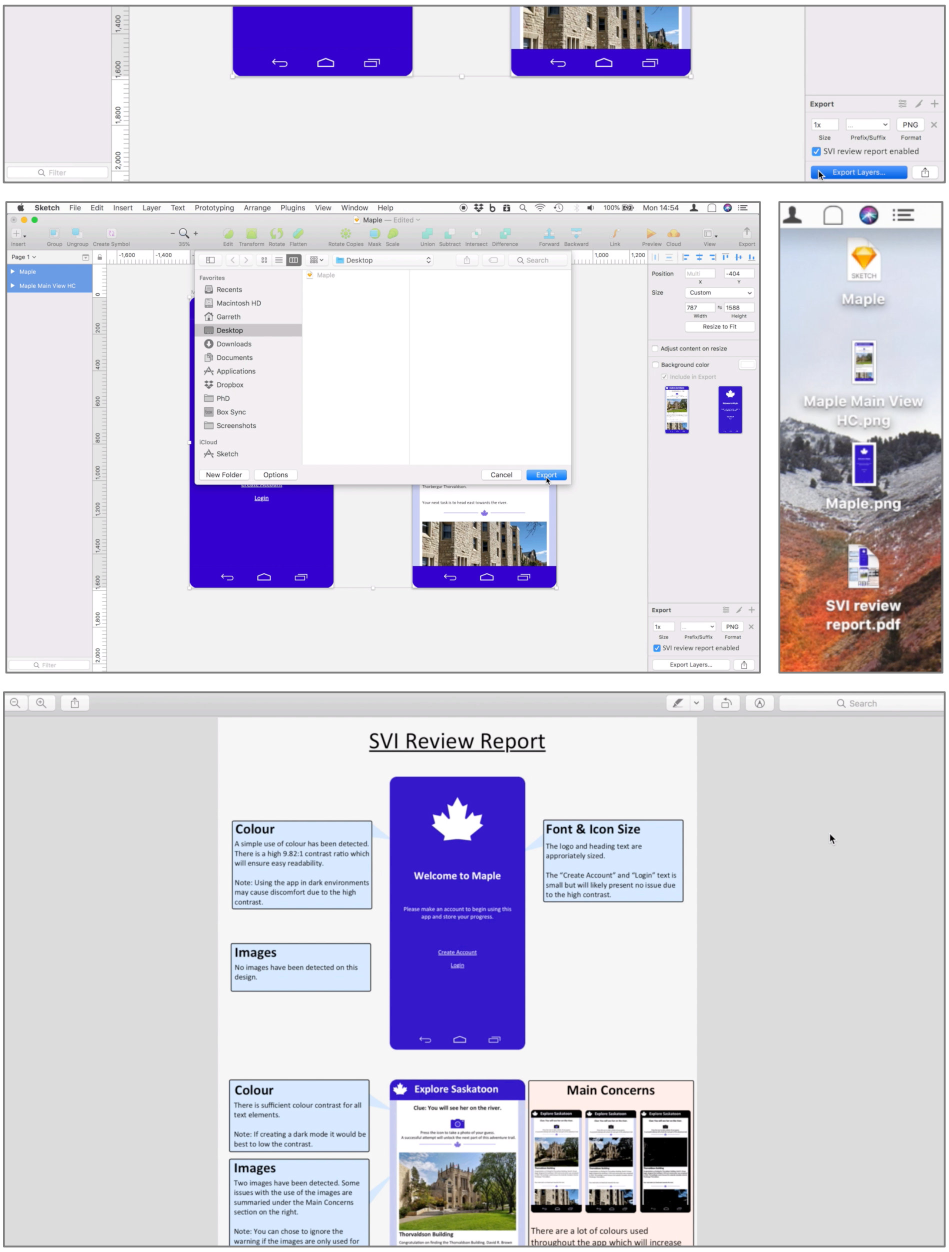


Figure 5.25: "Review on Export": When the designer selects all the layers of a finished mobile app interfaces, they are presented with an export layers button and can also enable the generation of an SVI review report (top image). The designer selects where they want to export the files, such as onto the desktop (middle left image). The desktop displays the mobile app interface PNG files and the SVI review report PDF (middle right image). The SVI review report will highlight potential problems with the different interfaces (bottom image).

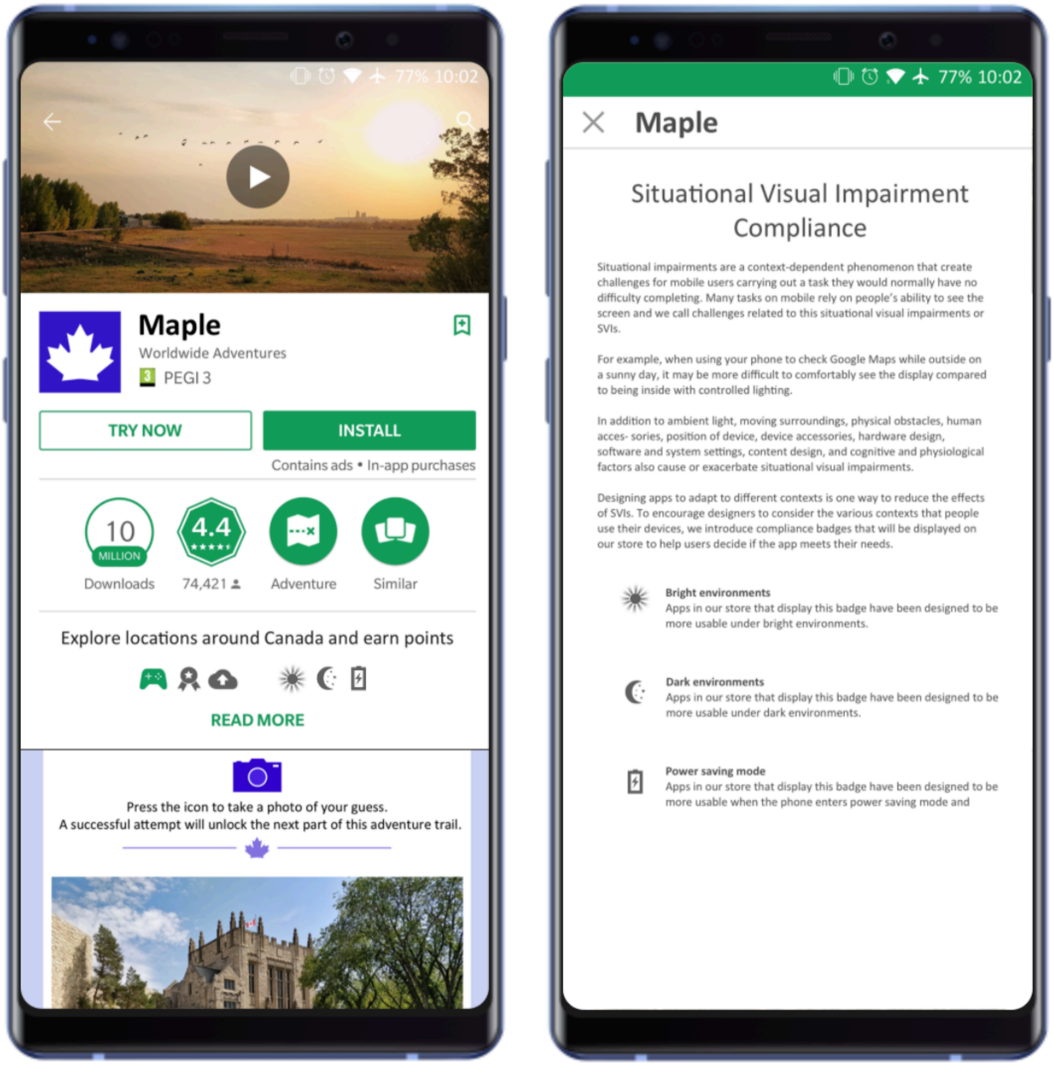


Figure 5.26: "Compliance Badges": This idea does not fall into a designer's design process. One way to inform users of an apps robustness to different contexts is to tell them on the download page of the app. Badges (e.g., sun for bright environments) can be used on the main download page of the app, where there would typically be other badges (left image). The user can select the badges to find out more details about their meaning (right image).

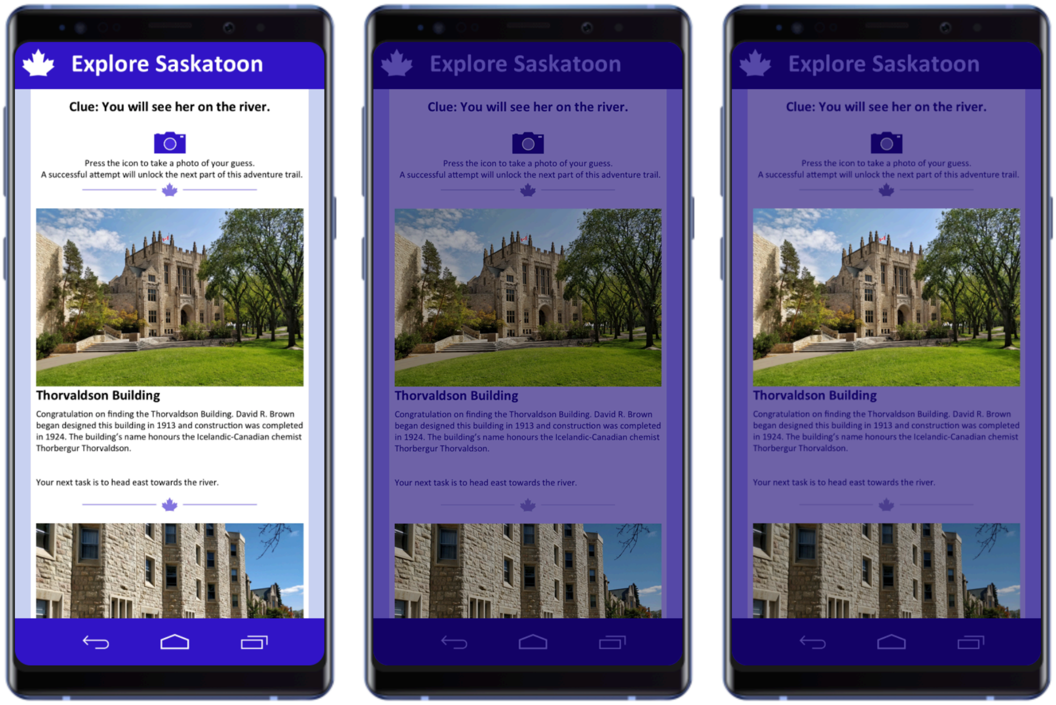


Figure 5.27: "Overcoming Dark Mode Limitations": This idea does not fall into a designer's design process. When an app goes into dark mode, user-generated content is typically unchanged. The idea with this concept is to give the user control. An app in a default mode (left image) enters dark mode (middle image) and the image also has a filter applied to match the dark mode theme. If a user wishes to see the image in its original form, they simply click on the image to disable the filter (right image).

I did not develop ideas 9, 11, 12, & 13 from Workshop 1 (see Table 5.1). I made sure to dedicate some time at the end of the second workshop to discuss with the participants my reasoning for not developing the ideas further. The justifications were:

1. **Guidelines** – Creating new SVI guidelines is important; however, designers generally have a negative view towards guidelines [Swallow et al., 2014] and the development of new guidelines falls out of the scope of the final studies goals, which is to provide recommendations for a digital SVI design tool. I have simply used WCAG 2.1 recommendations within my high-fidelity concepts to illustrate issues around contrast and font size.

2. **Designing not to impair bystander** – This would be very challenging to achieve through design alone, and a more straightforward solution might be to address the problem through hardware (e.g., using a polarising filter to minimise the displays viewing angle).

3. **Working in greyscale** – It was not clear whether only disabling colours would be enough or if designers would require a more intricate solution. Instead of creating a high-fidelity prototype, I planned to discuss this idea further at the end of the second workshop.

4. **Running physical tests** – This is a potentially useful approach; however, it would not be part of a digital design tool and therefore falls out of scope.

5.3.6 Design Workshop 2: Material and Procedure

The workshop took one and a half hours to complete, and was held in the same room as the first workshop (see Section 5.3.2).

I used part of the first 10 minutes of the second workshop as a recap of the first workshop. I summarised the different stages of the first workshop (discussion of SVIs and design, reviewing apps with alternative modes, the generated ideas from the sketching session, and the final discussion of those ideas). I then introduced the categories that I had identified the ideas fit within. The categories used were those summarised in Section 5.3.4: 1) interface adaption, 2) notification of issues (e.g., pop-ups, sidebar), 3) SVI simulations (e.g., live demo, conflicts with system changes such as night mode and accessibility font changes), 4) auto-generated alternative modes, 5) review on export, and 6) compliance badges.

Next, I explained what I had been doing for the two weeks that had passed since the first workshop, briefly mentioning that I created high-fidelity prototypes from the ideas generated in the first workshop. I mentioned that I had included two of my own ideas ("Compliance Badges" and "Overcoming Dark Mode Limitations"), and I explained the reason for not exploring four of the ideas further, but added that I did want to discuss those four ideas further near the end of the second workshop.

Twenty minutes were used to introduce and explain each of the 18 high-fidelity prototype videos. I provided the participants with feedback sheets (Appendix D.30) that included two statements with rating scales for each of the 16 high-fidelity prototype videos that fit within the design process[8]. The first statement was "*This feature would fit within my typical design workflow*" and the second was "*This feature is important if I was designing for SVIs*". Both scales went from 1 (Strongly Disagree) to 5 (Strongly Agree). I talked the participants through each video on its first play so that they were clear about what was happening. Then the video would continue to loop, and I waited for everyone to finish completing the two questions. Each video included a title and brief two line description, both of which I included on the feedback sheets.

I used the remaining hour for an active discussion of each video where the participants suggested improvements and I reimbursed each participant with a CAD$15 Amazon voucher.

5.3.7 Design Workshop 2: Participants

Four participants (three male, one female) took part in the first design workshop. All participants from the first workshop but P3 were able to attend the second workshop, a new participant (P5) was added. I provided P5 with information before he took part in the second workshop (e.g., the purpose of the first workshop, a summary of the tasks from the first workshop, the SVI explanation sheet). P5 completed the consent

[8] The last two videos "Compliance Badges" and "Overcoming Dark Mode Limitations" were not solutions that fit within the design process but solutions for the end user and were therefore not scored on the feedback sheet.

form and demographics questionnaire that I gave the first workshop participants (see Section 5.3.2). Participants 1, 2, and 4 were aged between 19 and 30 years-old (Mean = 23; SD = 6.08). P5 recorded his age as "25-35 years old".

The highest level of education attained for each participant was high school (P1), College (P2), Undergraduate University (P5), and Postgraduate University (P4).

The participants had varying degrees of design experience, with an average of 3.25 years of design experience (Range: 0-10 years; Median = 1.50 years; SD 4.56 years). With regards to designing for either app interfaces, mobile UI elements, or mobile Web interfaces, the participants had an average of 1.88 years of design experience (Range: 0-5 years; Median = 1.25 years; SD 2.17 years).

All four participants had experience with physical tools and graphics editors. Three participants (P1, P2, P5) had experience with visual effects software. Two participants (P4, P5) had experience with coding environments. P5 had experience using prototyping software, and feedback and guidance resources. P1 had experience using supported collaboration software.

P5 needed to leave the design workshop before it finished. He was present for the discussion of all the videos but missed the opportunity to provide other comments and discuss the four ideas I did not prototype after the first workshop.

5.3.8 Design Workshop 2: Observations and Findings

I followed a similar approach to the first workshop. I primarily used an audio recorder to capture the discussion during the design workshop. In this section, I quantify the participants' opinions on the prototypes using rating scale data. In addition, I asked the participants to come to a consensus on which prototypes they liked within each category and they would provide reasons why they did not like some of the ways in which the prototypes functioned. I highlight key moments during the design workshop and use quotes from the participants as evidence to support these observations.

Video high-fidelity prototype Scores

For each of the 16 videos, I summarise the average score and SD from the participants' completed feedback sheets in Table 5.3. I also summarise the average score in for each participant in Table 5.4 to help identify which participants were overall more receptive to the high-fidelity prototypes.

The lowest mean score when judging if the feature would fit within a workflow was 3.25 for "Controlled Warning Notification" and "Free Exploration". Interestingly, "Controlled Warning Notification" scored much higher on average (4.25) than "Free Exploration" (3.25) when judged on the importance of the feature. Overall, I found that the mean score across all the high-fidelity prototypes for how well they fit with the typical design workflow (Mean = 4.08, SD = 0.81) was lower than the mean score for the importance of the high-fidelity prototypes (Mean = 4.41, SD = 0.81). The score difference suggests the participants recognise the benefit each tool has for addressing SVIs but that further refinement is necessary, and this was clear from the discussion that I summarise next.

Regarding experience P1, P2, and P4 had less design experience (1.5, 0, 1.5 years) and experience with Mobile App Interfaces, Mobile UI elements, Mobile Web Interfaces (1, 0, 1.5 years) compared to P5 (10 years and 5 years). Therefore, it is interesting to note that P5 was much more critical about the high-fidelity prototypes fitting his design workflow (Mean 3.19) compared to P1, P2, P4 (Mean 4.94, 4.38, 3.81). P5 did provide higher ratings when saying if he felt the feature was important for designing to reduce SVIs.

	"This feature would fit within my typical design workflow"		*"This feature is important if I was designing for SVIs"*	
	Mean	**SD**	**Mean**	**SD**
1. Interface Adaption	**4.75**	**0.50**	**4.75**	**0.50**
2. Pre-select Alternative Modes	**3.75**	**1.26**	**4.25**	**0.96**
3. Forced Warning Notification	3.25	0.96	4.25	0.96
4. Controlled Warning Notification	4.00	0.82	4.75	0.50
5. Text-based Sidebar Warning Notification	**4.50**	**0.58**	4.75	0.50
6. Simulation-based Sidebar Warning Notication	4.50	1.00	**5.00**	**0.00**
7. Notification of Problematic Areas	4.25	0.96	4.50	0.58
8. Sunlight Simulation	3.75	0.96	4.25	0.96
9. Night Mode Simulation	4.00	0.82	**4.75**	**0.50**
10. In Situ Simulation	**4.50**	**0.58**	4.50	0.58
11. System Conflict Simulation	**4.50**	**0.58**	4.50	0.58
12. Free Exploration	3.25	1.50	3.25	1.26
13. Constrained Exploration	**3.50**	**1.29**	**3.75**	**0.96**
14. Simultaneous Real-time Alternative Mode	3.75	0.96	3.75	0.96
15. Auto-generate Alternative Mode	**4.50**	**1.00**	**4.50**	**1.00**
16. Review on Export	**4.50**	**0.58**	**5.00**	**0.00**

Table 5.3: The average score (with SD) given to each high-fidelity prototype by the second workshop participants. Bold scores indicate the best rated high-fidelity prototype per question for each category.

These scores were recorded individually before the participants took part in any group discussion. The scores are more positive than the feedback given during the group discussion. However, the prototype preferences demonstrated by the highest scores in each category match the group consensus voiced during the discussion. During the discussion I wanted the participants to tell me what they would change or improve and so it was more likely that the discussion would include much more critical reflection

	"This feature would fit within my typical design workflow"		*"This feature is important if I was designing for SVIs"*	
	Mean	**SD**	**Mean**	**SD**
P1	4.94	0.25	4.94	0.25
P2	4.38	0.50	4.56	0.63
P4	3.81	0.91	4.00	0.97
P5	3.19	0.91	4.13	0.89

Table 5.4: The average score given to the high-fidelity prototypes by each participant in the second workshop.

on the prototypes.

Group Discussion of High-Fidelity Prototype Videos

Overall, there were some general comments that are worth highlighting to provide more insights into how the participants work. I will summarise these points first and then discuss the feedback for each category of videos.

Sometimes the high-fidelity prototype could be too intrusive or disruptive when considering that the features demonstrated in the videos would have to fit a designer's design process:

> P5: "*From a person who uses a lot of apps...it seems like a lot of them are very intrusive, you're kind of like doing your colour and it's like BAM... if a plugin or something was constantly doing that I would end up disabling it.*"

> P2: "*...having a pop-up kind of...I don't know, hinders your efficiency...because you are distracted.*"

It was important that I refined the high-fidelity prototypes to avoid an outcome in which a designer will not want to use a particular feature.

Limited project time was an issue that participants reported in both Study 3 and Study

4 (see Chapter 4). Exploring SVI solutions is likely to be a low priority due to restrictions on time unless the client specifically requests the designer address SVIs. Therefore, enabling a system to do some of the work is useful and would support designers; however, the issue is that an SVI design tool needs to function well in this role and some designers (particularly those who enjoy their job) would miss out on being creative:

> P4: "*... if there is a time constraint and like an employer doesn't care much about like SVI, I would go ok, it's the best option is like the interface itself generates those different modes. But if there is no time constraints and there is enough money, I would say ok I will do it myself because a human can design better than a computer...*"

> P5: "*I'm hesitant about using a plugin that auto-generates palettes and stuff, just cause, especially [because] it [would be] very much app dependent, that would work good on very simplistic apps with very few layers and very few colours. As soon as you start doing more complex things, it seems like it could kind of either be difficult to use or just give you wrong results but that's just an estimation.*"

Designers may be receptive to using the automatic options built into an SVI design tool; however, the support should be approached in a way that meets their needs when they are doing their own work.

During the group discussion, I mentioned that I was surprised by the number of tools designers use for different parts of their design process. P1 said there would "*usually [be] four programs running at the same time*" and he will "*copy and paste*" between those programs. In spite of this variety, I chose to use Sketch for my high-fidelity prototypes because 1) it was the most popular tool in Study 5, and it had been discussed during Study 4 as well, and 2) the core ideas of the high-fidelity prototypes should translate to other design environments due to the typical interface layout of design software. I did not demonstrate the use of additional programs alongside Sketch when showing the high-fidelity prototypes.

Another finding was that within a single design program the designers might have many things going on, increasing demands on screen real estate. I asked the participants that use Sketch how many artboards they tend to have:

> P1: "*A lot that it crashes.*"

> P5: "*Crap load.*"

An SVI design tool built into a program should not take up more space than is required. Similarly, the space concern was raised again when showing the high-fidelity prototypes that made use of the sidebar. I asked whether the participants were required to scroll through the sidebar often because in my limited experience of Sketch it was not a lot:

> P1: "*Not too much, but I'm just concerned. That's taking up kind of like half of the sidebar.*"

For some designers, it is likely to be unacceptable for the system to behave in this way.

Colour is an important aspect of design, and on realising the complexity of the set up some designers have, I was interested in finding out how the participants keep track of colours in Sketch:

> P1: "*There's an option where, for example, if you have like brand colours... I'll be able to put like the HEX value and you would save it. You'd just like click the add and it'll just be there. It comes in handy!*"

> P5: "*Other things I've seen people do is either like make a bunch of squares with the different colours or we're using Material Design so we have the Material Design colours and they just built an Adobe XD and I believe a Sketch file just [with] all*

the different colour variations. You can just copy and paste them from those, that Sketch document to yours. So kind of like using a palette, you just kind of make elements with those colours and save them for late."

Designers use features of the system (when available) or find an approach that is at least suitable for their design process. I asked if it was possible to label colours and P1 said "*I guess I just work on it so much that I just know.*" It is clear that designers have a specialised skill that although a labelling feature would help non-designers, it is potentially unnecessary for professional designers.

Discussion on interface adaption

The designer is prompted to indicate which SVIs they want to design to address. The design software interface adapts as necessary. See Figure 5.10 for details.

Although P4 was positive about the idea: "*...I feel that's good because I know at the beginning...you can read on what kind of different modes you want at first. So that would be easier like ok we have this amount of time, and we probably can end up just like designing three modes*", there was criticism from other participants who felt the interface adaption would be better hidden within a menu:

> P1: "*It kind of like makes Sketch as specifically for that which I don't think it is, we don't do...all the time... Sometimes I use Sketch just to like design icons and stuff and I don't think for that purpose I specifically need [the mode selection screen appearing], it's kind [of] annoying.*"

> P5: "*I would probably have it that as kind of the menu there, the menu lets you drop down and checkbox happens instead of a big modal, just something that's more like sitting there ... It's too much.*"

There is a fine balance between making a feature's existence known and not making it the primary feature of the software. P1 makes the important point that sometimes the software is used for very simple tasks (e.g., icon design). Although I would argue that even icons do need alternative designs to fit more seamlessly within alternative modes, if the designer just wants to work on the general design without consideration of size and colour, then choosing SVI modes for the appropriate software interface is not needed.

Discussion on pre-select alternative modes

The designer is prompted to indicate which SVIs they want to design for and is then asked to upload assets for each context. See Figure 5.11 for details.

P5 mentioned prompting the designer from the start is not good, especially when a designer is unlikely to have all the assets:

> P5: "*If you're starting from a blank state you're not necessarily going to have all the assets made, you'll probably be making them as you're going. So having to upload everything and having everything prepped at the beginning I don't know if everyone will have that.*"

P5 decided that it would be easier to sketch out the idea on paper (Figure 5.28) to demonstrate how the system could avoid pop-up messages.

According to P5, the designer would work within the design software, and when the designer selects a colour there would be options "*...underneath where you have the night mode. As you go on you can add it. In the colour palette itself you are adding the colours for one thing I want to also make sure I add this for night mode and stuff. So it's kind of in the interface there. It's not popping up. It's just as you're going you can do that and hopefully switch between the modes, it would switch colours that you are using.*"

P4 suggested that rather than the approach demonstrated within the high-fidelity pro-

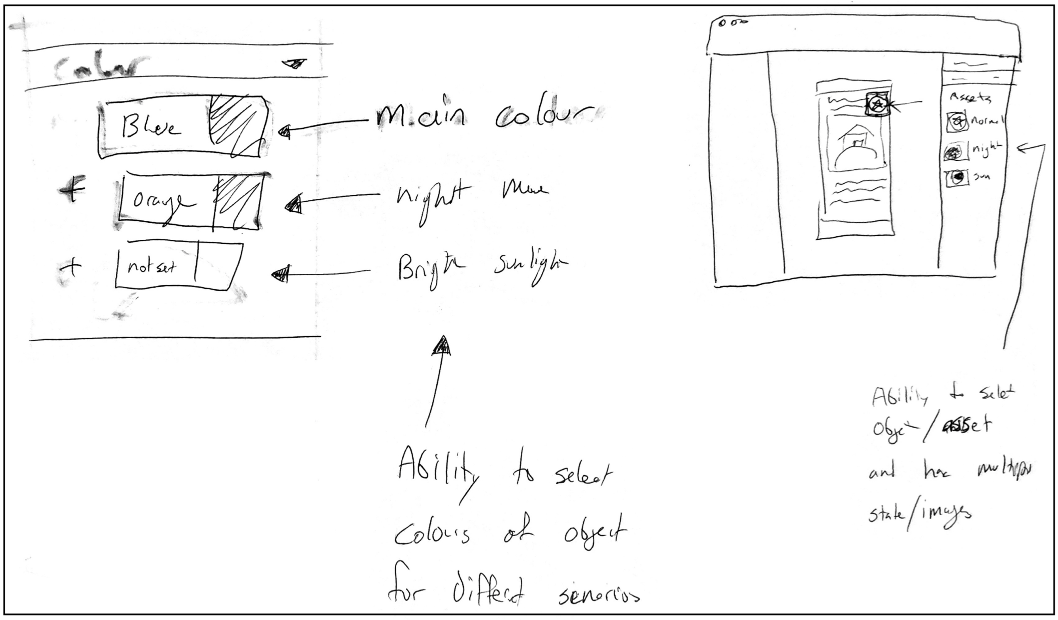


Figure 5.28: P5's sketch that demonstrates how to build the feature into the design software and avoid relying on pop-up messages.

totype, the system should ask for additional assets as the designer progresses. For example, when the designer adds an image the system can ask for the appropriate image for alternative design mode. P1 suggested there could "*be an option to turn it off*", which is likely to apply to many of the ideas if it is something the designer does not want to see.

Discussion on notification of issues

The design software notifies the designer of a potential issue, and either a solution or guidance on where to fix the problem. See Figures 5.12, 5.13, 5.14, 5.15, and 5.16 for details.

P1 approved of the sidebar notification that I had made use of in two of the videos ("Text-based Sidebar Warning Notification" & "Simulation-based Sidebar Warning Notification"). However, P5 was concerned that the sidebar notification "*closes all the other palettes*". The notification only appears when an element is deselected, and therefore the sidebar would have displayed empty space; however, it is important that I consider P5's point more carefully and if the notification only appears when nothing is selected there might be a better way to ensure that designers observe the warning. In addition, P5 also felt the approach "*makes you lose your thought process*", a clearly undesirable side effect that could lead to abandonment.

P1 and P2 were positive about the notification with simulation ("Simulation-based Sidebar Warning Notification"); however, there was concern about its accuracy and drain on resources (e.g., processor, ram) it would have:

> P2: "*I like the idea of [the notification simulation sidebar high-fidelity prototype] but from my little experience with design videos just rendering would be an issue I think.*"

Considering that design software can be resource intensive, and designers can be working with huge files when designing (e.g., P1 can work on files with so many artboards that they sometimes crash), and SVI design tools should be optimised for efficiency.

This discussion focused again on the ability to turn features on and off. P5 wanted the option to choose to give the system control in highlighting areas with issues. P2 suggested that it might be better to move the notifications into a separate space so that the designer can focus on their main task. P4 and P5 both contributed to this idea by suggesting that the information is hidden behind the main design software window with only a list of violations being displayed:

P4: "*For example, you finish your design you see…there are fifteen errors and you click on each one, and it opens, and then you have options, and then you are taken to that specific part of the design.*"

The participants disliked the first notification high-fidelity prototype ("Forced Warning Notification") most out of the notification videos. P1 commented it was his "*least* *favourite one*" and the participants' had also given it the lowest scores on the feedback sheet when compared to the other notification high-fidelity prototypes. The participants felt that referring to "Forced Warning Notification" as an invasive pop-up was accurate.

Discussion on SVI simulations

The design software will provide the designer with a simulation of an SVI (e.g., changing light, system level conflicts). See Figures 5.17, 5.18, 5.19, and 5.20 for details.

"In Situ Simulation" & "System Conflict Simulation" were the highest rated for fitting with the participants' typical design workflow, and the participants rated video "Night Mode Simulation" as being the most important for design for SVIs. Later on, during the design workshop, P2 did state that my approach at demonstrating the problem was "*a good simulation.*"

P5 did like the real-time video simulation "In Situ Simulation" demonstrates, but he had some concerns about the feasibility of the high-fidelity prototype:

> P5: "*I like the video preview because it kind of shows the real life thing. The issues are it will only work on phones with those dimensions. So if you're doing web stuff or something like that it'll not really fit.*"

A simple solution would be for the designer to indicate the aspect ratio of their designs so that the appropriate simulation is loaded. P5 was also concerned about the system conflict simulator with regards to how the SVI design tool would know which elements to change within the simulation:

> P5: "*I think that one would be, especially [the "System Conflict Simulation"], will be really hard to do. Because you'll have to somehow be making inferences about what each element is to kind of guess which to blow up and which to not.*"

The comment does provide some insight into the concern of simulations not being accurate again and the designer having to trust the system. Any simulations built for design software would need to have their accuracy verified.

I showed two different designs next to each other in the “Sunlight Simulation” and “Night Mode Simulation” high-fidelity prototype videos. My reasoning was to demonstrate how low and high contrast mobile app interfaces are better in different contexts. P4 pointed out that this was not how a designer would necessarily work:

> P4: “*Well I feel the first one, you know, I won’t use this kind of design guide that puts different previews next to each other because...you have to make each design smaller, and smaller, and then, like I don’t know, it’s good to compare them and see both at the same time but like [this approach] makes everything very small, so it’s really hard, you have to do more and zoom in, which is not desirable.*”

I realised that this was an issue with how I chose to present the high-fidelity prototype and clarified this to the group, and I could address P4’s concerns by ensuring that was not an expected part of the feature. Interestingly, P4’s concern created the discussion around how mobile app designers work (already summarised above in ‘general comments’).

Similar to the discussion around the notification high-fidelity prototype videos, the idea of using a separate window was suggested as a technique for demonstrating simulations, which is especially convenient if “*...you have a lot of extensions...*” (P1) and the extensions take up the limited design software interface space. All of the participants felt this way.

P5 spoke highly of a program called xScope, which includes a colour vision deficiency simulation Loupe tool that a designer can drag over the screen to check their work underneath. Such a technique could be used to show SVI simulations.

Ann from Study 4 suggested many accessibility tools are poorly designed and it is convenient if they can be accessed within the main design software in use. Previous work has also investigated improving accessibility tools to meet the needs of designers [Tigwell et al., 2017]; however, xScope is an independent application that offers a degree of flexibility because the designer can use it on top of other applications they are working within. While making a tool separate to the primary design software package seems counter-intuitive because the designer has to leave the system and potentially interrupt their workflow, if kept simple and designed well, designers might be happy to use another tool, as is the case with P5. P1 already spoke of "*usually four programs running at the same time*", and so it is not necessarily an issue to include another tool.

Discussion on design exploration

The design software has a set of tools that allow the designer to explore alternative designs quickly and to design within constraints. See Figures 5.21 and 5.22 for details.

The survey in Study 5 indicated almost all designers will consider multiple design ideas. I also knew from Study 4 the limitations of time when designing, and so I felt that I should include a couple of high-fidelity prototypes that support a method for quickly exploring design ideas. These were a "Free Exploration" tool, and the other was a "Constrained Exploration" tool, inspired by previous work [Sandnes, 2018; Tigwell et al., 2017].

P2 and P5 voiced concerns about the usefulness of "Free Exploration":

> P2: "*Hmm, it just seem like [the "Free Exploration" tool] simplifies it quite a bit. I don't use Sketch so I don't really know but I would think you would just want to design it the way you would regularly.*"
>
> P5: "*I don't think I'd use [the "Free Exploration" tool], personally… And if I really needed to do that I would just take a screenshot and bring it into Photoshop.*"

P2 found the demo simplifies the problem and P5 identified another program (Photoshop) he has access to that would already be suited to adjusting hue, inverting colours, and changing contrast. Towards the end of the second workshop, P4 returned the discussion to 'Free Exploration":

> P4: "*So uh one problem here is that you're trying to enable users to explore the ideas, but it's not like just three sliders. There should be more options here. And then like with more options it will, you will have a huge number of different possibilities so it's basically like a condition in which the user cannot explore anything because there is so much that like they cannot do.*"

I asked P4 to expand on this point to clarify that the concern was not just the lack of options shown in the high-fidelity prototype (which I could easily address in a refinement of the high-fidelity prototype) and he confirmed that it was an issue that the "*tremendous number of different options*" for manipulating the designs that would result in "*information overload.*"

P2 was curious to know if Sketch already had a similar feature and P1 said "*not that I know of.*" P2 then discussed an online tool called Canva that could do something similar. During the workshop, both Canva and Photoshop were suggested tools the participants had at their disposal for achieving what the free exploration high-fidelity prototype was demonstrating.

On showing the "Constrained Exploration" video, P5 thought it was "*cool*" how the SVI design feature hid colours to save the designer wasting time looking at the wrong colours; however, P5 felt that "*if your design isn't very simple like two or three colours, you'll get into issues*". For this approach to be successful, it would need to work for more complicated designs. There was an overall consensus that the participants preferred the "Constrained Exploration" high-fidelity prototype over the "Free Exploration" high-fidelity prototype, which is supported by the feedback sheet scores.

One suggestion that P5 made was a palette generator, where the designer chooses a base colour and then other colours are suggested. One benefit of this approach would be that the designer can then use those colours while working, and they have saved time exploring colours that work together and are suitable for different contexts the user may use their app. The designer can focus on doing what they do best, knowing that the colours they have available will be suitable for a particular context and thereby minimise SVIs.

Discussion on auto-generate alternative mode

The design software will automatically construct alternative versions (e.g., dark mode) of the mobile app interface. See Figures 5.23 and 5.24 for details.

When focusing on the first video ("Simultaneous Real-time Alternative Mode") that showed a real-time simultaneous generation of an alternative mode. Both P2 and P4 discussed issues. P2 said "*I didn't like this one. I just don't think you need to see it designed like really you just need the finished product...*" and P4 returned to a previous concern that he had: "*As I said, two windows at the same, two previews at the same time it's like, uh, I had to zoom too much, if I want to work on the design.*" P2 did think that one potentially practical use for seeing a side-by-side comparison would be when exploring colours and it may be difficult to know which colour is going to work, but she did not feel it needed to be in real time.

P5 suggested it would be necessary to turn the feature on and off: "*If it was something like this, it would be something you turn on and off.*"

The second video ("Auto-generation Alternative Mode") demonstrated the high-fidelity prototype of an SVI feature where several high and low contrast designs are created by clicking a button. All of the layers from the original mobile app interface remained and were editable. This approach was received more positively compared to "Simultaneous Real-time Alternative Mode", and it scored higher on the feedback sheet for both questions. However, there were still concerns about ensuring auto-generation meets the needs of designers.

P1 said that auto-generation is "*helpful if you need something quick to show*" he continued to say that he would want to go "*deep and accurate*" into editing the design suggesting there was either a lack of trust in letting the system do the job or fear that the role of the designer may become obsolete if they no longer have to design. P5 felt that when progressing through the design process things would become "*more complicated*". The idea of trust was presented again when P5 said "*I don't know if I would trust a system to auto-generate*", however, he was at least open to trying the idea to see if it could work.

Discussion on export review

When the designer is finished and exporting their designs, they can prompt the system to output a review of potential problems. See Figure 5.25 for details.

"Review on Export" was very well received and scored highly on the feedback sheet:

> P1: "*Come on, it's automatic, who won't like that. It's like someone writing an essay for you.*"
>
> P5: "*...this was so cool... [I]t's there if you need it, it would be really helpful as soon as you need to grab it and look at it.*"

The positivity shown towards this high-fidelity prototype seems to contradict the views held about the auto-generation; however, unlike "Simultaneous Real-time Alternative Mode" and "Auto-generation Alternative Mode", the "Review on Export" high-fidelity prototype does not take the job away from the designer. "Review on Export" is only compiling a report on potential issues, pointing out where those issues are, and how to resolve those issues. The designer can then choose to address those concerns how they see fit. Furthermore, "Review on Export" is integrated seamlessly into the system in a way that means it is out of sight until the point at which the designer needs to enable it, which avoids the concerns the designers raised about previous high-fidelity prototypes that were too invasive.

P5 suggested tweaks to the high-fidelity prototype such as the option for the report pdf to open automatically and to allow a designer to run a review at any point rather than only on export. When P5 mentioned using this approach to see all the errors, P2 said it "*kind of goes back to popups*", in that the designer is now in control as to when they find out about the issues with their current design. A further improvement suggested by P4 was to allow for categorisation of the errors in the output:

> P4: "*...I would have categorised the notes because...then I can decide based on my timing...which group of problems I want to tackle. For example... night mode, do I need glare free design?...I would say, glare free design for now it's not a priority so I would just skip that, but like night mode is important...*"

By categorising the feedback in "Review on Export", it would make it easier for designers to focus on the aspects of the design that are important for their projects. In doing so, the designer can prioritise their time accordingly.

Remaining discussion

Although I showed the participants the "Compliance Badges" high-fidelity prototype and "Overcoming Dark Mode Limitations" high-fidelity prototype during the 20 minute video walkthrough, the discussion afterwards did not focus on those high-fidelity prototypes due to time constraints. Besides, these two high-fidelity prototypes were more directed towards end users rather than a designer's design process. However, I was curious to see what the participants thought about my idea for addressing the issue of images when switching to a dark mode since the issue of images in dark mode was identified in the first workshop. Here are some of their reactions:

> P1: "*I really like that. Our idea was reversed. How the image has its original colour. But, I like that one much better.*"

> P2: "*Yeah I like that.*"

Both P1 and P2 were positive about the high-fidelity prototype, which demonstrated giving the user control over quickly switching between brightening and darkening images (e.g., similar to those found within a social media app such as Twitter).

After P5 had left, I discussed the ideas from the first workshop that I did not explore further.

The first unexplored idea was guidelines; however, as previously stated there is generally a negative view towards accessibility guidelines [Swallow et al., 2014], and there are already many different guidelines online that introducing another set is likely going to have limited influence. Exploring guidelines requires a different type of study and the participants did not have any comments on this.

The second unexplored idea was designing for bystanders. I believe that a hardware solution would be a simpler and more effective approach (e.g., how aeroplane entertainment screens work).

> P1: "*The bystander one, I think that one makes sense to me, the way you [describe it as] more like a hardware thing.*"

> P2: "*I think the hardware works … but there might be a design for, a hardware design.*"

P2 correctly pointed out that an aspect of design will still need to be explored but more concerning the design of hardware rather than software.

The third unexplored idea was working in greyscale mode. I asked for more information on how the participants envisaged it working because I was unsure whether they would only want colours turned off.

> P2: "*I would think that the greyscale like from whatever I recall would be similar to [the free exploration high-fidelity prototype] where you are changing it and then you see the colours that would fit. I don't know. It would be a similar idea to [the free exploration high-fidelity prototype].*"

Considering that P2 and P5 identified two different design software tools that allow for adjusting the design in the same manner that the free exploration high-fidelity prototype demonstrated, it is likely unnecessary to pursue the 'greyscale only' idea further.

The fourth and final unexplored idea was physical design tools (e.g., support the designer in being able to test their designs away from a screen such as going outside to evaluate a design in a bright environment). I asked the participants if physical design tools were something they would want. P1 asked for clarification if I mean "*testing it on an actual phone?*" I agreed and explained the idea of testing away from their desks. Although P1 said they would test how a design looks on different devices the tests were "*not for accessibility purposes specifically*" and he was unable to say for sure if physical design tools would be something he would use.

Finally, both P1 and P2 took the time to praise the high-fidelity prototype videos overall:

> P1: "*You did a great job with these prototypes.*"

> P2: "*Mm hmm.*"

The high-fidelity prototype videos served their purpose in supporting the continued discussion of ideas from the first workshop.

5.3.9 Conclusion

In Study 3, I found that mobile content designers wanted guidelines, education, and digital design tools for improved SVI design support.

In this chapter, I reported two studies (Study 5 and Study 6) that I conducted to identify recommendations on how a design tool should best function to support mobile app designers and to avoid the risk of abandonment. I surveyed 50 mobile app designers (Study 5) using an online survey to understand how they design mobile app interfaces and I ran two design workshops (Study 6) to explore ideas for SVI design tools that fits within the designers' typical workflow. In the next chapter, I make recommendations on how to build SVI design tools that support mobile app designers looking to address SVIs. I base my recommendations on the feedback from the participants in the second design workshop. I put these recommendations into practice by refining the high-fidelity prototypes and using a narrative to walk through the whole design process.

Chapter 6

SVI Design Tool Recommendations and Exemplars

6.1 Introduction

In this chapter, I define a set of recommendations that provide companies with guidance on how to build or incorporate SVI design tools within design software (e.g., Sketch). I then used my recommendations to further refine high-fidelity prototypes that cover the beginning, middle, and end of the design process and present these exemplars in narrative that shows how they can be used throughout the whole design process. For the categories that included more that one video high-fidelity prototype I selected the most appropriate to refine based on the feedback scores and group discussion.

6.1.1 Recommendations

I have reflected on key points raised during the discussion in second workshop and compiled a list of recommendations to support designing to address SVIs within design tools. When considering the many small businesses and independent app designers without the resources to dedicate to addressing SVIs, offering solutions within the tools they are already using should result in a positive change on a huge scale. The five recommendations are:

1. **Include SVI design features as options.** It is not helpful if SVI support is made a dominating feature within the design software, unless that is the primary purpose of the specific design software. Instead, it is more useful, and would therefore avoid abandonment, if the SVI tools are offered as features within menus that can be enabled when required.

2. **Carefully consider screen real estate.** It was clear that designers may work with many applications at any one time, and within a single program a designer may be working with many artboards, plugins, etc. It is essential to create SVI tools that either blend seamlessly within the design software or are separate from the design software interface and can be called upon when necessary. By following this guidance the SVI design tools are more likely to be used rather than permanently disabled.

3. **Do not distract the designer.** It is important to notify the designer of potential problems that will cause SVIs. However, warnings and suggestions provided by the software that result in pop-ups or other distracting prompts increase the risk of disrupting a designer's workflow and will likely result in SVI support being disabled.

4. **Provide the designer with control.** Designers should be able to disable or delay

particular SVI tool features that are not relevant for the work they are doing. For example, if the designer is not ready to address an SVI issue within their design, such as when they do not have assets available for alternative modes, then the designer should be allowed to tell the system to remind them later.

5. **Do smart automation & simulations.** Limited resources (e.g., time) and replicating the environment were some factors restricting mobile app interface designers from addressing SVIs. It is therefore useful to automate tasks and simulate SVIs to highlight issues within the design. However, mobile app interfaces can be complex and so these SVI design tool features must be implemented in a smart way. If designers are expected to use SVI design tools that support them during the design process, then the designers need to trust that the feature is capable and accurate. Automated adjustments to designs (e.g., generating dark modes) must retain any layer structure present, and the designer should be able to edit any and all aspects of the new design.

6.2 Exemplars and How They Can Be Used

After defining my recommendations, I use them as guidance to refine several of the high-fidelity prototypes into exemplars, which I have made available.[1] In this section, I use a narrative to demonstrate how the exemplars complement one another as a complete set of SVI design tools within the Sketch environment. I also detail how a designer would use each exemplar within the different stages of their design process.

[1]https://www.dropbox.com/sh/meo0g8opbjisrsq/AABqJ8ZH_9uGlY9AJGVzM2m_a?dl=0

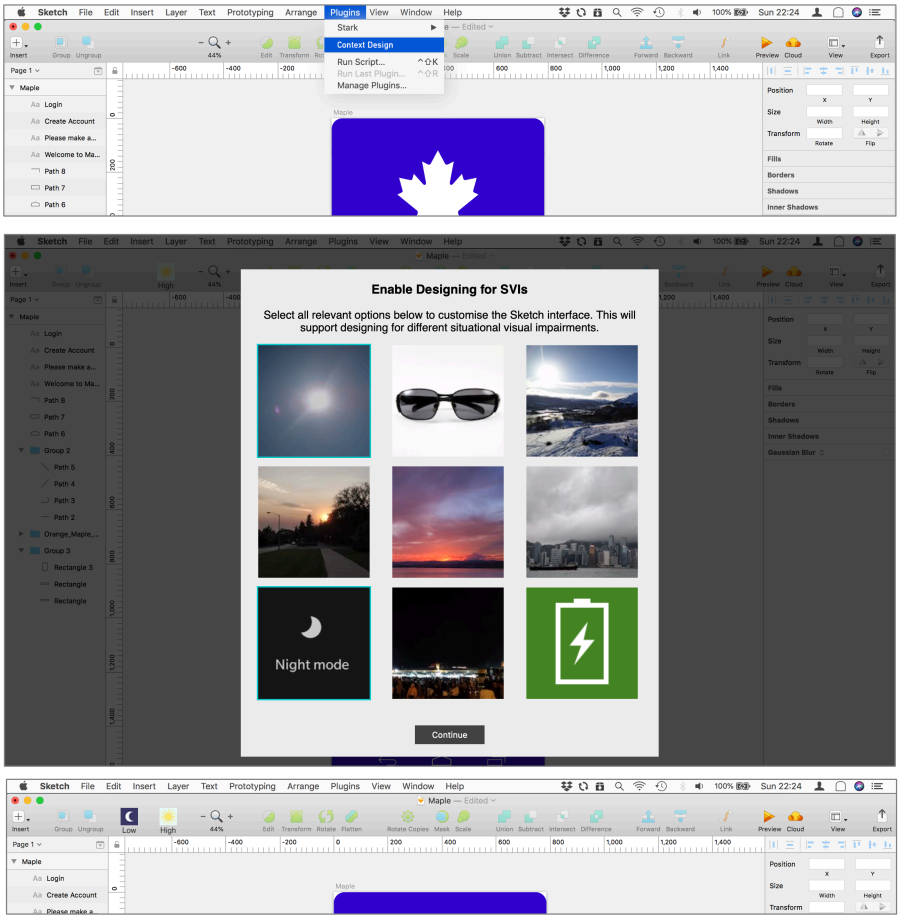


Figure 6.1: “Interface Adaption” lets the designer inform Sketch of the context they will be designing for and Sketch will enable access to features that will support the designer.

At the beginning of a design project, the designer can use “Interface Adaption” (see Figure 6.1) to enable different SVI design tools within Sketch to support them when creating a mobile app interface that will be used in different contexts. There is a reduced emphasis on SVIs by allowing the designer to select “Interface Adaption” under the plugin menu. The designer can then select which SVIs they want to reduce through design (e.g., bright sunlight, night mode). The Sketch toolbar displays icon shortcuts to the necessary tools for each context that was selected and for flexibility, the designer can right-click on any SVI icon to recall the context menu to add or remove SVI tools.

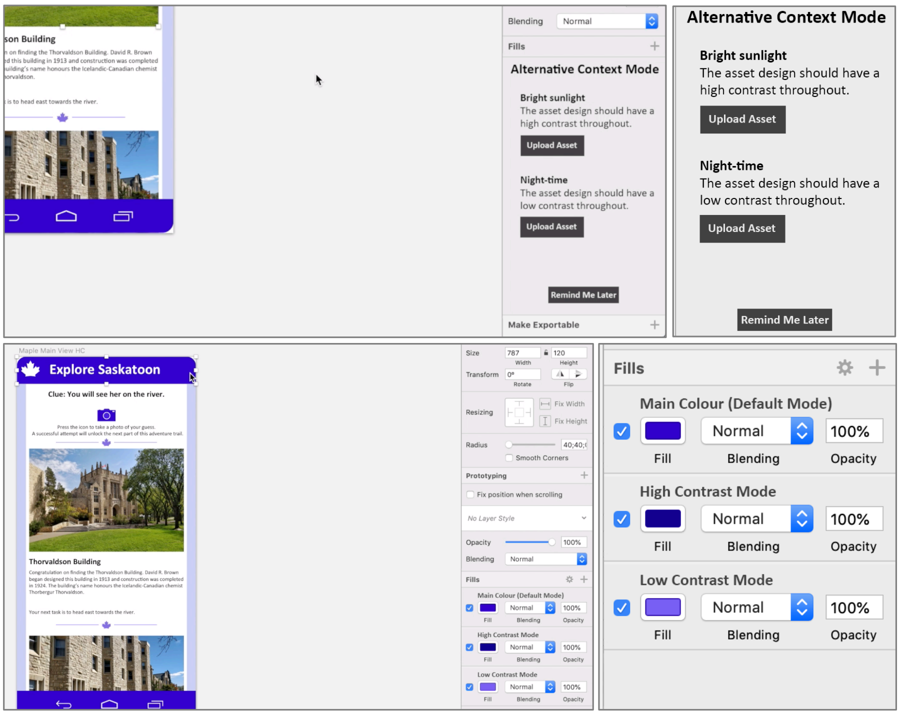


Figure 6.2: "Alternative Assets" lets the designer upload design assets for alternative modes (e.g., different style buttons), as well as choosing different colours for the alternative modes.

During the design process, the designer may be faced with limited time during a project and may look to utilise SVI design tools that improve efficiency. One way to achieve this is through "Alternative Assets" (see Figure 6.2). Rather than prompt the designer from the outset, "Alternative Assets" allow the designer to upload different assets when they are ready. When the designer selects a design element (e.g., an icon) they see an option to upload assets for different SVIs in the sidebar (e.g., different icon styles), the option to "remind me later" is also available to hide the prompt. Sketch can use the assets when the designer is ready to generate alternative versions of a mobile app interface. In addition, when the designer chooses colours, Sketch allows the designer to chose the colours for other modes that they have previously told the system they wish to design for.

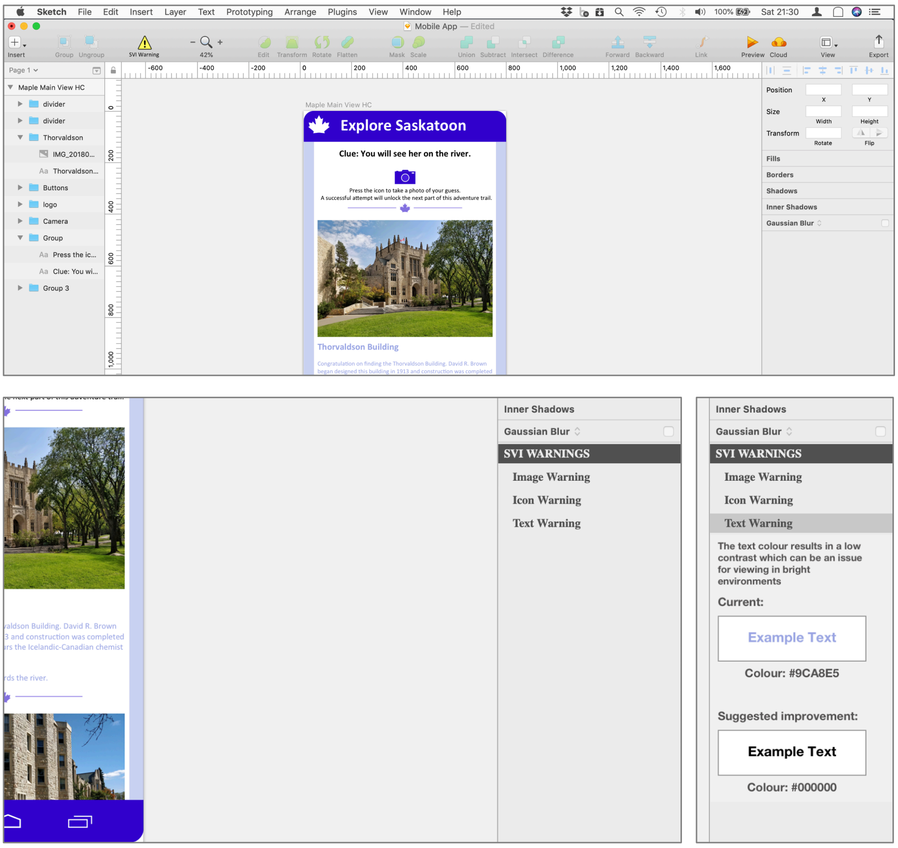


Figure 6.3: "Sidebar Warning Notification" subtly prompts the designer about an issue with their design. The designer can then investigate further when they are ready to. The warnings are grouped to utilise the space limitations of Sketch.

It is useful to notify designers of potential design issues as early as possible to avoid the situation where a mobile app is released and found to be inaccessible in a number of contexts. "Sidebar Warning Notification" (see Figure 6.3) first provides designers with a warning when an initially greyed out 'SVI warning icon' lights up due to a detected issue. This is enough for the designer to notice but they can continue to work until they are ready to investigate the warning. When the designer selects the icon, further information appears in the sidebar. The warnings are categorised (e.g., Image Warning, Text Warning) and those categories can be expanded to identify the issue detected and the solution. The designer can hide the warnings by selecting the 'SVI warning icon' again.

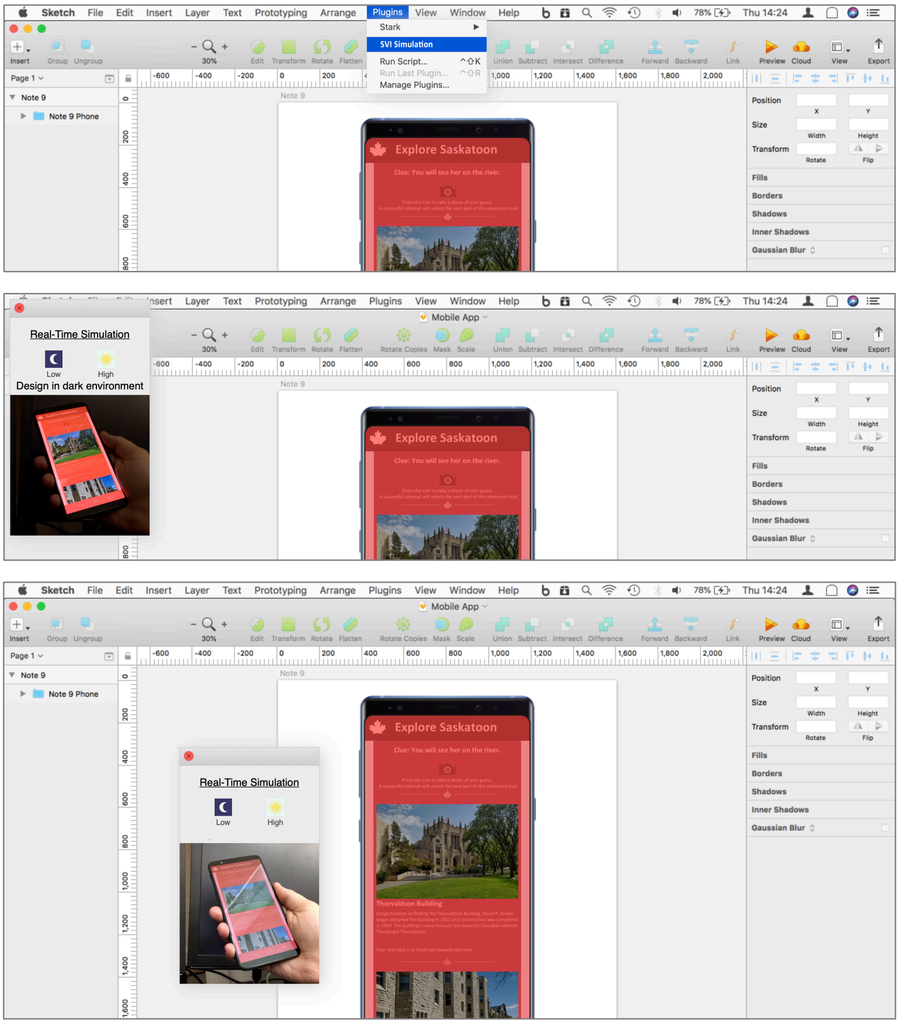


Figure 6.4: "SVI Simulation" offers the designer a viewing window to inspect their design viewed on a mobile device in a real environment. The designer can switch between different contexts and they can reposition the window.

If at any point the designer wants to observe the mobile app interface design under a range of simulated contexts, they can do so by accessing "SVI Simulation" (see Figure 6.4) under the plugins menu. A window will appear showcasing the design in use on a mobile device. The benefit of a separate window means that the designer can drag the simulation window to a position they want to on the screen, or even onto the workspace of a connected monitor; therefore, the SVI simulation is not taking up valuable screen space.

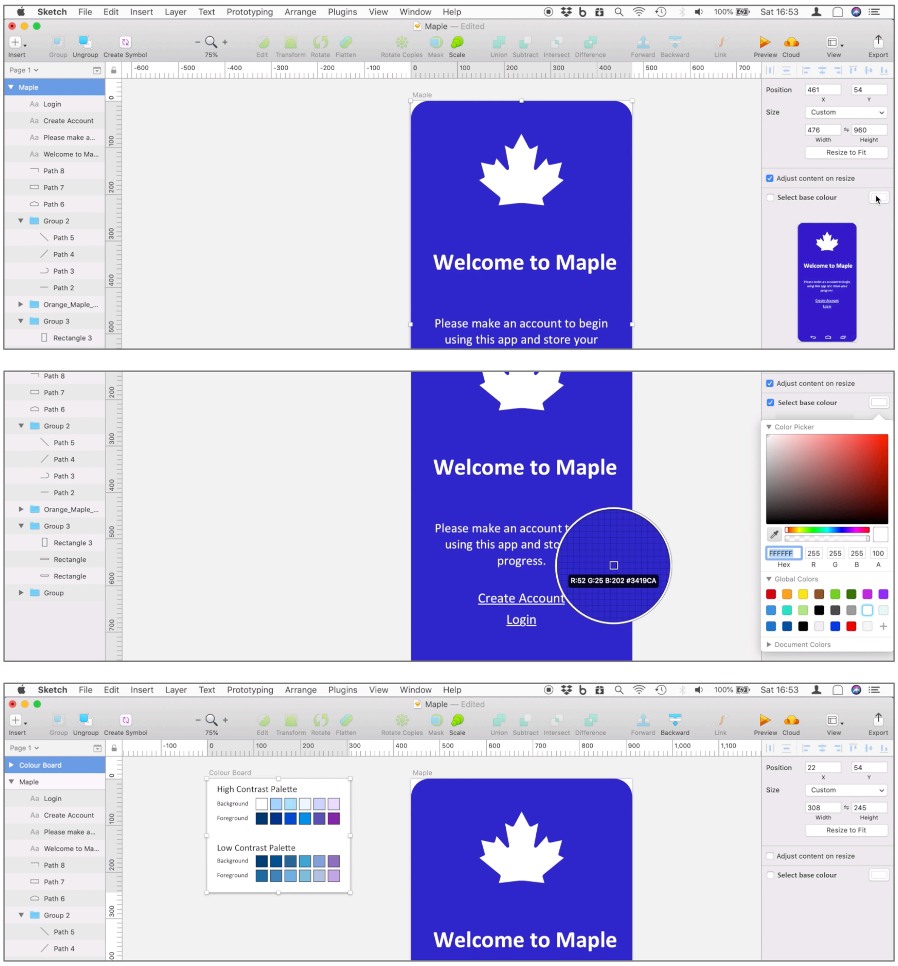


Figure 6.5: "Palette Generation" lets the designer choose a base colour from their design and Sketch will generate a colour palette suitable for different contexts.

When creating alternative modes, the designer may want to have control over the look and feel of those designs. However, with restrictions on time and money, it is useful for a system to offer suggestions that the designer can work with. After the designer has indicated within Sketch the SVI that they are designing for, "Palette Generation" will be offered as a feature that can be used when desired (see Figure 6.5). "Palette Generation" works when the designer selects the base colour of a design they are working on. This idea was suggested by P5 in the second workshop. Sketch will then generate an artboard with colour palettes for different modes (e.g., high contrast mode). The designer can alter any of the colours within the generated palette if they wish to. There is a restriction on how much those colours can be changed otherwise there is a risk of producing an unsuitable design for a specific context.

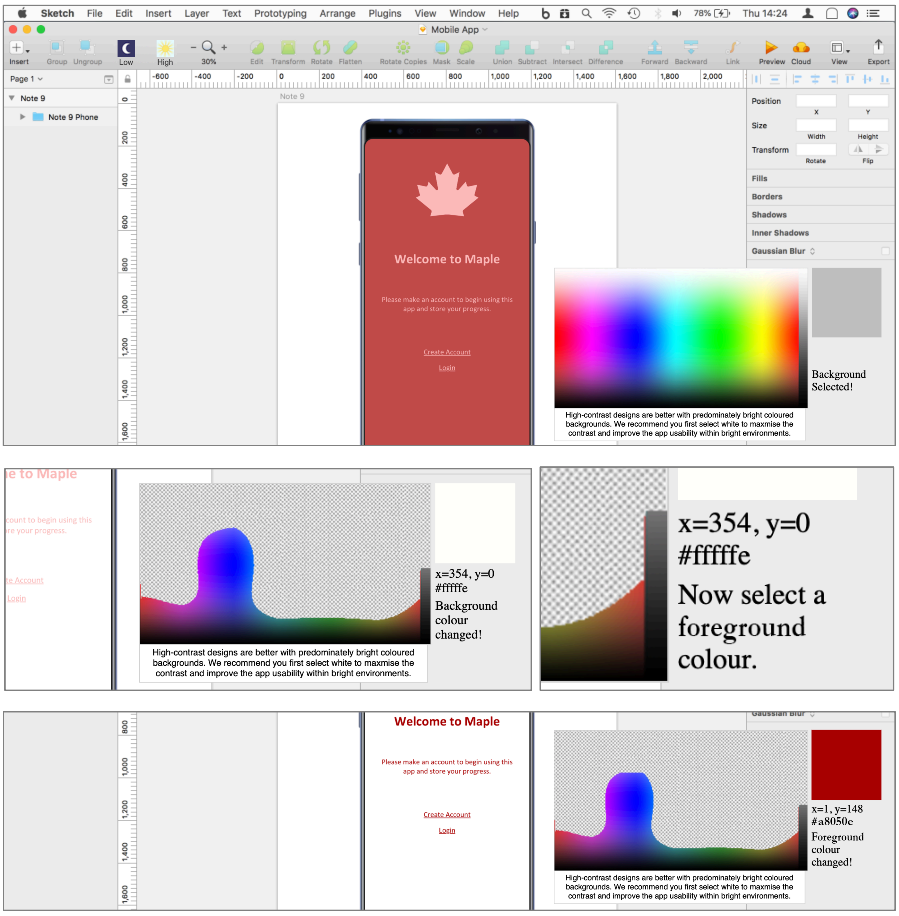


Figure 6.6: "Constrained Exploration" supports the designer in exploring colours for alternative modes through a contrained freedom of choice.

A different method to support the designer when they are choosing colours for alternative modes is "Constrained Exploration" (see Figure 6.6) of colours. The designer indicates whether they want to create a low or high contrast design using the respective icon in the toolbar. To avoid distraction, the designer is guided with prompts in the sidebar (e.g., background selected, background colour changed). The use of the sidebar rather than pop up messages benefits both designers who are a novice and require guidance, and designers who are familiar with the system and want to complete the task quickly. After the initial colour selection is made the designer is presented with a reduced set of colours to choose from, thereby giving them as much freedom of choice as possible within the constrained limits to meet the required contrast guidelines.

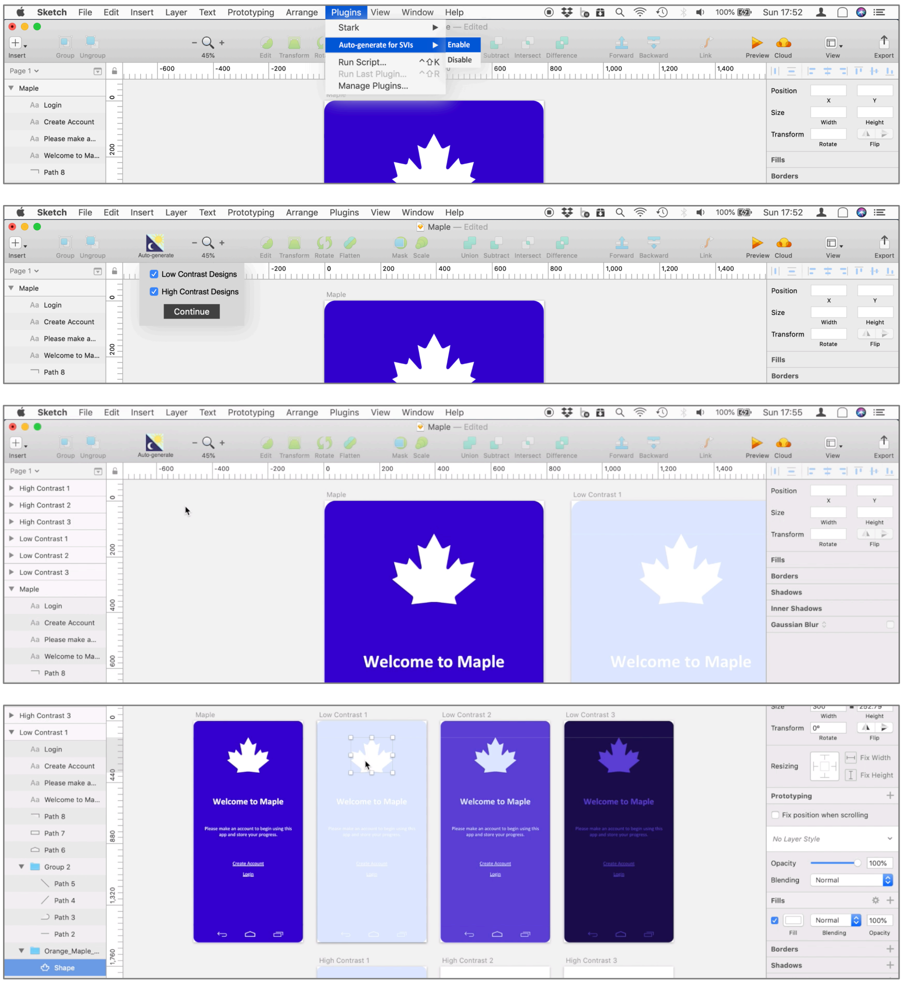


Figure 6.7: "Auto-generate Alternative Mode" offers the designer a quick way to create alternative mode designs for different contexts. The new artboards retain all editable layers so that the designer has control if they want to tweak any aspect of the design.

Another feature available to the designer to save time is the "Auto-generate Alternative Mode" (see Figure 6.7). The designer can enable or disable this feature within the Sketch plugin menu so that there is a shortcut within the toolbar. When the designer is ready to create alternative modes, they can click the auto-generate icon and select low and/or high contrast designs to be generated. Sketch will then generate several versions of each type using the current artboard as a basis. Each new design retains all editable layers.

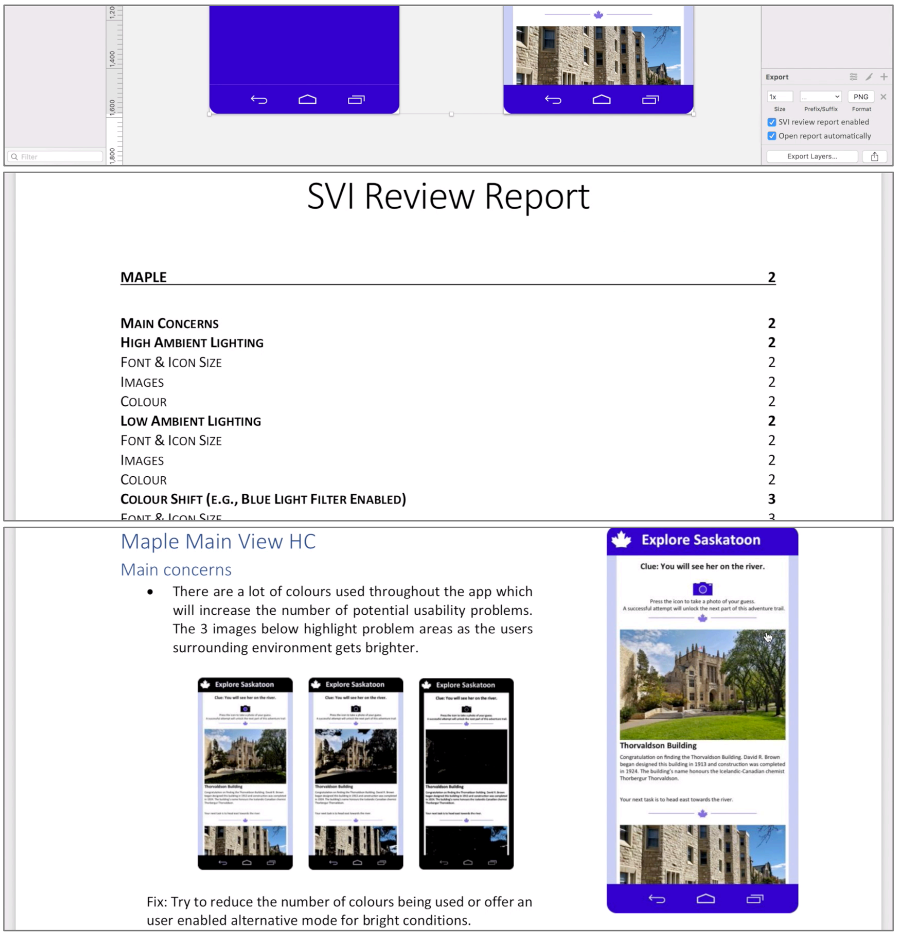


Figure 6.8: "Review on Export" lets the designer request a document with an analysis of any design issues and solutions to those issues. The report layout makes use of categories that allow the designer to quickly access the sections they wish to read.

At any point during the design process, the designer can prompt the system to review the current design's robustness to SVIs. The benefit of "Review on Export" (see Figure 6.8) is that there is no cluttering of the Sketch interface with warnings and solutions. It is possible for the designer to request the report opens automatically if that is something they prefer. Furthermore, the separate document can easily be shared with clients, whether digitally or as a printout, and this provides the designer with evidence that can be used to argue against fulfilling particular design requests (e.g., using brand colours). The report layout makes use of categories that allow the designer to quickly access the sections they wish to read. The designer can request an audit without exporting the design, but I did not demonstrate this feature within the high-fidelity prototype video.

Chapter 7

Discussion

7.1 Introduction

In this chapter, I provide an overview of my contributions, the implications of my research, the limitations of my research, and directions for future work.

7.2 Summary of Contributions

The main contribution of this work is a set of recommendations for developing SVI design tools that support designers in creating mobile content that reduces SVIs in different contexts. The recommendations provide guidance on how to incorporate SVI design support into existing design software (e.g., Sketch) and future design software. The outcome of design software companies following my recommendations will be an improved set of tools that allow designers to expand mobile content designs to different contexts. The development and inclusion of these designs within mobile apps (e.g., allowing alternative modes such as for day or night) will provide users with more control in addressing SVIs through enhanced content design.

My thesis also includes four secondary contributions:

1. The mobile device SVI Context Model (see Chapter 3). The mobile device SVI Context Model is rooted in empirical evidence from a large online survey with 174 participants and a two-week ecological momentary assessment with 24 participants (12 from Australia and 12 from Scotland, balanced by age and gender).

2. An understanding that mobile content designers are for the most part not currently addressing SVIs, plus ways that they can be supported in addressing SVIs (see Chapter 4). An online survey with 43 mobile content designers revealed key similarities and differences between accessibility and designing to reduce SVIs. A thematic analysis of follow-on semi-structured interviews with four designers provided an understanding of typical design processes, the challenges of addressing SVIs, and how to improve guidelines, education, and digital design tools to better support designing to reduce SVIs.

3. An understanding of the range of tools mobile app interface designers are using, as well as common approaches to exploring a variety of design ideas, gathered from an online survey with 50 participants.

4. Sample high-fidelity prototypes of SVI design tools. I obtained paper sketches and ideas from an initial design workshop with four designers and developed those ideas into high-fidelity prototypes. A second workshop with four designers was used to gather feedback. I determined a set of recommendations from the feedback and then refined a final set of high-fidelity prototypes (see Chapter 6).

7.3 Explanation of Contributions

I used an online survey and two-week ecological momentary assessment with mobile device users to understand the users, context of use, and adaptation strategies around SVIs, in order to better inform future solutions for SVIs. The outcome of this was the development of a *Mobile Device SVI Context Model* that highlights different factors involved in causing SVIs. One of those factors was content design.

I chose to address the issue of poorly designed mobile content because much of the related work discussed in Chapter 2 does not look at how to improve mobile content design to address situational impairments, and the few solutions to support mobile content designers in addressing SVIs are limited. It was also evident from Chapter 3 that users are frustrated when design causes SVIs and when users are unable to make adjustments to the design to address SVIs.

I then used an online survey and follow-on interviews with mobile content designers to more fully understand what designers currently do regarding SVIs, what resources they know of, and what resources are required to support them to best design for SVIs. The outcome of this was identifying that designers want improved *guidelines*, *education*, and *digital design tools*. Through thematic analysis of the follow-on interviews with designers, I identified three main themes relevant to supporting designers in addressing SVIs: *Design Practices Will Vary*, *Achieving Accessibility is Complex*, and *One Solution Does Not Fit All*.

Next, I conducted an online survey with mobile app designers to understand how they design mobile app interfaces. In particular, I was interested in learning more about the tools and software used, and how mobile app designers explore multiple design ideas. I identified a wide variety of tools and practices used, and the participants also raised challenges for designing mobile app interfaces that have implications for accessibility.

This online survey along with my previous studies provided me with a sufficiently deep understanding of the problem to begin exploring solutions with designers over two workshops.

Finally, I ran two design workshops. The goal of the first design workshop was to use paper-based prototyping to identify potential SVI design tools that would fit within a typical designer's workflow. I then developed high-fidelity prototypes based on ideas generated in the first design workshop. The goal of the second design workshop was to identify the necessary refinements to the high-fidelity prototypes, which allowed me to define a set of recommendations. I then used the recommendations to further refine the high-fidelity prototypes.

7.3.1 SVI Design Tool Recommendations

The value in my SVI design tool recommendations is that I have defined them through a participatory design approach [Spinuzzi, 2005] with mobile content designers at different levels. I ran two workshops, the first of which was used to elicit ideas for SVI design tools, and in a second workshop, I received feedback on high-fidelity prototypes based on those ideas. Feedback on those prototypes should contribute to the successful application of my recommendations [Olsson, 2004]. My high-fidelity prototypes were demonstrated using Sketch, which I identified in Study 4 and Study 5 as a popular design software tool among mobile designers. Sketch uses a familiar interface layout to other design software such as Adobe Illustrator with its use of a central workspace, toolbars on both the top and side of the workspace, and an additional menu at the top the screen. It was important that I provide a wide-reaching contribution to addressing SVIs; therefore, I identified feedback that could be made into recommendations that would apply to other design software.

The SVI design tool recommendations can be summarised in 5 main points (more details in Chapter 6):

1. Include SVI design features as options.
2. Carefully consider screen real estate.
3. Do not distract the designer.
4. Provide the designer with control.
5. Do smart automation & simulations.

My recommendations are an important contribution, particularly when considering the many small businesses and independent app designers that exist. Whereas large companies like Apple and Facebook have money to improve usability and accessibility by addressing SVIs, those with fewer resources need as much support as possible. If that support is built directly into the tools they are already using then we will see a positive change on a huge scale. My recommendations can be used by software design companies to successfully incorporate SVI design support into existing design software (e.g., Sketch) and future design software. The main benefit of this will be to minimise the risk of designers abandoning the use of such features that support them in addressing SVIs. The features will better fit with the designer's workflow, and in particular the recommendation of smart automation & simulations will address other restrictions (e.g., limited time) that can result in a lack of designing to address SVIs.

7.3.2 Mobile Device SVI Context Model

My mobile device SVI Context Model was created to allow HCI researchers, engineers, manufacturers, and designers to consider the many layers between the user and the content that are affected by an ever-changing environment, which will affect user interaction. Unlike previous models, my model is grounded in new empirical data for SVIs, and it visually represents the findings of my two studies. My model, therefore, provides different stakeholders (e.g., HCI researchers, engineers, manufacturers, designers) with a concise overview of the complex nature of SVIs and it is especially useful for people who are studying mobile interaction challenges.

During the first stage of understanding the problem, my model allowed me to contextualise the extent to which SVIs are a problem, and to better reflect on which factor I should focus my attention. When considering each "layer of the device", *content design* stood out as a practical first step where I could have the most influence since many other layers require outside cooperation (e.g., the hardware limitations would require manufacturer cooperation, which would be challenging when considering already defined production timelines for devices). Furthermore, related work suggests that there are limited solutions for improving mobile content design, and there are currently no solutions to support mobile content designers in addressing SVIs. Designers have control over the look and functionality of their content, while users are frustrated when design causes SVIs and when they are not able to make adjustments to the design to correct the problem. By supporting designers to create content that is less susceptible to SVIs, then users can be empowered to complete tasks in a variety of different contexts (e.g., by switching to a "night mode" interface when in a dark room).

7.3.3 High-Fidelity Prototypes

Study 6 was my final research study to gather data. I followed the Double Diamond model [Schneider, 2015] approach for exploring how to create SVI design tools that mobile app interface designers would use. Studies 1 to 5 allowed me to understand and define the problem of SVIs, what mobile designers were currently doing, and the problems mobile designers faced. I consolidated this information into a design brief that

I shared with the participants of the first workshop. I provided the participants with paper to sketch out ideas for SVI design tools that would fit within a software package (e.g., Sketch) and address several key issues: limited time and funding, accessibility as an afterthought, guidelines or tools restricting creativity, and the many aspects of interface design that would need to be altered to address SVIs.

The participants sketched many different ideas on paper and I developed those ideas into high-fidelity prototypes. The high-fidelity prototypes[1] can be used as inspiration for companies to begin exploring different SVI design tools. In addition, I used my SVI design tool recommendations to further refine a subset of the most preferred high-fidelity prototypes to demonstrate the usefulness of the recommendations and to emphasise that SVI design tools can be created in a way that will meet the needs of designers. In this thesis, I have included a narrative around the final high-fidelity prototypes to demonstrate how various SVI design tools can be used throughout the process of designing mobile app interfaces.

7.4 Limitations

There are several limitations to this research.

First, mobile devices are finding their way into high-risk occupations (e.g., pilots [Wikipedia, n.d.], healthcare practitioners [West et al., 2012]), yet my first two studies focused on understanding SVIs reported by the general population, without deliberately seeking participants in those high-risk professions. I have assessed the "typical" SVIs experienced by regular mobile users. It is worth highlighting that the logical first step would be to develop a deep but general understanding of SVIs before conducting research related to potentially serious health and safety risks. Future work targeting other user

[1] Videos available here: https://www.dropbox.com/sh/meo0g8opbjisrsq/AABqJ8ZH_9uGlY9AJGVzM2m_a?dl=0

groups (e.g., people using safety-critical systems) to broaden my findings is now possible.

Second, three of my studies have a small number of participants (Study 2, Study 4, Study 6). However, before I conducted each of those studies, I chose to run large online surveys (Study 1, Study 3, Study 5) to gather a broad understanding of particular research questions for the various stages of my research. Only after collecting this data could I run an in-depth qualitative study to answer more focused questions. Study 2 involved a two-week ecological momentary assessment with 24 participants (12 from Australia and 12 from Scotland), which resulted in an extensive collection of data, and addressed the frequency and memory bias issues of Study 1. Study 4 involved follow-on interviews with four designers who each had a unique career path that resulted in diverse information and opinions. The primary purpose of those interviews was as a means of further discussing certain points uncovered by the survey. Study 6 involved two design workshops, each with four participants who had different experiences with design. Before running Study 6, I ran an online survey to gather some final data for better understanding mobile app interfaces design practices and the potential challenges faced (Study 5). It was important to look into mobile app interfaces since they can be designed to include alternative modes, and these have the potential to empower users in reducing SVIs in different contexts. Study 6 was then an opportunity to reflect with designers on the various design challenges for SVIs and to explore SVI design tools. These two workshop sessions resulted in recommendations for developing SVI design tools that support designers in creating mobile content that reduces SVIs in different contexts. The recommendations provide guidance on how to incorporate SVI design support into existing design software (e.g., Sketch) and future design software. Design software companies following my recommendations will lead to an improved set of tools for designers to expand mobile content designs to different contexts.

Third, my recruitment advertisements for all studies were presented in English. Although some participants outside of the UK completed my online surveys (e.g., Study 3 was completed by 50% living outside of the UK) much of my data comes from western and English-speaking cultures. Therefore, I have to recognise that the design practices that I have gained a deep understanding for may not generalise everywhere. Education, guidelines, and design tools in other non-native English-speaking countries may include more extensive coverage for addressing SVIs. It would be interesting to investigate this further since there are acknowledged cultural differences in design preference [Reinecke and Bernstein, 2011], and it is likely there will also be different design practices and experience of client involvement.

7.5 Future Work

SVIs are a complex problem with many causal factors. I next discuss directions for future work that can be explored as a result of the findings from my work.

7.5.1 SVI Design Tools for Improving Entertainment

A large part of why people own a mobile device is the vast number of apps that can be accessed. Many of the tasks my participants identified in Studies 1 & 2 involved interacting with apps. During my research, I have identified an approach to supporting mobile app interface designers through the contribution of SVI design tool recommendations and high-fidelity prototypes. However, we also use mobile devices to play games and watch videos, and these were tasks that participants were doing when experiencing an SVI.

Next, it would be beneficial to support the creators of more complex entertainment content such as games and videos, which were tasks reported by participants in Study

1 and Study 2. During Study 4, the mobile games designer that I interviewed indicated that he and his company did not currently see a need to address SVIs or accessibility because it was something they would need to be pushed towards due to the perceived costs and expected time outweighing the benefits a more accessible game would have. This highlights the wider extrinsic challenges that can restrict accessibility [Ross et al., 2017].

During the discussion with my participants in Study 6, there was a concern about quickly redesigning complex interfaces for different contexts. Great care is given to the visual impact of movies as part of the storytelling. Colour has been an important aspect of storytelling in film for a long time [Kalmus, 1935] and the visual design has become increasingly determined using digital methods [Higgins, 2003]. For example, visual design and in particular colour can be used to help distinguish the 'real' world and a 'dream' world [Fikse and Johnsen, 2012]. Considering the effort put into designing the look of a film it would be interesting to explore how to ensure the original design intent is fulfilled as much as possible in different contexts.

High dynamic range displays have increased contrast and brightness capabilities, which offers more flexibility in displaying true to life images [Seetzen et al., 2004]. Dolby Vision is a type of high dynamic range (HDR) video format that retains dynamic metadata, which allows content to be adjusted scene-by-scene to ensure the best possible image and viewing experience [Chinnock, 2016]. A similar approach to Dolby Vision could be utilised to allow for custom modes to be applied to a movie when viewed in different contexts helping to reduce the effects of SVIs. People are already accustomed to home entertainment systems that include different modes for improved viewing experiences such as a 'default', 'sports', and 'movie' mode that adapts brightness, contrast, and framerate [Klosowski, 2012], and therefore offering the ability to switch between viewing modes on a mobile will be somewhat familiar. With HDR displays being developed for mobile devices [Alliance, n.d.], the inclusion of dynamic metadata to adapt the context would both preserve the artistic intent for the film, and empower the user in minimising SVIs. This is likely better than utilising current solutions such as automatically adapting mobile displays for the environment (e.g., boosting saturation) [Lee et al., 2007; Kim et al., 2017; Su et al., 2018a,b; Yu et al., 2015]. An example of a consumer devices that can do this is the OnePlus 5T[2], which can adapt the colours on screen for improved viewing in brighter environments, but unfortunately the user cannot control how this is done. Since only the device can make adjustments, the content may no longer retain the intended artistic look and the viewer might still find issues with the image (e.g., overly saturated and reddish skin tones). To explore the benefits of dynamic metadata, it would be necessary to develop tools for the film industry that would support workers such as the movie colour grader in fulfilling the director's and cinematographer's vision when the content is viewed in different contexts. I expect there will be similar cost and time-saving requirements that need to be addressed to ensure this happens.

7.5.2 Supporting Designers with Guidelines and Education

I focused on identifying the necessary features and implementation for an SVI design tool that would support designers because a tool would have an immediate and positive influence as opposed to more guidelines since most designers are using design tools but not guidelines. New SVI design tools would drive the demand for education, as well as make any guidelines developed immediately accessible.

There is some criticism of current accessibility guidelines (e.g., WCAG) [Brys and Vanderbauwhede, 2006; Swallow et al., 2014], and this was echoed by the participants I interviewed in Study 4. However, guidelines are still a valuable resource, they just need to be easy to understand and allow for a degree of flexibility. There is a need to establish

[2]https://www.oneplus.com/uk/oneplus-5t

new guidelines that are pertinent for SVIs on mobile devices. Some initial work has explored the possibility of gathering the necessary data on a large scale [Macpherson et al., 2018].

Closely related to guidelines is education. There is a large amount of work that has investigated introducing accessibility into education (e.g., [Lewthwaite and Sloan, 2016; Putnam et al., 2016; Youngblood et al., 2017]), but it is important to educate beyond the classroom. During my research, it has been clear that there are many ways for designers to learn about and refine their craft (e.g., online courses). An interesting approach to this problem would be to design educational content based on the findings of my research and disseminate them through popular and alternative streams such as Coursera[3], Udemy[4], Medium[5], and Dribbble[6].

7.5.3 Widening Understanding of SVIs and other situational impairments

I have assessed the "typical" SVIs experienced by regular mobile users. Using these findings I can now investigate SVIs experience when using mobile devices in high-risk occupations (e.g., pilots [Wikipedia, n.d.], healthcare practitioners [West et al., 2012]) to ensure people in these occupations have the most appropriate support.

My mobile device SVI Context Model is grounded within data and composed in a way that should generalise well to many mobile devices and contexts. However, it will eventually need to be revisited and updated to reflect any changes in technology and interaction techniques with future devices. One example of a recent shift in technology is the popularity of using transmissive screen technologies [Bae et al., 2011] (as

[3]https://www.coursera.org
[4]https://www.udemy.com
[5]https://medium.com
[6]https://dribbble.com

opposed to transflective) and moving toward glossy displays, both of which increase the difficulty of using mobile devices in bright environments. Furthermore, supporting designers will not resolve all SVIs and so other factors in my model will also need to be explored, such as working closely with device manufacturers to address hardware and software causes of SVIs.

Distributing an online survey followed by an EMA study resulted in the gathering of a rich data set. By following a similar approach, researchers would gain a deep and ecologically valid understanding of other types of (non-visual) situational impairments that have little research [Sarsenbayeva et al., 2017]. In doing so, more robust solutions can be identified.

7.6 Summary

In this chapter, I provide an overview of my contributions. The primary contribution is a set of recommendations for developing SVI design tools that support designers in creating mobile content that reduces SVIs in different contexts. Several secondary contributions are discussed that further our understanding of SVIs and the design practices of mobile designers. My contributions are grounded in extensive qualitative data to ensure that the solutions to SVIs are appropriate. I have outlined directions for future work, such as investigate design tools for creators of entertainment content (e.g., movies) that are viewed on mobile, supporting designers with guidelines and educations, and widening our understanding of other situational impairments.

Chapter 8

Conclusions

Mobile devices are used worldwide in both personal and professional settings. While we benefit from being able to use these devices in many different contexts, we can also experience usability and accessibility interaction challenges.

One particular challenge are Situational Visual Impairments (SVIs), which are a type of visual impairment that arises from a mobile device user's context (e.g., the challenge of watching Netflix under bright sunlight, the inability to distinguish on-screen colours due to a blue-light filter, the phone's screen brightness being limited due to low power). We rely on our devices to communicate, work, and have fun, and restrictions on using these devices can have major implications.

SVIs cause usability and accessibility problems for mobile device users, which suggests that current mobile industry practices are insufficient for supporting designers when addressing SVIs. However, there was no comprehensive understanding of the causes and prevalence of SVIs, or how people manage SVIs. My primary concern was that the necessary solutions for SVIs either did not exist or current solutions were insufficient because they were not informed by the true context of SVIs.

To address this, I recruited 174 participants for an online survey and 24 participants across Australia and Scotland for a two-week ecological momentary assessment to establish what factors contribute to SVIs experienced when using a mobile device. My findings revealed that SVIs are a complex phenomenon with several contributing and interacting factors. I grouped those factors into six themes: “External Influences”, “Accessory Interference”, “Problematic Hardware Design”, “Operating System and Software Inadequacy”, “Problematic Interface and Content Design”, and “Cognitive and Physiological Effects”. My findings were used to create a mobile device SVI Context Model, which indicated that creating solutions for improving mobile content design was the most practical first step towards addressing SVIs. Designers have control over the look and functionality of their content, while users are frustrated when design causes SVIs and when they are not able to make adjustments to the design to correct the problem.

Next, I surveyed 43 mobile content designers and ran four follow-on interviews to identify how often SVIs were considered and how I could provide effective support. I found key similarities and differences between accessibility and designing to reduce SVIs. The participants requested guidelines, education, and digital design tools for improved SVI design support. I focused on identifying the necessary features and implementation for an SVI design tool that would support designers because this would have an immediate and positive influence.

Next, I surveyed 50 mobile app designers using an online survey to understand how mobile app interfaces are designed. I identified a wide variety of tools and practices used, and the participants also raised challenges for designing mobile app interfaces that had implications for users experiencing SVIs. I ran two design workshops (Study 6) to explore SVI design tools that would fit within a typical designer’s workflow. Based on the feedback from the participants on the second design workshop high-fidelity prototype videos, I made recommendations on how to build SVI design tools that supported mobile app designers looking to address SVIs.

8.1 Is the Thesis Problem Solved?

In Chapter 1, Section 1.1, I state the problem to be addressed in this thesis as: *Situational visual impairments (SVIs) cause usability and accessibility problems for mobile device users, which suggests that current mobile industry practices are insufficient for supporting designers when addressing SVIs.*

I first confirmed that SVIs cause usability and accessibility problems for mobile device users by gathering quantitative and qualitative data in a large online survey and a two-week ecological momentary assessment. I also confirmed through these two studies that *content design* is one major factor causing SVIs. In particular, I found evidence that users are frustrated when design causes SVIs and when they are unable to address SVIs by through adjusting the design.

Using an online survey, I was able to confirm that mobile content designers do not typically design to reduce SVIs for four key reasons: 1) designing to reduce SVIs is often not in the design scope or part of the designer's current practice; 2) there are limited resources available (e.g., time, money, tools) to design for SVIs; 3) some designers are unaware of or have not considered SVIs before; and 4) designers view SVIs as a minor issue. Improved guidelines, education, and design tools were requested as necessary support and follow-on interviews were used to identify how support should be introduced. I established that design tools were likely to have an immediate and positive influence for reducing SVIs.

To address the problem stated in this thesis, I introduced recommendations for software design companies to successfully incorporate SVI design support into existing design software (e.g., Sketch) and future design software. The main benefit of this will be minimising the risk of designers abandoning the use of features that support them in addressing SVIs. To define the recommendations I used an online survey for gathering data about mobile app interface design and then using this new data along with the finding of my previous studies I ran two design workshops. The first workshop to generate ideas so that I could create high-fidelity prototypes, which I used to support a discussion eliciting feedback in the second workshop.

8.2 Future Work

In Chapter 7, I outlined several directions for future work that build on my findings.

SVI Design Tools for Improving Entertainment: I plan to work with people in the film and TV industry to explore ways to support the adaption of video content for different contexts. HDR displays will enhance the contrast, brightness, and colour capabilities of mobile devices. New standards such as Dolby Vision allow for meta-data to be embedded within the video source, which allows for content to be adjusted on a scene-by-scene basis. These technologies can be leveraged to enable editors to make adjustments to the video for different viewing contexts and SVI design tools will be a necessary part of supporting this happening.

Supporting Designers with Guidelines and Education: I plan to run a series of studies to model SVIs and use this data to inform the creation of new guidelines. In Study 4, I identified current positive and negative attitudes towards guidelines, which provides me with a basis from which to start. It will be important that I involve designers in the creation of new guidelines to ensure that they are easy to digest, understandable, and flexible. The new guidelines can then be paired with SVI design tools. I will also explore avenues to disseminate my research findings to raise SVI awareness on a large scale.

Widening Understanding of SVIs and other situational impairments: I will investigate SVIs within high-risk occupations. In addition, there are other types of situational impairment that require further investigation. I plan to use a similar qualitative methodological approach to understand and identify the required solutions to other non-visual situational impairments.

8.3 Closing Remarks

Mobile devices are now a fundamental part of society; we use mobile devices to communicate, control other appliances, have fun, and work. It is therefore inconvenient and potentially dangerous when we are unable to use mobile devices. Situational Visual Impairments (SVIs) are a common usability and accessibility interaction challenge that potentially all users can experience. One major factor that results in SVIs is content design, and there is a lack of support for designers to address this.

In this thesis, I defined a set of recommendations for incorporating SVI design tools into existing design software (e.g., Sketch) and future design software. My recommendations are based on extensive user data in order to create valid solutions to this problem. The outcome of companies following my recommendations will lead to an improved set of tools for designers that support them in exploring mobile content designs for different contexts, while accounting for typical work restrictions such as limited time and budget. The end benefit for mobile device users is providing them control over addressing SVIs through apps that include various alternative modes (e.g., high contrast mode, night mode).

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Appendix A. Ethical Approval Forms

This appendix contains the letters of approval from the University of Dundee Science and Engineering Research Ethics committee.

A.1: Understanding situational visual impairments (Part 1).

UNIVERSITY OF DUNDEE

Computing, School of Science and Engineering

Head of Discipline: Professor Emanuele Trucco

Ethics Committee
Convener
Professor Annalu Waller
Administrator
Mrs Kathleen Cummins

10/06/16

Garreth Tigwell
Computing
School of Science and Engineering
University of Dundee

Dear Garreth

Full title of study: Improving Content Visibility on Mobile Devices under Bright Lighting

SoCEC reference number: 16/003

Thank you for submitting an amended ethics application on 3 June. Your application has been reviewed by the Ethics committee.

Ethical issues arising from the proposed study

You have indicated that there are no significant ethical issues arising from this project. The Ethics Committee has approved this study.

Conditions of approval

By submitting an application to the Ethics Committee you confirm that you have read and understand the University of Dundee Guidelines for Ethical Practices in Research and the School of Computing Code of Practice for Research involving Human Participants and undertake to abide by these guidelines. Permission is therefore granted for you to proceed with the study.

Please inform the committee of any change in project methodology which may have ethical implications.

Best wishes for your research,

Yours sincerely

Annalu

Annalu Waller MBCS MIPEM
Professor
Convener: Computing Ethics Committee

Administrator: Mrs Kathleen Cummins
email SoC-EthicsMembers@dundee.ac.uk *telephone* 01382 386532

School of Science and Engineering
UNIVERSITY OF DUNDEE Dundee DD1 4HN Scotland UK *t* +44 (0)1382 388085
www.computing.dundee.ac.uk

A.2: Understanding situational visual impairments (Part 2).

University of Dundee

Research Ethics Committee
School of Science and Engineering
University of Dundee
Dundee
DD1 4HN

13 December 2017

Dear Garreth

Application Number: 17-014
Title: An ecological momentary assessment of mobile phone use under bright lighting

I am writing to advise you that your ethics application has been reviewed and approved on behalf of the School of Science and Engineering Research Ethics Committee.

Approval is valid for three years from the date of this letter. Should your study continue beyond this point, please request a renewal of the approval.

Any changes to the approved documentation (e.g., study protocol, information sheet, consent form) must be approved by this SREC.

Yours sincerely

Professor Annalu Waller OBE MBCS MIPEM
Convener: School of Science and Engineering Ethics Committee

Research Ethics Committee
School of Science and Engineering
UNIVERSITY OF DUNDEE
Dundee DD1 4HN Scotland UK

Administrator: Mrs Kathleen Cummins
e kycummins@dundee.ac.uk
direct line +44 (0) 1382 386532
www.dundee.ac.uk

A.3: Identifying designers' needs for addressing situational visual impairments.

UNIVERSITY OF DUNDEE

Computing, School of Science and Engineering

Head of Discipline: Professor Emanuele Trucco

Ethics Committee
Convener
Professor Annalu Waller
Administrator
Mrs Kathleen Cummins

3 June 2016

Garreth Tigwell
Computing
School of Science and Engineering
University of Dundee

Dear Garreth

Full title of study: Understanding the Design Process of Designers Creating Mobile Content

SoCEC reference number: *16/004*

Thank you for submitting an amended ethics application on 3 June. Your application has been reviewed by the Ethics committee.

Ethical issues arising from the proposed study

You have indicated that there are no significant ethical issues arising from this project. The Ethics Committee has approved this study.

Conditions of approval

By submitting an application to the Ethics Committee you confirm that you have read and understand the University of Dundee Guidelines for Ethical Practices in Research and the School of Computing Code of Practice for Research involving Human Participants and undertake to abide by these guidelines. Permission is therefore granted for you to proceed with the study.

Please inform the committee of any change in project methodology which may have ethical implications.

Best wishes for your research,

Yours sincerely

Annalu Waller MBCS MIPEM
Professor
Convener: Computing Ethics Committee

Administrator: Mrs Kathleen Cummins
email SoC-EthicsMembers@dundee.ac.uk *telephone* 01382 386532

School of Science and Engineering
UNIVERSITY OF DUNDEE Dundee DD1 4HN Scotland UK *t* +44 (0)1382 388085
www.computing.dundee.ac.uk

A.4: Supporting designers in reducing situational visual impairments

School of Science
and Engineering
University of Dundee

Research Ethics Committee

Professor Annalu Waller
T: 01382 388223
e: awaller@dundee.ac.uk

4 June 2018

Dear Garreth

Application Number: 18-005
Title: Supporting designers in designing to reduce situational visual impairments

I am writing to advise you that your ethics application has been reviewed and approved on behalf of the School of Science and Engineering Research Ethics Committee.

Approval is valid for three years from the date of this letter. Should your study continue beyond this point, please request a renewal of the approval.

Any changes to the approved documentation (e.g., study protocol, information sheet, consent form) must be approved by this SREC.

Yours sincerely

Kindest regards

Professor Annalu Waller OBE MBCS MIPEM

University of Dundee • Dundee, DD1 4HN • Scotland, UK t: +44 (0)1382 383000 w: dundee.ac.uk
Registered Scottish Charity No: SC015096

Appendix B. Study Material for Understanding Situational Visual Impairments

This appendix contains material used during Study 1 and Study 2 presented in Chapter 3.

B.5: Study 1 questionnaire.

Please give us some details about you and describe a time you found it difficult to use a mobile device because of bright lighting.

1. **Age (years)**

   ____

2. **Gender**
   Mark only one oval.
   - ◯ Male
   - ◯ Female
   - ◯ Other

3. **What type of mobile device were you using?**
   Mark only one oval.
   - ◯ Smartphone
   - ◯ Tablet
   - ◯ Smartwatch

4. **Were you outside or inside?**
   Mark only one oval.
   - ◯ Outside
   - ◯ Inside

5. **What were you trying to do?**

   ____

6. **What made it difficult?**

   ____

7. **How frustrated were you?**
   Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Extremely

8. **Were you able to complete your task?**
   Mark only one oval.
   - ◯ Yes
   - ◯ No

B.5: Study 1 questionnaire.

9. **[if yes to the previous question] What did you do so that you were able to complete the task?**

10. **[if no to the previous question] What did you end up doing instead?**

11. **In general, how often does bright lighting make it difficult to see things on your mobile display(s)?**
Mark only one oval.
   - Almost every day
   - At least once a week
   - At least once a month
   - Less than once a month
   - Never

B.6: Study 1 codebook.

Codebook

What were you trying to do?

1	Enact a System Change	Applies to any statement about completing a task that is related to the system state (e.g., adjusting brightness, unlocking the device).
2	Text-based Communication	Applies to any statement about checking, reading or sending messages in any form (e.g., email, SMS, instant message, status update).
3	Create, Consume, or Interact with Media	Applies to any statement about creating, consuming or interacting with non-text media (e.g., taking, viewing or editing a photo, watching a video, selecting music, playing a game).
4	Seeking Information	Applies to any statement about looking for information or keeping up to date (e.g., reading text, books, or eBooks, browsing the Internet, checking the time, accessing social media (except for messaging), checking fitness stats).
5	Navigation and Maps	Applies to any statement about navigating or using maps (e.g., navigating to a destination, checking current location).
6	Shopping	Applies to any statement about shopping online (e.g., Amazon).
7	Checking Notifications	Applies to any statement about notifications (e.g., Facebook Messenger notifications, system notifications).
8	Nonspecific	Applies to any statement in which no specific task was given (e.g., use my phone).
9	Making and Receiving Phone Calls	Applies to any statement about making or receiving phone calls.

B.6: Study 1 codebook.

What made it difficult?

1	Sun	Applies to any statement about the sun.
2	Accessories (Human)	Applies to any statement about an accessory worn by the participant (e.g., sunglasses, tinted safety glasses, running armband).
3	Screen Content Appearance	Applies to any statement about the appearance of any content displayed on the screen (e.g., thickness and colour contrast of icons or text, colour scheme for apps, games, or websites).
4	Difficult to See Content	Applies to any generic statement about the screen content being difficult to see (e.g., difficult to read track names).
5	Accessories (Mobile Device)	Applies to any statement about an accessory fitted to the mobile device (e.g., protective screen cover).
6	Screen Quality and Brightness	Applies to any statement about the quality of the mobile device screen (e.g., dark screen, dim backlight, general lack of screen visibility).
7	Automated System Adjustments	Applies to any statement about automatic operating system changes (e.g., auto-brightness adjustments, power saving mode).
8	Glare/Reflections	Applies to any statement about glare or reflections on the screen.
9	Bright Lighting	Applies to any statement about bright light or bright environment (inside or outside) where there is no specific mention of the sun.
10	Viewing Angle	Applies to any statement about trying to view the device at an angle or any statement about the direction of the light source.

B.6: Study 1 codebook.

What did you do...?

1	Altering (Device) Accessory	Applies to any statement about altering any device accessory (e.g., removing a protective cover).
2	Create or Use Local Shading	Applies to any statement about covering the device with the participant's body, hand, or item (e.g., book, clothing) to cause shade.
3	Continuing On	Applies to any statement about continuing on (e.g., concentrating more).
4	Squinting	Applies to any statement about squinting.
5	Completing by Memory	Applies to any statement about completing the task from memory.
6	Reorienting Body and/or Device	Applies to any statement about changing posture, body position or device angle to adjust the amount of light falling on the screen.
7	Auto Brightness	Applies to any statement about enabling (or disabling) auto brightness, or waiting for auto brightness to activate.
8	Increasing Screen Brightness or Contrast	Applies to any statement about increasing screen brightness or contrast (e.g., via accessibility options).
9	Altering (Human) Accessory	Applies to any statement about altering any human accessory (e.g., removing sunglasses, taking phone out of armband).
10	Relocating	Applies to any statement about changing location (e.g., finding shade under a tree).
11	Waiting	Applies to any statement about waiting until the problem subsides.
12	Switching to Another Task or App	Applies to any statement about switching to a different application to complete the task or switching task altogether.
13	Could Not Recall	Applies to any statement about a participant not recalling what they actually did.
14	Speak to Somebody	Applies to any statement about asking another person for assistance.
15	Stop Altogether	Applies to any statement about a participant stopping using the device or application altogether.

B.7: Study 2 pilot example recruitment text.

Pilot Sample Recruitment Text

Hello,

I am looking for people who use a mobile device (or mobile devices) such as smartphones, tablets, and smartwatches, to take part in my research.

Mobile devices play a large role in people's everyday lives due to their portability and computing power, and this has extended our freedom for completing tasks at our convenience and to stay connected with friends and family. We are interested in people's daily experiences when using a mobile device.

1. First, you will be asked to complete a demographics questionnaire (5 minutes)
2. Second, I will arrange a time for you to take part in an ecological momentary assessment (EMA), which would involve you receiving 5 short self-report questionnaires (approximately 2 minutes to complete) in an email throughout the day over a 1-week period.
3. Finally, you may be asked to take part in a follow up interview. We can arrange a time that suits you.

More information can be found here https://uod.box.com/v/pilot-info

You will be reimbursed with a £10 voucher for taking part in this project.

If you have any questions or would like to take part, please contact me.

Thanks,
Garreth Tigwell

B.8: Study 2 pilot self-report.

P1 - Self-Report

P1 - Self-Report

We are interested in understanding situational visual impairments (SVIs). A SVI is the phenomenon experienced when you struggle with a visual task that you would normally have no trouble with (e.g., reading directions on Google Maps on a cloudy vs bright sunny day). There are a number of factors that can contribute to experiencing a SVI, e.g., the problem can occur due to the design of the mobile device, the design of the content being viewed, the environment, etc. SVI can also occur from a combination of these factors.

1. **How many times in the last 2-3 hours did you experience a SVI?**
   Please put 0 if there were none and submit the form. Thank you.

   ____

Please tell us about one of these SVI experiences

2. **What device were you using?**
   Mark only one oval.
   - ◯ Apple iPhone
   - ◯ Apple iPad
   - ◯ Other: ________________

3. **Were you outside or inside?**
   Mark only one oval.
   - ◯ Outside
   - ◯ Inside

4. **What were you trying to do?**
   Please select all that apply
   Check all that apply.
   - ☐ Text-based communication (checking, reading or sending messages in any form e.g., email; status update; instant message)
   - ☐ Seeking information (looking for information or keeping up to date e.g, browsing; reading; checking time; accessing social media (except messaging or status updates); checking fitness stats)
   - ☐ Create, consume, or interact with media (creating, consuming or interacting with non-text media e.g. taking, viewing, editing a photo; watching video; selecting music; playing a game)
   - ☐ Navigation and maps (navigating or using maps e.g., navigating to a destination or checking current location)
   - ☐ Checking notifications (looking at notifications e.g., facebook messenger notifications; system notifications)
   - ☐ Enact a system change (tasks related to the system state e.g., adjusting screen brightness; typing a pin to unlock the device)
   - ☐ Shopping (shopping online e.g., using Amazon)
   - ☐ Making or receiving a phone call
   - ☐ Other: ________________

B.8: Study 2 pilot self-report.

5. **What made it difficult?**
Please select all that apply
Check all that apply.

- [ ] External Influences (e.g., the environment, position or angle of device)
- [ ] Human Accessory Interference (e.g., sunglasses, running armband holding device)
- [ ] Device Accessory Interference (e.g., screen protector)
- [ ] Problematic Hardware Design (e.g., quality of the display, glare and reflections)
- [ ] Operating System Inadequacy (e.g., automated adjustments such as auto-brightness and power saving mode)
- [ ] Problematic Interface and Content Design (e.g., thickness and colour contrast of icons or text, overall colour scheme)
- [ ] Other: ____________________

6. **How frustrated were you?**
Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Extremely

7. **What did you do?**
Please select all that apply
Check all that apply.

- [ ] Persevere (e.g., continuing by concentrating more or completing task by memory)
- [ ] Change Tactic (e.g., relocating, switching to a different application, switching to a different task)
- [ ] Fixing Accessories (e.g., removing the device from the "device accessory" or removing the "human accessory")
- [ ] Adjusting Display (e.g., increasing screen brightness, toggling auto-brightness, or waiting for auto brightness to activate)
- [ ] Physical Solutions (e.g., cover the device, reorienting body and/or device)
- [ ] Not Rely on Device (e.g., stop using the device or closing the application, seeking assistant elsewhere such as talking to somebody)
- [ ] Waited until the problem subsided
- [ ] Other: ____________________

8. **How important was this task?**
Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Extremely

B.8: Study 2 pilot self-report.

P1 - Self-Report

9. **Additional Comments**

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B.9: Study 2 pilot end-of-day report.

P1 - End of Day Report

P1 - End of Day Report

We are interested in understanding situational visual impairments (SVIs). A SVI is the phenomenon experienced when you struggle with a visual task that you would normally have no trouble with (e.g., reading directions on Google Maps on a cloudy vs bright sunny day). There are a number of factors that can contribute to experiencing a SVI, e.g., the problem can occur due to the design of the mobile device, the design of the content being viewed, the environment, etc. SVI can also occur from a combination of these factors.

1. **If you were you unable to complete any of the self-reports today, please tell us the reasons why?**
   Check all that apply.

   - [ ] I did not have time to complete the self-report
   - [ ] No data connection
   - [ ] Unsafe to do so
   - [ ] Other: ____________________

If there is a particular experience of BL-SVI that you did not report today, and wish to do so, please describe it for us.

2. **What device were you using?**
   Mark only one oval.

   - ( ) Apple iPhone
   - ( ) Apple iPad
   - ( ) Other: ____________________

3. **Were you outside or inside?**
   Mark only one oval.

   - ( ) Outside
   - ( ) Inside

B.9: Study 2 pilot end-of-day report.

P1 - End of Day Report

4. **What were you trying to do?**
Please select all that apply
Check all that apply.

- [ ] Text-based communication (checking, reading or sending messages in any form e.g., email; status update; instant message)
- [ ] Seeking information (looking for information or keeping up to date e.g, browsing; reading; checking time; accessing social media (except messaging or status updates); checking fitness stats)
- [ ] Create, consume, or interact with media (creating, consuming or interacting with non-text media e.g. taking, viewing, editing a photo; watching video; selecting music; playing a game)
- [ ] Navigation and maps (navigating or using maps e.g., navigating to a destination or checking current location)
- [ ] Checking notifications (looking at notifications e.g., facebook messenger notifications; system notifications)
- [ ] Enact a system change (tasks related to the system state e.g., adjusting screen brightness; typing a pin to unlock the device)
- [ ] Shopping (shopping online e.g., using Amazon)
- [ ] Making or receiving a phone call
- [ ] Other: ______________________

5. **What made it difficult?**
Please select all that apply
Check all that apply.

- [ ] External Influences (e.g., the environment, position or angle of device)
- [ ] Human Accessory Interference (e.g., sunglasses, running armband holding device)
- [ ] Device Accessory Interference (e.g., screen protector)
- [ ] Problematic Hardware Design (e.g., quality of the display, glare and reflections)
- [ ] Operating System Inadequacy (e.g., automated adjustments such as auto-brightness and power saving mode)
- [ ] Problematic Interface and Content Design (e.g., thickness and colour contrast of icons or text, overall colour scheme)
- [ ] Other: ______________________

6. **How frustrated were you?**
Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Extremely

B.9: Study 2 pilot end-of-day report.

7. **What did you do?**
Please select all that apply
Check all that apply.

- [ ] Persevere (e.g., continuing by concentrating more or completing task by memory)
- [ ] Change Tactic (e.g., relocating, switching to a different application, switching to a different task)
- [ ] Fixing Accessories (e.g., removing the device from the "device accessory" or removing the "human accessory")
- [ ] Adjusting Display (e.g., increasing screen brightness, toggling auto-brightness, or waiting for auto brightness to activate)
- [ ] Physical Solutions (e.g., cover the device, reorienting body and/or device)
- [ ] Not Rely on Device (e.g., stop using the device or closing the application, seeking assistant elsewhere such as talking to somebody)
- [ ] Waited until the problem subsided
- [ ] Other: ____________

8. **How important was this task?**
Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Extremely

9. **Additional Comments**

____
____
____
____
____

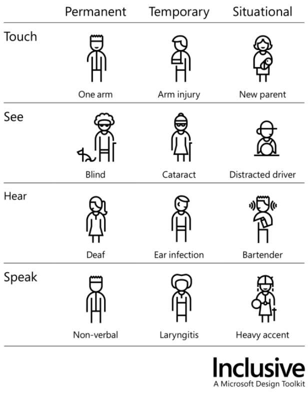
Powered by Google Forms

B.10: Study 2 SVI explaination sheet.

My research explored situational impairments. Situational Impairments occur when a person has difficulty completing a task because of the situation they are in.

For example, you are holding heavy shopping bags (*your situation*) when your mobile phone rings. You are unable to answer your phone (*your task*), because you are encumbered by your bags. This would be a situational **physical** impairment. If you did not have the bags of shopping you would have been able to pick up the phone.

The following image from the Inclusive Microsoft Design Toolkit helps illustrate different permanent, temporary, and situational impairments.



This study is exploring Situational **Visual** Impairments (SVIs). SVI occurs when your situation causes you to struggle with a **visual** task that you would typically have no trouble with. Here are design cards (created by HaptiMap), which are used by designers to consider some example situations that could cause SVIs:

There are many factors that can cause SVIs. "**Environment**" (e.g., bright lighting) is one, but some other factors are also "**human accessories**" (e.g., sunglasses making a screen appear dark), "**device accessories**" (e.g., glossy screen protector causing glare), "**hardware limitations**" (e.g., an insufficiently bright screen), "**system settings**" (e.g., auto brightness not responding quickly enough), and "**content design**" (e.g., low contrast text or icons reducing readability).

Situational visual impairments depend on so many different factors that some people will experience SVIs more than others. For this study, there is no minimum expected number of SVIs to be experienced each day, and you may find that on some days you experience no SVIs. This is perfectly acceptable.

B.11: Study 2 demographics questionnaire.

P13 - Demographics

* Required

1. **Please state your age** *

   ____

2. **Please state your gender** *

   Mark only one oval.

   - ◯ Male
   - ◯ Female
   - ◯ Other: ______________________

3. **What country do you currently live in?** *

   Mark only one oval.

   - ◯ Australia (NSW, TAS, VIC, ACT)
   - ◯ Scotland
   - ◯ Other: ______________________

4. **Do you plan to visit another country or timezone during part 2 of this study (i.e., the 2-week EMA study)?** *

   Part 2 will occur between 1st - 19th of February

   Mark only one oval.

   - ◯ Yes
   - ◯ No
   - ◯ Other: ______________________

5. **What is your highest level of education?** *

   Mark only one oval.

   - ◯ High School
   - ◯ College
   - ◯ University (Undergraduate)
   - ◯ University (Postgraduate)
   - ◯ Other: ______________________

6. **Please rate your level of computer literacy** *

   Mark only one oval.

   - ◯ Poor
   - ◯ Fair
   - ◯ Good
   - ◯ Excellent
   - ◯ Other: ______________________

1/3

B.11: Study 2 demographics questionnaire.

7. **Does your work or study mainly occur in outside or inside environments? ***
Mark only one oval.

- ( ) Outside
- ( ) Inside
- ( ) N/A

8. **Please list and describe any visual impairments you have ***
E.g., glaucoma, cataract, near-sightedness, far-sightedness

____
____
____
____
____

9. **Do you wear contacts or glasses? ***
Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Other: ______________________________

10. **How many mobile devices do you own? ***
We are interested in mobile phones, tablets, and smartwatches

____

11. **Please tell us the make and model of each mobile device you own ***
We will use this information so that your self-reports are tailored to you and this will save you time completing the self-reports. E.g., Samsung Galaxy S7 Edge, iPad Pro 9.7", Huawei Watch 2.

____
____
____
____
____

2/3

B.11: Study 2 demographics questionnaire.

12. **On average, what is the total number hours per day that you use these mobile devices?** *

Please estimate to the nearest whole hour from 0 to 24

Mark only one oval.

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16
- 17
- 18
- 19
- 20
- 21
- 22
- 23
- 24

3/3

B.12: Study 2 codebook.

Codebook

Where did this SVI experience take place?

1	At an event	Applies to any statement about being present at an event (e.g., a concert, conference).
2	In a public space	Applies to any statement about being present in a public space (e.g., food court, park, on the street).
3	In a shop	Applies to any statement about being in a shop (e.g., queuing in a shop, inside a café, restaurant). Not food court or public places.
4	Home	Applies to any statement about a person's home.
5	Work or school	Applies to any statement related to work or school (e.g., university).
6	Transport	Applies to any statements related to using and waiting transportation (e.g., driving the vehicle, being a passenger, sitting inside a parked car) except cycling.
7	Being active	Applies to any statements about being active (e.g., walking, running, cycling, at the gym).
8	At the hospital	Applies to any statement about being inside a hospital.
9	Unspecified	Applies to any statement that does not clearly mention where the SVI took place.

B.12: Study 2 codebook.

What were you trying to do?

1	Enact a System Change	Applies to any statement about completing a task that is related to the system state (e.g., adjusting brightness, unlocking the device).
2	Text-based Communication	Applies to any statement about checking, reading or sending messages in any form (e.g., email, SMS, instant message, status update).
3	Create, Consume, or Interact with Media	Applies to any statement about creating, consuming or interacting with non-text media (e.g., taking, viewing or editing a photo, watching a video, selecting music, playing a game).
4	Seeking Information	Applies to any statement about looking for information or keeping up to date (e.g., reading text, books, or eBooks, browsing the Internet, checking the time, accessing social media (except for messaging), checking fitness stats).
5	Navigation and Maps	Applies to any statement about navigating or using maps (e.g., navigating to a destination, checking current location).
6	Shopping and payments	Applies to any statement about shopping online (e.g., Amazon) or using the device for off-line purchases (e.g., NFC, scanning vouchers).
7	Checking Notifications	Applies to any statement about notifications (e.g., Facebook Messenger notifications, system notifications).
8	Nonspecific	Applies to any statement in which no specific task was given (e.g., use my phone).
9	Making and Receiving Phone Calls	Applies to any statement about making or receiving phone calls.
10	Setting up device or application	Applies to any statement about setting up a device, installing or setting up an application.

B.12: Study 2 codebook.

What made it difficult?

1	Sun	Applies to any statement about the sun.
2	Accessories (Human)	Applies to any statement about an accessory worn by the participant (e.g., sunglasses, tinted safety glasses, running armband).
3	Screen Content Appearance	Applies to any statement about the appearance of any content displayed on the screen (e.g., thickness and colour contrast of icons or text, colour scheme for apps, games, or websites, overlaid content such as pop-ups, layout).
4	Difficult to See Content	Applies to any generic statement about the screen content being difficult to see (e.g., difficult to read track names, hard to see screen).
5	Accessories (Mobile Device)	Applies to any statement about an accessory fitted to the mobile device (e.g., protective screen cover).
6	Screen Quality and Brightness	Applies to any statement about the quality of the mobile device screen (e.g., dark screen, dim backlight, display too bright).
7	Automated System Adjustments	Applies to any statement about automatic operating system changes (e.g., auto-brightness adjustments, power saving mode).
8	Glare/Reflections	Applies to any statement about glare or reflections on the screen.
9	Bright environment	Applies to any statement about bright light or bright environment (inside or outside) where there is no specific mention of the sun.
10	Viewing Angle	Applies to any statement about trying to view the device at an angle, position of person to the light, or any statement about the direction of the light source.
11	Dark environment	Applies to any statement about dark environments (inside or outside).
12	Physical obstacles	Applies to any statement about an object obscuring the screen (e.g., dirty screen, cover over the screen).
13	Recently waking up or becoming alert	Applies to any statement about having woken up (e.g., woke up to check my phone) or previously resting with eyes closed.
14	Discomfort/Pain	Applies to any statement about experiencing discomfort or pain (e.g. hurts my eyes with the brightness of the screen).
15	Moving environment	Applies to any statement about the environment moving or shaking.
16	Screen filter	Applies to any statement about the use of a screen filter (e.g., blue light filter, night mode).
17	App/Web initiated changes	Applies to any statement about an application/website enabling the user to make style changes or an application that can override system settings (e.g., rotating orientation, screen brightness)

B.12: Study 2 codebook.

What strategy (or strategies) did you use to overcome the SVI?

1	Altering (Device) Accessory	Applies to any statement about altering any device accessory (e.g., removing a protective cover).
2	Create or Use Local Shade	Applies to any statement about covering the device with the participant's body, hand, or item (e.g., book, clothing) to cause shade.
3	Continuing On	Applies to any statement about continuing on (e.g., concentrating more, putting up with it).
4	Perceptual strategy	Applies to any statement related to the eyes (e.g., squinting, closing eyes)
5	Completing by Memory	Applies to any statement about completing the task from memory.
6	Reorienting Body and/or Device	Applies to any statement about changing posture, body position or device angle. This could be to adjust the amount of light falling on the screen or to make viewing more comfortable.
7	Auto Brightness	Applies to any statement about enabling (or disabling) auto brightness, or waiting for auto brightness to activate.
8	Manually Adjust Display	Applies to any statement about manually increasing or decreasing screen brightness or contrast (e.g., via accessibility options), enabling or disabling inverted colours.
9	Altering (Human) Accessory	Applies to any statement about altering any human accessory (e.g., removing sunglasses, taking phone out of armband).
10	Relocating	Applies to any statement about changing location (e.g., finding shade under a tree).
11	Waiting	Applies to any statement about waiting until the problem subsides.
12	Switching Approach	Applies to any statement about switching to a different application to complete the task, switching task altogether, or changing the device used to complete the task.
13	Could Not Recall	Applies to any statement about a participant not recalling what they actually did.
14	Speak to Somebody	Applies to any statement about asking another person for assistance.
15	Not overcoming SVIs	Applies to any statement about not overcoming the SVI. A strategy may not have been possible, or a participant might stop using the device/application altogether.
16	Screen Filter	Applies to any statement about enabling (or disabling) a screen filter (e.g., blue light filter), or waiting for a screen filter to activate or deactivate automatically.
17	Use Alternative App features	Applies to any statement about changing how the information is delivered by an app (e.g., listening to audio output instead of reading, zooming into small text, changing from widget/lock screen view to the full app).
18	Remove physical obstacles	Applies to any statement about removing the physical obstacles that are causing the SVI.
19	Reboot device or app	Applies to any statement about switching the device off and on again or restarting an application.
20	Adjust room lighting	Applies to any statement about adjusting the room lighting (e.g., turning off the light, turning on the light).
21	Charge device	Applies to any statement about plugging the device in to charge.

B.13: Study 2 self-report.

P13 - Mobile Device SVIs

We are interested in understanding situational visual impairments (SVIs) experienced when using a mobile device. An SVI is the phenomenon experienced when you struggle with a visual task that you would normally have no trouble with. Many factors can contribute to experiencing an SVI, e.g., the problem can occur due to the mobile device (e.g., reflective displays), the design of the content being viewed (e.g., struggling to read content on a poorly designed website), or the environment (e.g., reading directions on Google Maps on a bright sunny day). SVIs can also occur from a combination of these factors. More details are available here: https://goo.gl/N7RFmY

* Required

1. **What mobile device were you using? ***
   You can type a response under the "other" option
   Mark only one oval.

   - ⬭ iPhone SE
   - ⬭ Other: ______________________

2. **Were you outside or inside? ***
   Mark only one oval.

   - ⬭ Outside
   - ⬭ Inside

3. **Where did this SVI experience take place? ***
   E.g., at home, in the garden, at work, at the beach, in the street, inside a shop

   ____

1/4

B.13: Study 2 self-report.

4. **What were you trying to do?** *

It would be great if you could type a full sentence to provide more context, e.g., "*I was trying to find out information about a film on IMDB.com*".

At minimum, please use a verb and a noun (e.g., *reading an email*, *taking a photo*, *writing a message*, *making a phone call*, *checking notifications*, *posting a status update*, *playing a game*, *unlocking the device*, *adjusting screen brightness*, *checking current location*, *purchasing an online order*).

____

____

____

____

____

5. **How important was this task?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Extremely

2/4

B.13: Study 2 self-report.

6. **What made it difficult?** *

Please write a full sentence to provide us with enough details. Remember that sometimes there is more than one factor that contributes to an SVI. Some examples:

- *"My phone battery was low, which activated a power saving mode that reduced the screen brightness and I was standing under bright lighting."*
- *"The text and icons on the website were difficult to see while wearing my sunglasses."*
- *"The device's auto-brightness was too slow to react when stepping outside, making it difficult to see the screen."*
- *"The game design uses lots of dark colours, making it difficult to play, even with the screen at maximum brightness."*
- *"It was really sunny and the angle I was holding my device and its reflective display made the screen appear very dark."*

7. **How frustrated were you?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Extremely

3/4

B.13: Study 2 self-report.

8. **What strategy (or strategies) did you use to overcome the SVI?** *

Please write a full sentence to tell us how you overcame the SVI (or if you didn't).

____

____

____

____

____

9. **Additional Comments**

____

____

____

____

____

4/4

B.14: Study 2 end-of-day report.

P13 - End of Day Report

* Required

1. **Are you still in Scotland? ***
   Mark only one oval.
   - ⬭ Yes
   - ⬭ No

2. **Were there any SVIs you did not (or were unable to) report today? ***
   Please let us know if you missed submitting a self-report during the day
   Mark only one oval.
   - ⬭ Yes *Skip to question 3.*
   - ⬭ No *Stop filling out this form.*

Mobile Device SVIs

We are interested in understanding situational visual impairments (SVIs) experienced when using a mobile device. An SVI is the phenomenon experienced when you struggle with a visual task that you would normally have no trouble with. Many factors can contribute to experiencing an SVI, e.g., the problem can occur due to the mobile device (e.g., reflective displays), the design of the content being viewed (e.g., struggling to read content on a poorly designed website), or the environment (e.g., reading directions on Google Maps on a bright sunny day). SVIs can also occur from a combination of these factors. More details are available here: https://goo.gl/N7RFmY

3. **How many SVIs do you remember experiencing today that you were not able to report? ***
   If zero, there is a back button at the bottom of this page to change your response to the previous question "Were there any SVIs you were unable to report on today?"

   ____

4. **Please tell us the reasons you were unable to submit a self-report ***
   You can type a response under the "other" option
   Check all that apply.
   - ☐ I did not have time to complete the self-report
   - ☐ No data connection
   - ☐ Unsafe to do so
   - ☐ I forgot
   - ☐ Other: ______________________________

Please describe ONE of those unreported SVIs

1/4

B.14: Study 2 end-of-day report.

5. **What mobile device were you using?** *
You can type a response under the "other" option
Mark only one oval.

- iPhone SE
- Other: ____________

6. **Were you outside or inside?** *
Mark only one oval.

- Outside
- Inside

7. **Where did this SVI experience take place?** *
E.g., at home, in the garden, at work, at the beach, in the street, inside a shop

____

8. **What were you trying to do?** *

It would be great if you could type a full sentence to provide more context, e.g., "*I was trying to find out information about a film on IMDB.com*".

At minimum, please use a verb and a noun (e.g., *reading an email*, *taking a photo*, *writing a message*, *making a phone call*, *checking notifications*, *posting a status update*, *playing a game*, *unlocking the device*, *adjusting screen brightness*, *checking current location*, *purchasing an online order*).

____

9. **How important was this task?** *
Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Extremely

2/4

B.14: Study 2 end-of-day report.

10. **What made it difficult?** *

Please write a full sentence to provide us with enough details. Remember that sometimes there is more than one factor that contributes to an SVI. Some examples:

- *"My phone battery was low, which activated a power saving mode that reduced the screen brightness and I was standing under bright lighting."*
- *"The text and icons on the website were difficult to see while wearing my sunglasses."*
- *"The device's auto-brightness was too slow to react when stepping outside, making it difficult to see the screen."*
- *"The game design uses lots of dark colours, making it difficult to play, even with the screen at maximum brightness."*
- *"It was really sunny and the angle I was holding my device and its reflective display made the screen appear very dark."*

11. **How frustrated were you?** *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Extremely

3/4

B.14: Study 2 end-of-day report.

12. **What strategy (or strategies) did you use to overcome the SVI?** *
Please write a full sentence to tell us how you overcame the SVI (or if you didn't).

____
____
____
____
____

13. **Additional Comments**

____
____
____
____
____

4/4

Appendix C. Study Material for Identifying Designers' Needs for Addressing Situational Visual Impairments

This appendix contains material used during Study 3 and Study 4 presented in Chapter 4.

C.15: Study 3 questionnaire.

Please tell us about your design process

Please tell us about your design process

Through this questionnaire we want to understand the process designers take to improve functionality and usability when creating content for mobile devices.

Anyone who is 18 years old or over can take part in this study. Participation is voluntary, all questions are optional, and you can withdraw at any time without penalty and for any reason. The data will be treated with full confidentiality and if published or presented at conferences it will be completely anonymous.

To show our appreciation for your time you will be entered for a chance to win 1 of 4 $50 USD (or equivalent value) Amazon gift vouchers if you provide your email address.

If you have any questions, contact the principal investigator Garreth Tigwell g.w.tigwell@dundee.ac.uk or the project supervisor Dr David Flatla d.flatla@dundee.ac.uk

BY CONTINUING TO THE QUESTIONNAIRE YOU ARE AGREEING THAT:
(a) you have read and understood the information above
(b) questions about your participation in this study have been answered satisfactorily
(c) you are taking part in this research study voluntarily (without coercion)
(d) you are at least 18 years old

UNIVERSITY OF DUNDEE

Computing
at the University of Dundee

Questionnaire

1. **Age**

    ____

2. **Gender**
    Mark only one oval.
    - ◯ Male
    - ◯ Female
    - ◯ Other

3. **In which country do you live?**

    ____

C.15: Study 3 questionnaire.

Please tell us about your design process

4. **Please select all options that describe your design training.**
   Tick all that apply.

   - [ ] Apprenticeship
   - [ ] College
   - [ ] University (Undergraduate)
   - [ ] University (Postgraduate)
   - [ ] I have not received any formal design training
   - [ ] Other: ____________________

5. **Which option best describes your design career?**
   Mark only one oval.

   - ( ) Working for a company
   - ( ) Self-employed
   - ( ) Designing as part of a hobby or pastime activity
   - ( ) Other: ____________________

6. **What mobile content do you design?**
   Tick all that apply.

   - [ ] Mobile friendly websites
   - [ ] Mobile apps
   - [ ] Games
   - [ ] Books
   - [ ] Advertising
   - [ ] Other: ____________________

7. **How many years have you been designing mobile content that is publicly or commercially released?**

   ____

Accessibility

Products, devices, or services designed for accessibility can be used by people with a disability or impairment.

C.15: Study 3 questionnaire.

Please tell us about your design process

8. **Do you include accessibility when designing mobile content?**
Mark only one oval.

- ◯ Never *Skip to question 20.*
- ◯ Sometimes *Skip to question 10.*
- ◯ Always *Skip to question 9.*

Skip to question 22.

Accessibility

9. **Please describe the reason(s) why you include accessibility when designing mobile content.**

____
____
____
____
____

Skip to question 13.

Accessibility

10. **Please specify the frequency of your design projects that include accessibility?**
Mark only one oval.

- ◯ Rarely (Less than 20%)
- ◯ Occasionally (20-40%)
- ◯ About half (40-60%)
- ◯ Often (60-80%)
- ◯ Almost always (Greater than 80%)

11. **Please describe the reason(s) why you don't always include accessibility when designing mobile content.**

____
____
____
____
____

C.15: Study 3 questionnaire.

Please tell us about your design process

12. **Please describe the reason(s) why you sometimes include accessibility when designing mobile content.**

Skip to question 13.

Accessibility

13. **Typically, what is the earliest point in the design process that you usually design for accessibility?**
Mark only one oval.
- From the beginning
- During the process
- When a design is complete
- After the product is released
- Other:

14. **Consider your design projects that include accessibility. In what proportion of these projects do you make use of accessibility guidelines?**
Mark only one oval.
- None of the projects
- Some of the projects
- About half of the projects
- Most of the projects
- All of the projects

15. **Please list any accessibility guidelines that you use.**

C.15: Study 3 questionnaire.

Please tell us about your design process

16. **Consider your design projects that include accessibility. In what proportion of these projects do you make use of accessibility design tools?**
Mark only one oval.
- None of the projects
- Some of the projects
- About half of the projects
- Most of the projects
- All of the projects

17. **Please list any accessibility design tools that you use.**

18. **Consider your design projects that include accessibility. In what proportion of these projects do you run evaluations with people who have a disability or impairment?**
Mark only one oval.
- None of the projects
- Some of the projects
- About half of the projects
- Most of the projects
- All of the projects

19. **Please describe how you evaluate the designs with people who have a disability or impairment.**

Skip to question 22.

Accessibility

C.15: Study 3 questionnaire.

Please tell us about your design process

20. **Please explain why you don't include accessibility when designing mobile content?**

21. **Which of the following options to assist in accessibility design are you aware of?**
Tick all that apply.

- [ ] Accessibility guidelines
- [ ] Accessibility design tools
- [ ] Evaluation techniques

Skip to question 22.

Situational Impairment

Situational impairments are usually caused by environment conditions that negatively affect a person's ability to complete a task when they would otherwise not have a problem. Examples of situational impairments include: standing in a noisy crowd while trying to have a phone conversation (situational hearing impairment); carrying shopping bags and trying to compose an SMS on your mobile phone (situational mobility impairment); or wearing glasses with tinted or coloured lenses and trying to accurately determine the colours on a screen (situational visual impairment).

22. **How often do you design to reduce situational impairments?**
For example, providing an alternative input method or providing an alternative output for content so that it can be used for people experiencing a situational impairment.
Mark only one oval.

- Never
- Sometimes
- Always

23. **In particular, do you design to reduce situational VISUAL impairments?**
Mark only one oval.

- Never *Skip to question 37.*
- Sometimes *Skip to question 25.*
- Always *Skip to question 24.*

Skip to question 38.

Situational Visual Impairment

C.15: Study 3 questionnaire.

Please tell us about your design process

24. **Please describe the reason(s) why you design to reduce situational visual impairment when designing mobile content.**

Skip to question 28.

Situational Visual Impairment

25. **Please specify the frequency of your design projects in which you design to reduce situational visual impairment?**
Mark only one oval.
- Rarely (Less than 20%)
- Occasionally (20-40%)
- About half (40-60%)
- Often (60-80%)
- Almost always (Greater than 80%)

26. **Please describe the reason(s) why you don't always design to reduce situational visual impairment when designing mobile content.**

27. **Please describe the reason(s) why you sometimes design to reduce situational visual impairment when designing mobile content.**

Skip to question 28.

C.15: Study 3 questionnaire.

Please tell us about your design process

Situational Visual Impairment

28. **Please list the situational visual impairments you design to reduce the effects of.**

____
____
____
____
____

29. **Typically, what is the earliest point in the design process that you usually design to reduce situational visual impairment?**
Mark only one oval.
- ◯ From the beginning
- ◯ During the process
- ◯ When a design is complete
- ◯ After the product is released
- ◯ Other: _______________

30. **Consider your design projects where you reduce situational visual impairment. In what proportion of these projects do you make use of situational visual impairment guidelines?**
Mark only one oval.
- ◯ None of the projects
- ◯ Some of the projects
- ◯ About half of the projects
- ◯ Most of the projects
- ◯ All of the projects

31. **Please list any situational visual impairment guidelines that you use.**

____
____
____
____
____

C.15: Study 3 questionnaire.

Please tell us about your design process

32. **Consider your design projects where you reduce situational visual impairment. In what proportion of these projects do you make use of situational visual impairment design tools?**

    Mark only one oval.

    - None of the projects
    - Some of the projects
    - About half of the projects
    - Most of the projects
    - All of the projects

33. **Please list any situational visual impairment design tools that you use.**

    ____
    ____
    ____
    ____
    ____

34. **Consider your design projects where you reduce situational visual impairment. In what proportion of these projects do you run evaluations with people experiencing situational visual impairment?**

    Mark only one oval.

    - None of the projects
    - Some of the projects
    - About half of the projects
    - Most of the projects
    - All of the projects

35. **Please describe how you evaluate the designs with people experiencing situational visual impairment.**

    ____
    ____
    ____
    ____
    ____

C.15: Study 3 questionnaire.

Please tell us about your design process

36. **When designing, do you distinguish between visual impairment and situational visual impairment? Please explain your answer.**

____
____
____
____
____

Skip to question 38.

Situational Visual Impairment

37. **Please explain why you don't design to reduce situational visual impairment when designing mobile content.**

____
____
____
____
____

Skip to question 38.

Situational Visual Impairment

38. **What would best help you create designs that reduce the effects of situational visual impairment?**
    Tick all that apply.

- [ ] Physical design tools
- [ ] Guidelines
- [ ] Education
- [ ] Support service
- [ ] Digital design tools
- [ ] Other: _______________

Skip to question 39.

Contact

C.15: Study 3 questionnaire.

Please tell us about your design process

39. **Please enter your email address so that we can enter you into the prize draw.**

40. **Tick here if you are happy for us to contact you to take part in a follow up interview.**
Tick all that apply.

- [ ] I consent to being contacted

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Google Forms

C.16: Study 4 interview guide.

<u>Interview guide</u>

1. I want to begin by asking a few basic demographic questions.
    a. How old are you?
    b. Please state your gender?
    c. How many years have you been designing mobile content that has been publicly or commercially released?
2. I'd like to find out some more about your design history and career.
    a. Can you tell me a bit about your design training?
        - [prompt] DEGREE – at what level? How was the course structured? How were you assessed?
        - [prompt] APPRENTICESHIP – how much structure was there during the apprenticeship? Did you get a lot of opportunity to refine your skill? Did you learn through observation?
        - [prompt] SELF-TAUGHT – how did you go about learning? Any recommendations by other designers?
    b. I'd like to find out a bit more about the design process you follow.
        i. Can you walk me through your typical design process? E.g., from initial client contact through to final product?
        ii. How involved are your clients during the design process?
            1. [prompt] What are your opinions of clients having a little involvement or a lot of involvement?

C.16: Study 4 interview guide.

3. Now we're going to talk about specific design practises.
    a. Are you aware of accessibility?
        i. [if yes]
            1. Can you tell me your understanding of what accessibility is?
            2. When did you become aware of accessibility?
                a. [prompt] was any/how much focus was given to accessibility during your degree/apprenticeship?
            3. As a designer, what are your thoughts on accessibility?
            4. What is your perception of the design community's attitude towards accessibility?
        ii. [if no]
            1. "'Accessibility' has historically referred to design that enables people with disabilities to interact with buildings, products, services, etc." – henry et al. (2014).
            2. Digital content can either be accessible or inaccessible.
            3. With this in mind, what are your thoughts on accessibility?

4. We're going to talk about situational visual impairment. You may remember this from the questionnaire that you completed. *A situational impairment is when a person experiences a temporary inability to complete a task that in another context the person would normally have no issues with*. I'd like us to focus on the SVI experienced when using a mobile device in bright surroundings.
    a. Can you think of a time when you have experienced this yourself?
        i. [Prompt] What factors contributed to the problem?

C.16: Study 4 interview guide.

b. How did to resolve the issue?
c. Do you consider SVI when designing?
    i. How do you do this?
    ii. Do you ever run user evaluations?
    iii. What are your thoughts on running a user evaluation?
d. Has your perception or attitude towards situational visual impairment changed since you took part in the survey last year? How?
e. Have you adjusted your design approach since you took part in the survey last year? How?
f. Are you aware of guidelines or tools to help reduce SVI when designing?
    i. [Prompt] Please tell me more?

5. We've identified four themes from the responses to the questionnaire summarising why a designer might not design to reduce SVI occurring. I want to discuss each of them with you and if you can it would be good to reflect on practices within accessibility such as what you believe works or does not work.
    a. (1) It was not in the design scope or current practice
        i. Tell me about a time when you've been required to make a design and thought the design brief or client requirement was missing something?
        ii. [Prompt] How did you deal with this?
        iii. [Prompt] How did clients respond to this?
        iv. How do you think we can increase designing for SVI in current design practice or as part of the project scope?

C.16: Study 4 interview guide.

b. (2) There are limited resources (e.g., time constraint or deadline, budget, limited tools)
    i. Have you experienced this issue?
    ii. How did you deal with this problem?
    iii. What do you think is the most feasible way to reduce this problem?
c. (3) Designers are unaware of SVI or they have not considered it
    i. How can we increase awareness or help prompt designers to consider it as something they can help with?
    ii. Can you give me an example where you were unaware of something you should have considered when designing? What was it and how was it brought to your attention?
d. (4) SVI is viewed as a minor issue (although we suspect that this is a bigger issue than people realise and we have some data from a previous study to support this).
    i. [Prompt] how could we change the perception that it is a small issue?
e. When asked what could help during the survey, the top three requests in the survey for assistance were guidelines, education, and digital design tools.
    i. Do you have experience of these?
    ii. Where/What were they?
    iii. What are your thoughts on each?

Appendix D. Study Material for Supporting Designers in Reducing Situational Visual Impairments

This appendix contains material used during Study 5 and Study 6 presented in Chapter 5.

D.17: Study 5 questionnaire.

How do you design mobile app interfaces?

In this 5-10 minute questionnaire, we would like you to tell us about the process you typically follow when designing mobile app interfaces. The data we gather in this questionnaire will help to increase our understanding of design processes that are followed by designers of mobile app interfaces.

We require all questions to be completed for the purposes of accurate analysis, however, you can withdraw at any time without penalty and for any reason by closing this page.

The data will be treated with full confidentiality and if published or presented it will be completely anonymous.

If you have any questions, contact the principal investigator Garreth Tigwell (g.w.tigwell@dundee.ac.uk) or the project supervisors Dr David Flatla (dflatla@uoguelph.ca) and Dr Rachel Menzies (r.menzies@dundee.ac.uk).

BY CONTINUING TO THE QUESTIONNAIRE YOU AGREE THAT:
(a) You have read and understood the information above
(b) You have been given the opportunity to ask questions about this study and they were answered satisfactorily
(c) You are at least 18 years old, are taking part voluntarily (without coercion), and you understand you can withdraw at anytime
(d) You understand that your data may be published or disseminated in research outputs
(e) You consent to the data you provide being archived in data repositories, such as UoD Pure and the ACM Digital Library

* Required

1. **Age** *
   Please enter a whole number.

   ____

2. **Gender** *
   Mark only one oval.
   - ◯ Male
   - ◯ Female
   - ◯ Other: ____________________

3. **In which country do you live** *

   ____

4. **Please select all options that describe your design training.** *
   Check all that apply.
   - ☐ Apprenticeship
   - ☐ College
   - ☐ University (Undergraduate)
   - ☐ University (Postgraduate)
   - ☐ I have not received any formal design training
   - ☐ Other: ____________________

D.17: Study 5 questionnaire.

5. **Which option best describes your design career?** *
Mark only one oval.

- ( ) Working for a company
- ( ) Self-employed
- ( ) Designing as part of a hobby or pastime activity
- ( ) Other: ____________

6. **How many years have you been designing mobile app interfaces?** *
Please enter a whole number.

____

7. **Which mobile platforms do you design for?** *
Please select all that apply.
Check all that apply.

- [ ] Android
- [ ] iOS
- [ ] Universal Windows Platform (UWP)
- [ ] Other: ____________

8. **Do you ever work on paper?** *
E.g., making sketches or paper prototypes
Mark only one oval.

- ( ) Yes *Skip to question 9.*
- ( ) No *Skip to question 12.*

Skip to question 12.

Working on paper

9. **Considering all projects you have completed in which you designed a mobile app interface, in what proportion of those did you work on paper?** *
Mark only one oval.

- ( ) Rarely (Less than 20%)
- ( ) Occasionally (20-40%)
- ( ) About half (40-60%)
- ( ) Often (60-80%)
- ( ) Almost always (Greater than 80%)
- ( ) Always

10. **Typically, when during the design process do you work on paper?** *
Please explain your response.

____
____
____
____
____

D.17: Study 5 questionnaire.

11. **Why do you chose to work on paper?** *
Please explain your response.

Skip to question 12.

12. **Please list each design software/tool you use when designing mobile app interfaces and include a short statement about when it is used.** *
E.g., Adobe XD – I use this throughout the whole design process (i.e., from working on the initial concept to the finished app interface design).

13. **Have you ever considered multiple design ideas for a mobile app interface during a project?** *
I.e., you consider more than one potential design before a final design is chosen
Mark only one oval.

- Yes *Skip to question 14.*
- No *Skip to question 18.*

Working on multiple design ideas for a mobile app interface

14. **Considering all projects you have completed in which you designed a mobile app interface, in what proportion of those did you have multiple design ideas?** *
Mark only one oval.

- Rarely (Less than 20%)
- Occasionally (20-40%)
- About half (40-60%)
- Often (60-80%)
- Almost always (Greater than 80%)
- Always

15. **Typically, when during the design process do you work on multiple design ideas?** *
Please explain your response.

D.17: Study 5 questionnaire.

How do you design mobile app interfaces?

16. **How do you approach working on multiple design ideas for a mobile app interface?** *
Please include as many details as possible.

17. **How do you decide on the final version of a mobile app interface?** *
Please explain your response.

Alternative modes for mobile app interfaces

18. **Have you ever designed a mobile app interface that had alternative modes or themes that the user could enable (e.g., a dark mode for night-time use)?** *
Mark only one oval.
    - ◯ Yes *Skip to question 19.*
    - ◯ No *Skip to question 24.*

Alternative modes for mobile app interfaces

19. **Considering all projects you have completed in which you designed a mobile app interface, in what proportion of those did you design alternative modes or themes?** *
Mark only one oval.
    - ◯ Rarely (Less than 20%)
    - ◯ Occasionally (20-40%)
    - ◯ About half (40-60%)
    - ◯ Often (60-80%)
    - ◯ Almost always (Greater than 80%)
    - ◯ Always

20. **Typically, when during the design process do you work on alternative modes or themes?** *

D.17: Study 5 questionnaire.

How do you design mobile app interfaces?

21. **How do you approach working on alternative modes or themes for mobile app interfaces?** *

22. **How do you decide on the final version(s) of these alternative modes or themes?** *
Please explain your response.

23. **Are there any challenges you face when you design alternative modes or themes?** *
Please explain your response.

24. **Typically, when during the design process do you explore the mobile app interface colour scheme?** *
Please explain your response.

25. **[Optional] Please leave any further comments about your design process and experiences when designing a mobile app interface that you think is important but was not covered by the previous questions.**
E.g., Is there something you would like to be improved? Is there a design tool you think more people should be using? Etc.

D.18: Study 6 pilot information sheet.

PARTICIPANT INFORMATION SHEET

Project title: Supporting designers in designing to reduce situational visual impairments

Investigators: Garreth Tigwell, Dr David Flatla, Dr Rachel Menzies

Invitation:
You are being asked to take part in a pilot research study. Before you decide if you would like to take part, it is important you understand why the research is being done and what it involves. Please take your time to read the following information carefully and feel free to ask any questions. If you agree to take part in the study, you will be asked to sign a consent form. Thank you for your time.

Purpose of the Research:
This pilot study is being undertaken by Garreth Tigwell as part of his PhD studies at the University of Dundee to determine any necessary changes to a future design workshop study.

Mobile devices play a large role in people's everyday lives due to their portability and computing power, and this has extended our freedom for completing tasks at our convenience and to stay connected with friends and family. I am interested in supporting designers in designing to reduce situational visual impairments that are experienced by people using mobile devices. E.g., improving the UX when a device is used in a dark or in a bright environment.

What to Expect:
I would like you to take part in a pilot design workshop (1-1.5 hours) that will take place at the University of Dundee. You will be helping to design a digital design tool and testing protocol for SVIs that fits within your typical workflow. Paper-based prototyping will be the main focus of the workshop.

Cost, Reimbursement and Compensation:
You will receive a £10 amazon voucher for the pilot workshop.

Risks:
There are no risks associated with this study and I hope that the task will be enjoyable.

Participation:
It is up to you to decide if you would like to take part or not. Your participation is voluntary and you are free to withdraw from the study at any time without penalty and without explanation. I will delete any data or information collected at this point so that it will not be included in any future publications.

Confidentiality:
The data collected will not contain any personal information about you. I will follow ethical and legal practice and all information about you will be handled in confidence.

It will not be possible to link publicly the data you provided to your identity and name. I will not link the consent form to any data you submit. You will be provided with a participant ID so that I can keep track of the data you submit, while ensuring it cannot be linked to you. With regards to images used, I have provided an image release form so that you can indicate how you wish any images that may include yourself to be handled for publications.

All digital data and documents containing (or linking to) the original identification of the participants will be stored securely on the University's encrypted Box file storage system, only accessible to the named researchers. I will keep the consent forms and data in separate folders.

The research data recorded will only be accessible to the named researchers and will be stored for up to 10 years, after which time the files will be destroyed.

Supporting designers in designing to reduce situational visual impairments
Participant Pilot Information Sheet Version 1, 02/08/18 Page 1 of 2

Computing, School of Science &, Engineering
UNIVERSITY OF DUNDEE Dundee DD1 4HN Scotland UK t +44 (0)1382 386559

D.18: Study 6 pilot information sheet.

PARTICIPANT INFORMATION SHEET

The anonymised data and results of the study may be used in future publications and incorporated into databases to inform future professional practice.

Further Information:

Garreth Tigwell, Dr David Flatla, and Dr Rachel Menzies will be glad to answer your questions about this study at any time. If you want to find out about the final results of this study, you may contact them at:

Garreth Tigwell

Email: g.w.tigwell@dundee.ac.uk

Telephone: (+44) 01382 384 820

Dr David Flatla

Email: dflatla@uoguelph.ca

Telephone: (+1) 519-824-4120 x53872

Dr Rachel Menzies

Email: r.menzies@dundee.ac.uk

Telephone: (+44) 01382 386 540

The School of Science and Engineering Research Ethics Committee, University of Dundee, has reviewed and approved this research study. If you have any ethical concerns or complaints about the conduct of this research, you should contact the Convener of the University Research Ethics Committee, Dr. Beth Hannah (e.hannah@dundee.ac.uk).

Supporting designers in designing to reduce situational visual impairments
Participant Pilot Information Sheet Version 1, 02/08/18 Page 2 of 2

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D.19: Study 6 pilot consent form.

CONSENT FORM

Supporting designers in designing to reduce situational visual impairments

Please mark the appropriate boxes with an 'X'	**Yes**
Taking Part	
I have read and understood the project information sheet dated 02/08/18.	
I have been given the opportunity to ask questions about the project.	
I agree to take part in the project.	
I understand that my taking part is voluntary; I can withdraw from the study at any time and I do not have to give any reasons for why I no longer want to take part.	
I understand that my words may be quoted in publications, reports, web pages, and other research outputs.	
Use of the information I provide beyond this project	
I agree for the data I provide to be archived in data repositories, such as UoD Pure and the ACM Digital Library	
I understand that other researchers will have access to this data only if they agree to preserve the confidentiality of the information as requested in this form.	
I understand that other genuine researchers may use my words in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form.	

________________________ ______________________ ________

Name of participant [printed] Signature Date

Project contact details for further information:

Garreth Tigwell
Email: g.w.tigwell@dundee.ac.uk
Telephone: (+44) 01382 384 820

Dr Rachel Menzies
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Consent Form Version 1, 02/08/18 Page 1 of 1

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UNIVERSITY OF DUNDEE Dundee DD1 4HN Scotland UK t +44 (0)1382 386559

D.20: Study 6 pilot image release form.

University of Dundee

Image Release Form

Thank you for participating in the "*Supporting designers in designing to reduce situational visual impairments*" research project.

We would like to ask your permission to be able to use photographs that include yourself in the image.

If you agree for us to use these images we may use them for:

- Research purposes: This will enhance our publications and allow other researchers to visualise our study set-up.
- Teaching purposes, public outreach events, press for general publication: We will be able to inform the students and the general public about our research.

Images might appear online or in print. The photos may be made publicly available along with our project findings for research publication.

We ask that you complete the section below, sign the form and return it to us.

	YES	NO
I confirm that I give permission for photographs of myself to be disseminated as described above.		
I am happy to release the photographs of myself as long as my face is obscured.		
I do not consent to the images being used for the purpose of teaching and presentation and wish for it to be destroyed after the study is completed.		

____
Name

________________________________ __________________
Signature Date

School of Science & Engineering (Computing), UNIVERSITY OF DUNDEE,
Dundee DD1 4HN, Scotland, phone: 01382 384471

D.21: Study 6 pilot demographics form.

Participant ID: Demographics Form

1. Age: ________ years-old

2. Gender: ____________

3. What is the highest level of education you have attained? (Please tick **only one**)

- High School ☐
- College ☐
- University (Undergraduate) ☐
- University (Postgraduate) ☐

4. How many years of design experience do you have?

________ years

5. How many years of experience do you have designing for any of the following: Mobile App Interfaces, Mobile UI elements, Mobile Web interfaces?

________ years

6. Which of the following do you have experience with? (Please tick **all that apply**)

- Graphic editors (e.g., Adobe Photoshop, Adobe Illustrator, CorelDRAW) ☐
- Prototyping software (e.g., Axure RP, InVision) ☐
- Visual effects software (e.g., Adobe After Effects) ☐
- Coding environments (e.g., Android Studio, Unity) ☐
- Supported collaboration software (e.g., Lucid Chart, Zeplin) ☐
- Feedback and guidance (e.g., Pendo) ☐
- Physical tools (e.g., pen and paper, whiteboards) ☐

D.22: Study 6 pilot design brief worksheet.

Design Brief Worksheet

Your task today (PLEASE READ)

- You will outline on paper a new design tool interface and testing protocol for Situational Visual Impairments.
- Imagine your design tool fits into a software package that designers are already using such as Sketch, Photoshop, Illustrator, etc.
- Alternative UI modes can reduce SVIs (e.g., a UI mode for a dark environment or a UI mode for a bright environment). Consider how your tool supports taking a default UI design to an alternative UI modes (see example cards on table).
- You can take inspiration from your own knowledge and experiences, as well as using information on this worksheet and on the table. You can ask questions at any point.

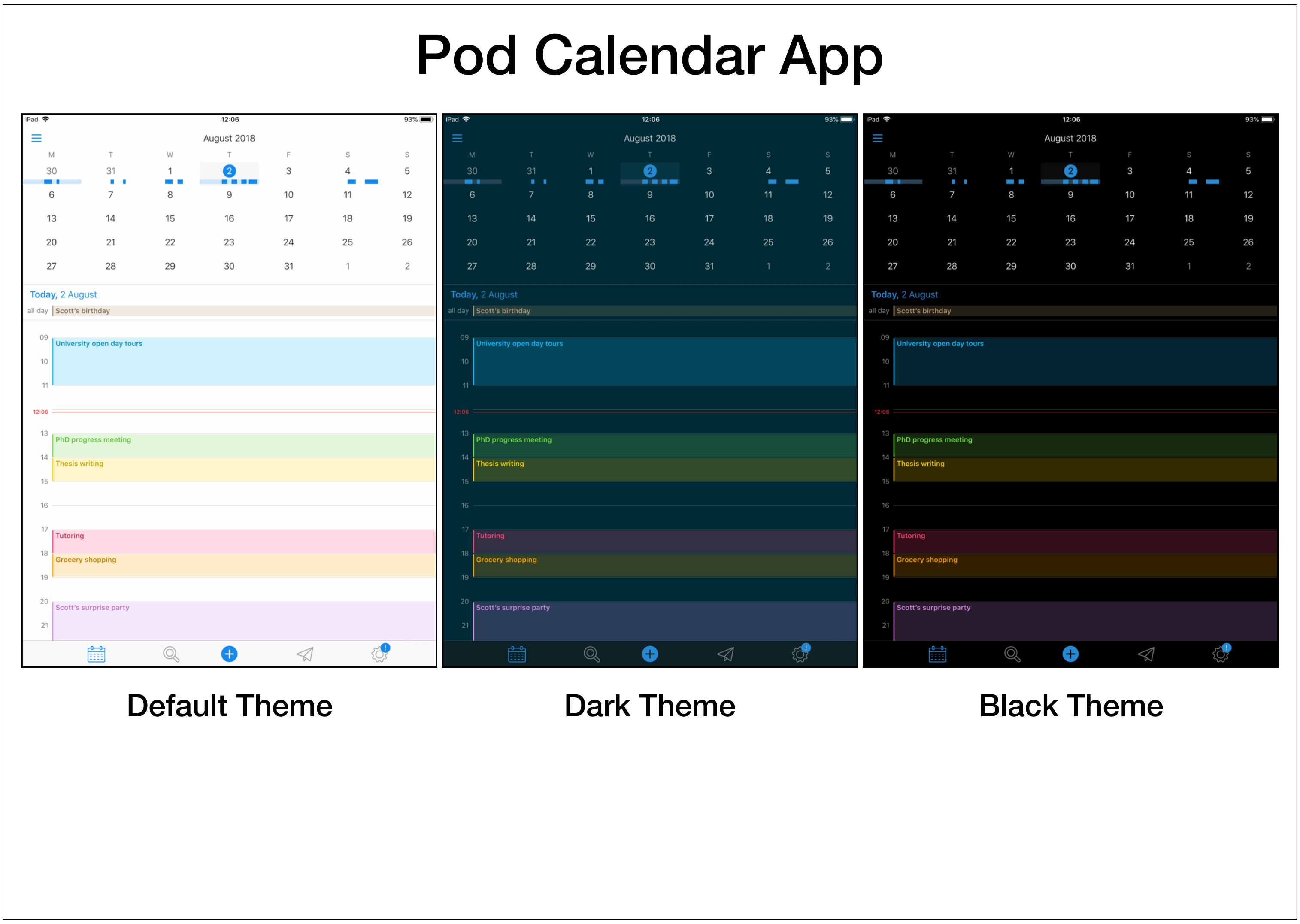
Important considerations

- Designers can have limited time and funding when working on a design – especially accessibility-related design ideas.
- Your design tool should support rapid designing for SVIs. However, it is important to also provide the freedom to explore SVI design ideas when time is available.
- Designers do not like guidelines or tools that restrict their creativity.
- Content design related SVIs can be caused by many factors. Consider how a designer might use your tool to adjust the following for an alternative UI mode.
    - Some examples are: use of colour and contrast, brightness of elements, font size, UI elements and icon size, line thickness).

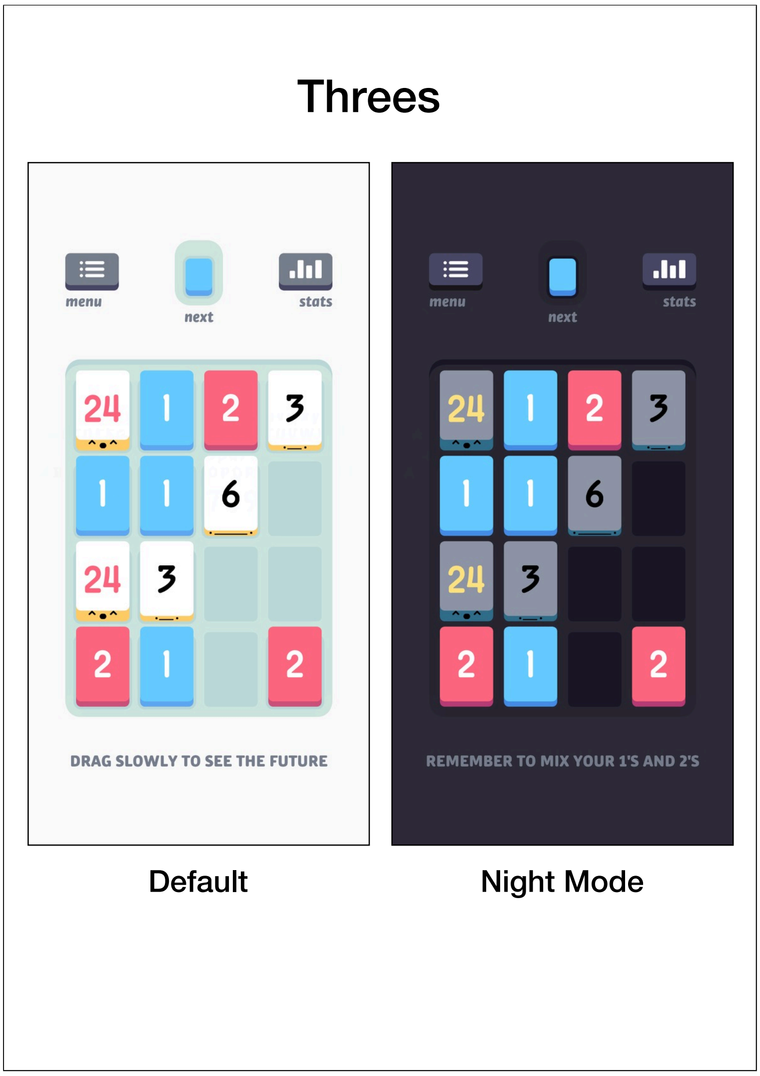
Some questions to get you started

- What problems do you see when comparing an app's different modes as shown on the example cards? (E.g., is the dark mode design successful?) Can you find a way to address those issues?
- How could your design tool support easily changing an interface attributes and elements to explore alternative design modes?
- How could your design tool support handle with images?
- How could your design tool support handle lots text throughout a design?
- How could you deal with adverts in free apps?
- Design tools can also serve as educational tools (e.g., by displaying simulations of colours as seen by somebody who has colour blindness or colour vision deficiency).
    - How could your design tool improve a designers understanding of situational visual impairments?
    - How could your design tool support designers in recognising potential problems with their designs choices?
    - How could you incorporate an educational/training aspect to your design tool?
- How could your design tool support a designer who is required to work with a specific set of brand colours?
- How could your design tool assist designers in evaluating a design idea for different situational contexts?
- How could you ensure your design tool supports the designer in considering potential accessibility issues arising due to SVIs when exploring alternative designs?
- Is there a way to implement your design tool in a way that will automate the process of exploring alternative designs to overcome deadlines and limited budgets?

D.23: Study 6 pilot support cards.

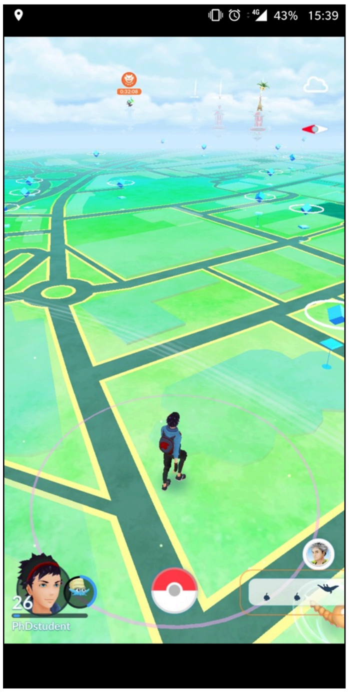


D.23: Study 6 pilot support cards.

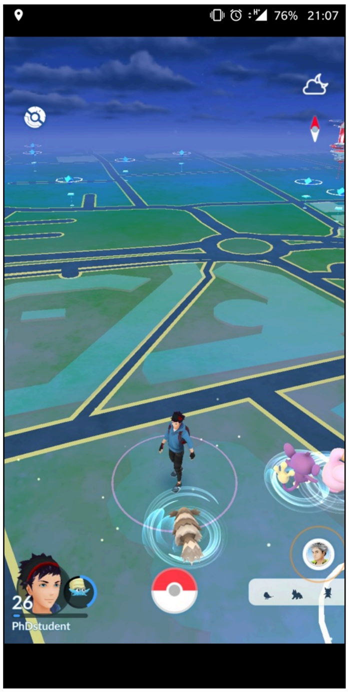


D.23: Study 6 pilot support cards.

Pokémon Go

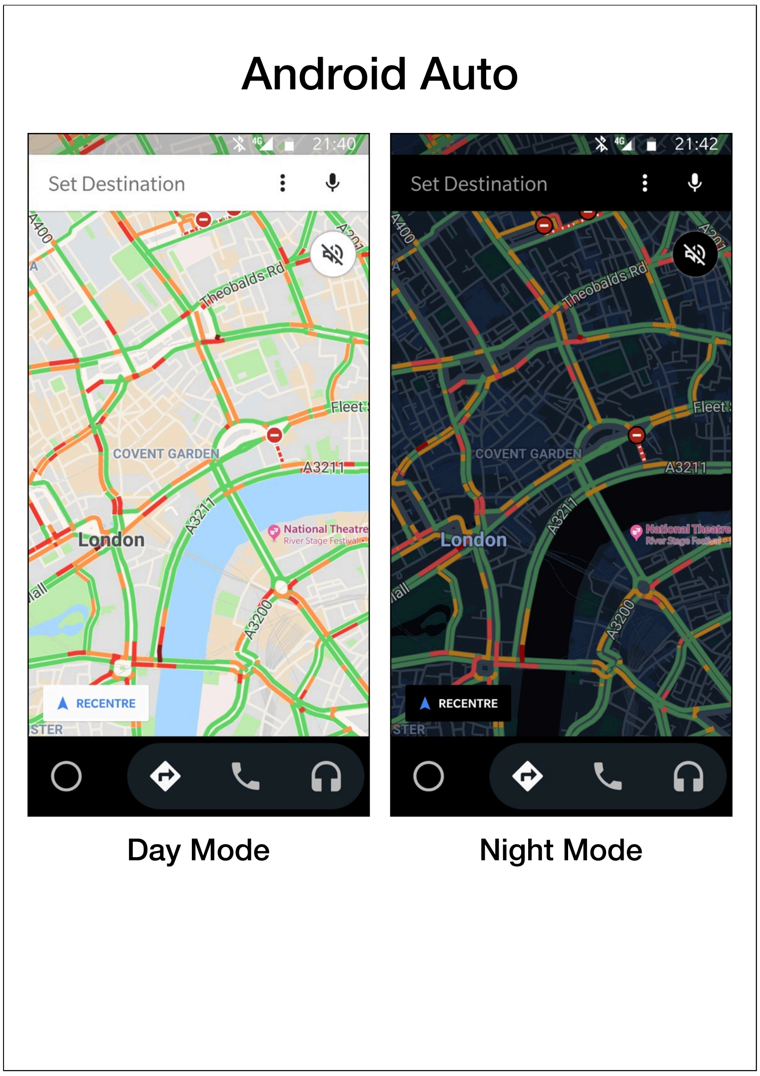


Day

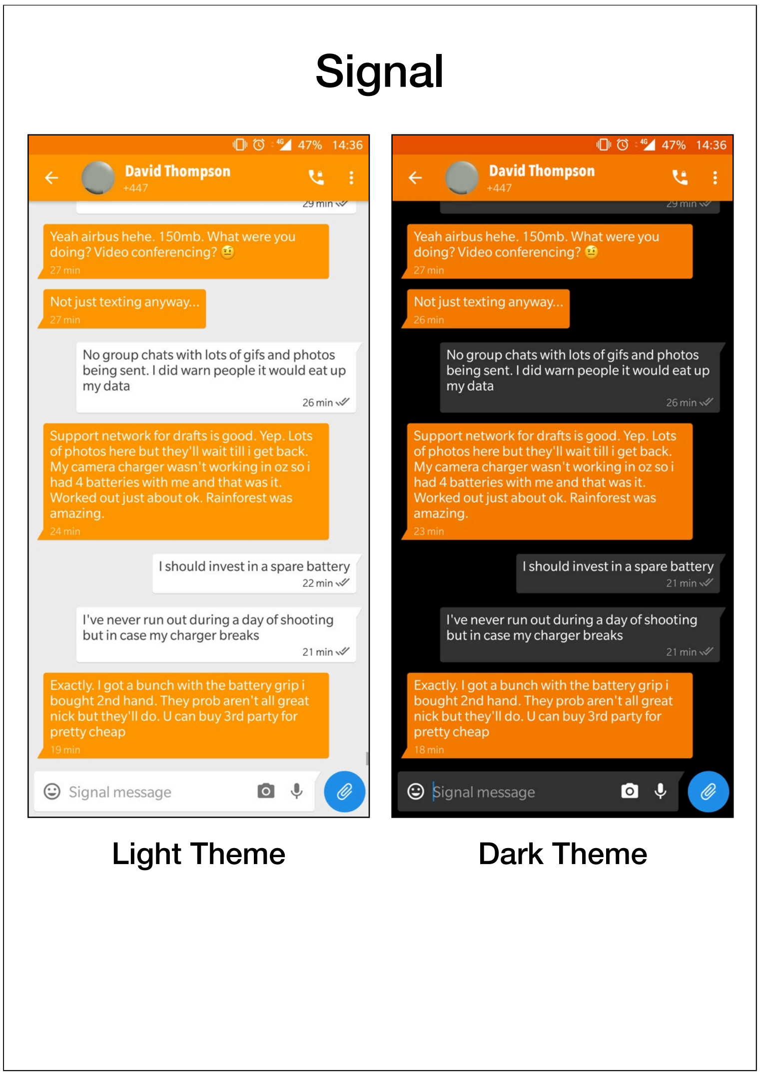


Night

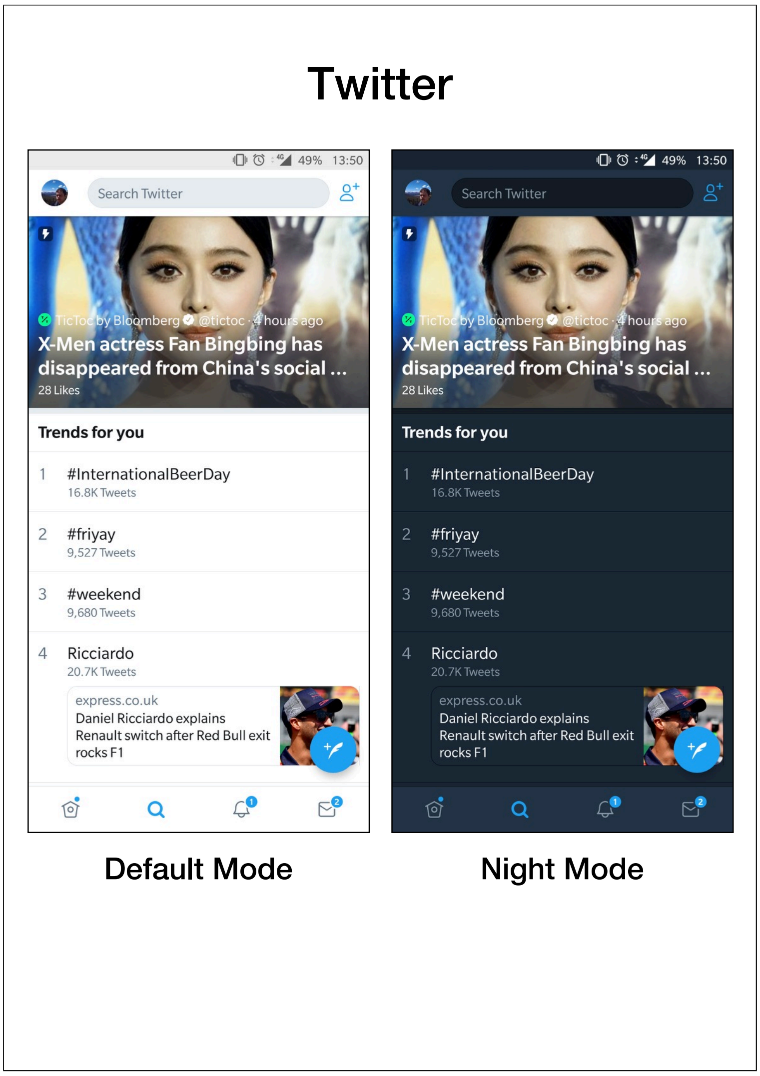
D.23: Study 6 pilot support cards.



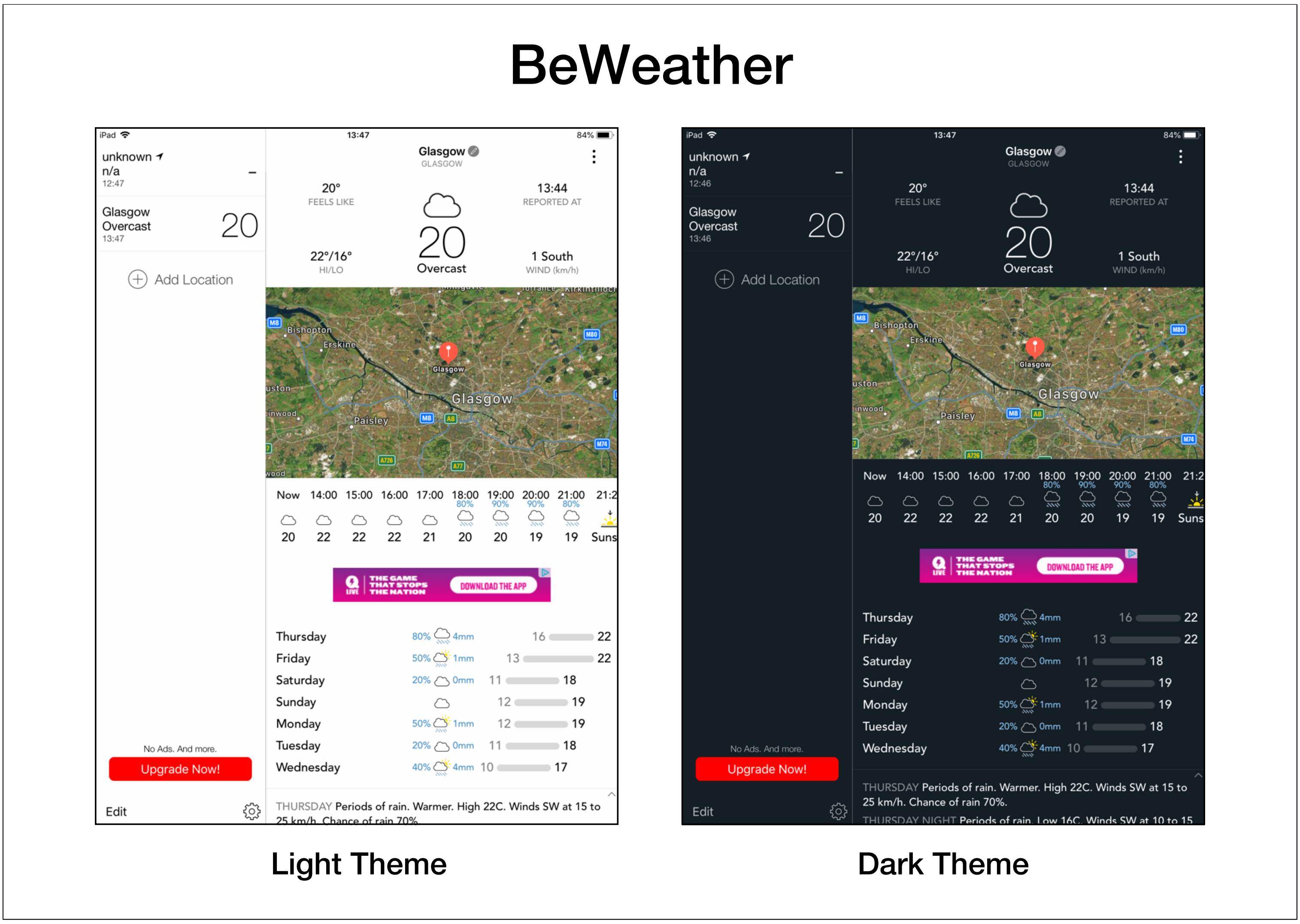
D.23: Study 6 pilot support cards.



D.23: Study 6 pilot support cards.



D.23: Study 6 pilot support cards.



D.24: Study 6 pilot study feedback sheet.

Participant ID:

Pilot Study Feedback Sheet

Was the time dedicated to each section of the design workshop sufficient?

____

____

What are your opinions on the material used as support during the design workshop?

____

____

Was there anything that could have been explained in more detail?

____

____

Any Other Comments?

____

____

____

____

____

D.25: Study 6 information sheet.

PARTICIPANT INFORMATION SHEET

Project title: Supporting designers in designing to reduce situational visual impairments

Investigators: Garreth Tigwell, Dr David Flatla, Dr Rachel Menzies

Invitation:
You are being asked to take part in a research study. Before you decide if you would like to take part, it is important you understand why the research is being done and what it involves. Please take your time to read the following information carefully and feel free to ask any questions. If you agree to take part in the study, you will be asked to sign a consent form. Thank you for your time.

Purpose of the Research:
This study is being undertaken by Garreth Tigwell as part of his PhD studies at the University of Dundee.

Mobile devices play a large role in people's everyday lives due to their portability and computing power, and this has extended our freedom for completing tasks at our convenience and to stay connected with friends and family. I am interested in supporting designers in designing to reduce situational visual impairments that are experienced by people using mobile devices. E.g., improving the UX when a device is used in a dark or in a bright environment.

What to Expect:
There are two main sessions planned with an online evaluation.

First, I would like you to take part in a design workshop (1-1.5 hours) that will take place within Saskatoon (e.g., at the University of Saskatchewan). The location will be confirmed over email. You will be helping to design a digital design tool and testing protocol for SVIs that fits within your typical workflow. There will be a group discussion on situational impairments and design, followed by session focusing on paper-based prototyping.

Second, I would like you to take part in a second design workshop (1-1.5 hours) that will take place within Saskatoon (e.g., at the University of Saskatchewan). The location will be confirmed over email. I intend for this workshop to consist of the same group as the first design workshop. You will be asked to deconstruct high-fidelity concepts that I will have created based on the outcomes of the first design workshop. You will then be asked to redesign or refine those concepts.

Third, there will be an evaluation of the final digital design tool and testing protocol. I will refine the digital design tool and testing protocol based on the outcome of the second design workshop and set up an online system that will allow you to provide feedback. This should take no more than 20 minutes.

Cost, Reimbursement and Compensation:
You will receive a $15 amazon voucher for each workshop attended. Refreshments will be provided during the two design workshops as well.

During the final evaluation survey you will be given the opportunity to enter into a prize draw for $25 USD (or equivalent in another currency, e.g., £20).

Risks:
There are no risks associated with this study and I hope that the task will be enjoyable.

Participation:
It is up to you to decide if you would like to take part or not. Your participation is voluntary and you are free to withdraw from the study at any time without penalty and without explanation. I will delete any data or information collected at this point so that it will not be included in any future publications.

Confidentiality:

Supporting designers in designing to reduce situational visual impairments
Participant Information Sheet Version 2, 22/08/18 Page 1 of 2

Computing, School of Science &, Engineering
UNIVERSITY OF DUNDEE Dundee DD1 4HN Scotland UK t +44 (0)1382 386559

D.25: Study 6 information sheet.

PARTICIPANT INFORMATION SHEET

The data collected will not contain any personal information about you. I will follow ethical and legal practice and all information about you will be handled in confidence.

It will not be possible to link publicly the data you provided to your identity and name. I will not link the consent form to any data you submit. You will be provided with a participant ID so that I can keep track of the data you submit, while ensuring it cannot be linked to you. With regards to images taken during the session, I have provided a release form so that you can indicate how you wish any images that may include yourself to be handled for publications. You will also be given a chance to consent to audio being recorded during the session. The audio will only be used to facilitate producing an anonymised transcript.

All digital data and documents containing (or linking to) the original identification of the participants will be stored securely on the University's encrypted Box file storage system, only accessible to the named researchers. I will keep the consent forms and data in separate folders.

The research data recorded will only be accessible to the named researchers and will be stored for up to 10 years, after which time the files will be destroyed.

The anonymised data and results of the study may be used in future publications and incorporated into databases to inform future professional practice.

Further Information:
Garreth Tigwell, Dr David Flatla, and Dr Rachel Menzies will be glad to answer your questions about this study at any time. If you want to find out about the final results of this study, you may contact them at:

Garreth Tigwell

Email: g.w.tigwell@dundee.ac.uk

Telephone: (+44) 01382 384 820

Dr David Flatla

Email: dflatla@uoguelph.ca

Telephone: (+1) 519-824-4120 x53872

Dr Rachel Menzies

Email: r.menzies@dundee.ac.uk

Telephone: (+44) 01382 386 540

The School of Science and Engineering Research Ethics Committee, University of Dundee, has reviewed and approved this research study. If you have any ethical concerns or complaints about the conduct of this research, you should contact the Convener of the University Research Ethics Committee, Dr. Beth Hannah (e.hannah@dundee.ac.uk).

D.26: Study 6 consent form.

CONSENT FORM

Supporting designers in designing to reduce situational visual impairments

Please mark the appropriate boxes with an 'X'	**Yes**
Taking Part	
I have read and understood the project information sheet dated 22/08/18.	
I have been given the opportunity to ask questions about the project.	
I agree to take part in the project.	
I understand that my taking part is voluntary; I can withdraw from the study at any time and I do not have to give any reasons for why I no longer want to take part.	
I understand that my words may be quoted in publications, reports, web pages, and other research outputs.	
Use of the information I provide beyond this project	
I agree for the data I provide to be archived in data repositories, such as UoD Pure and the ACM Digital Library	
I understand that other researchers will have access to this data only if they agree to preserve the confidentiality of the information as requested in this form.	
I understand that other genuine researchers may use my words in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form.	

________________________ ________________________ ________

Name of participant [printed] Signature Date

Project contact details for further information:

Garreth Tigwell
Email: g.w.tigwell@dundee.ac.uk
Telephone: (+44) 01382 384 820

Dr Rachel Menzies
Email: r.menzies@dundee.ac.uk
Telephone: (+44) 01382 386 540

Dr David Flatla
Email: d.flatla@dundee.ac.uk
Telephone: (+44) 01382 385 491

Consent Form Version 2, 22/08/18 Page 1 of 1

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UNIVERSITY OF DUNDEE Dundee DD1 4HN Scotland UK t +44 (0)1382 386559

D.27: Study 6 image and audio release form.

University of Dundee

Image and Audio Release Form

Thank you for participating in the "*Supporting designers in designing to reduce situational visual impairments"* research project.

We would like to ask your permission to be able to:

1. take photographs during the design workshop, which will enhance our publications and allow other researchers to visualise our study set-up
2. record audio in order for the researcher to later transcribe for accurate data.

Image Release Consent

	YES	NO
I confirm that I give permission for anonymised photographs of myself to be disseminated for research purposes.		
I am happy to release the photographs of myself as long as my face is obscured.		

Audio Release Consent

	YES	NO
I confirm that I am aware the design workshop will be recorded to allow the researcher to review it at a later time.		
I understand that the recording will not be released and will only be used by the research team to produce an anonymised transcript.		
I agree to have this interview audio recorded		

____
Name

________________________________ ________________
Signature Date

School of Science & Engineering (Computing), UNIVERSITY OF DUNDEE, Dundee DD1 4HN, Scotland, phone: 01382 384471

D.28: Study 6 demographics questionnaire.

Participant ID:

Demographics Form

1. Age: ________ years-old

2. Gender: ____________

3. What is the highest level of education you have attained? (Please tick **only one**)

- High School ☐
- College ☐
- University (Undergraduate) ☐
- University (Postgraduate) ☐

4. How many years of design experience do you have?

________ years

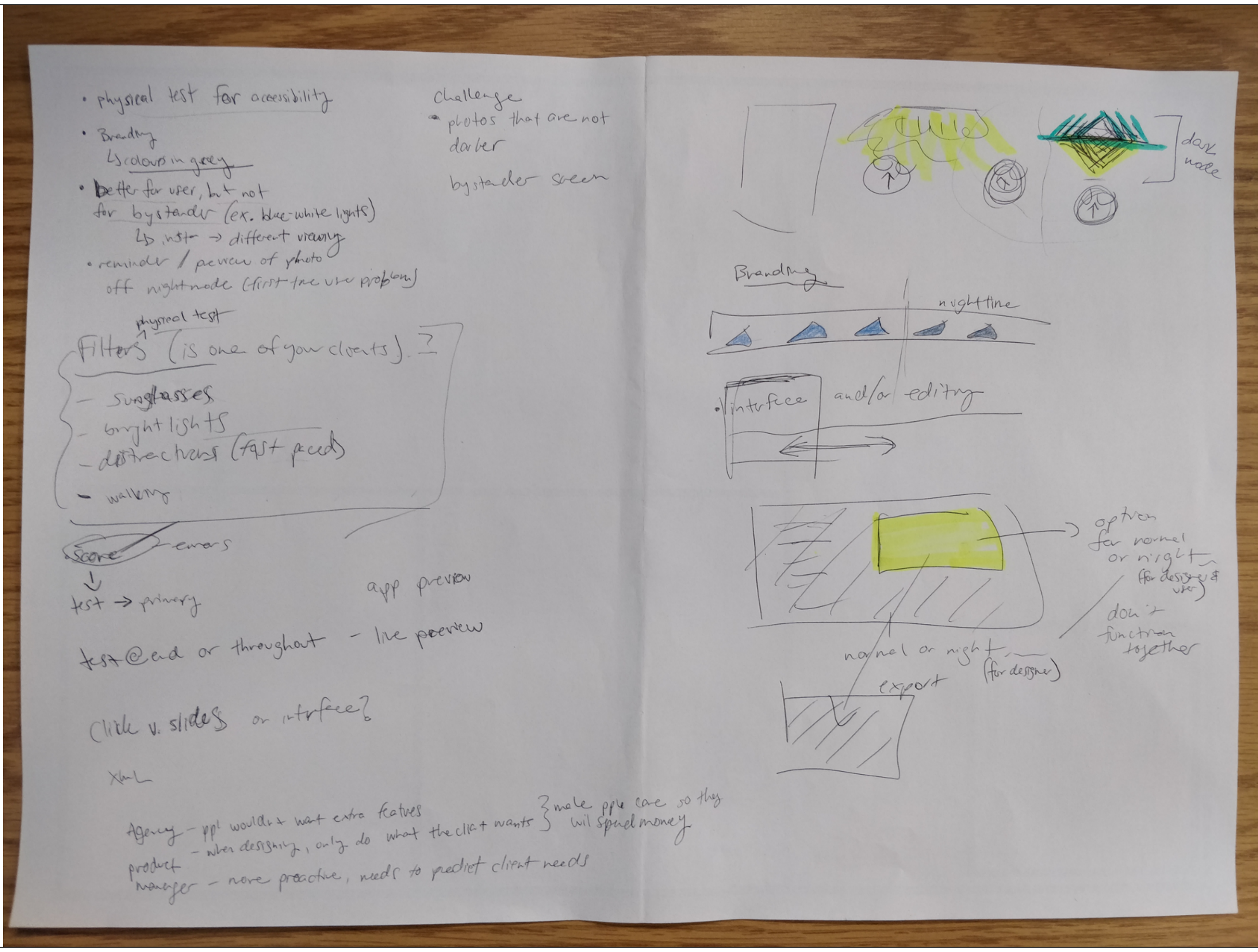
5. How many years of experience do you have designing for any of the following: Mobile App Interfaces, Mobile UI elements, Mobile Web interfaces?

________ years

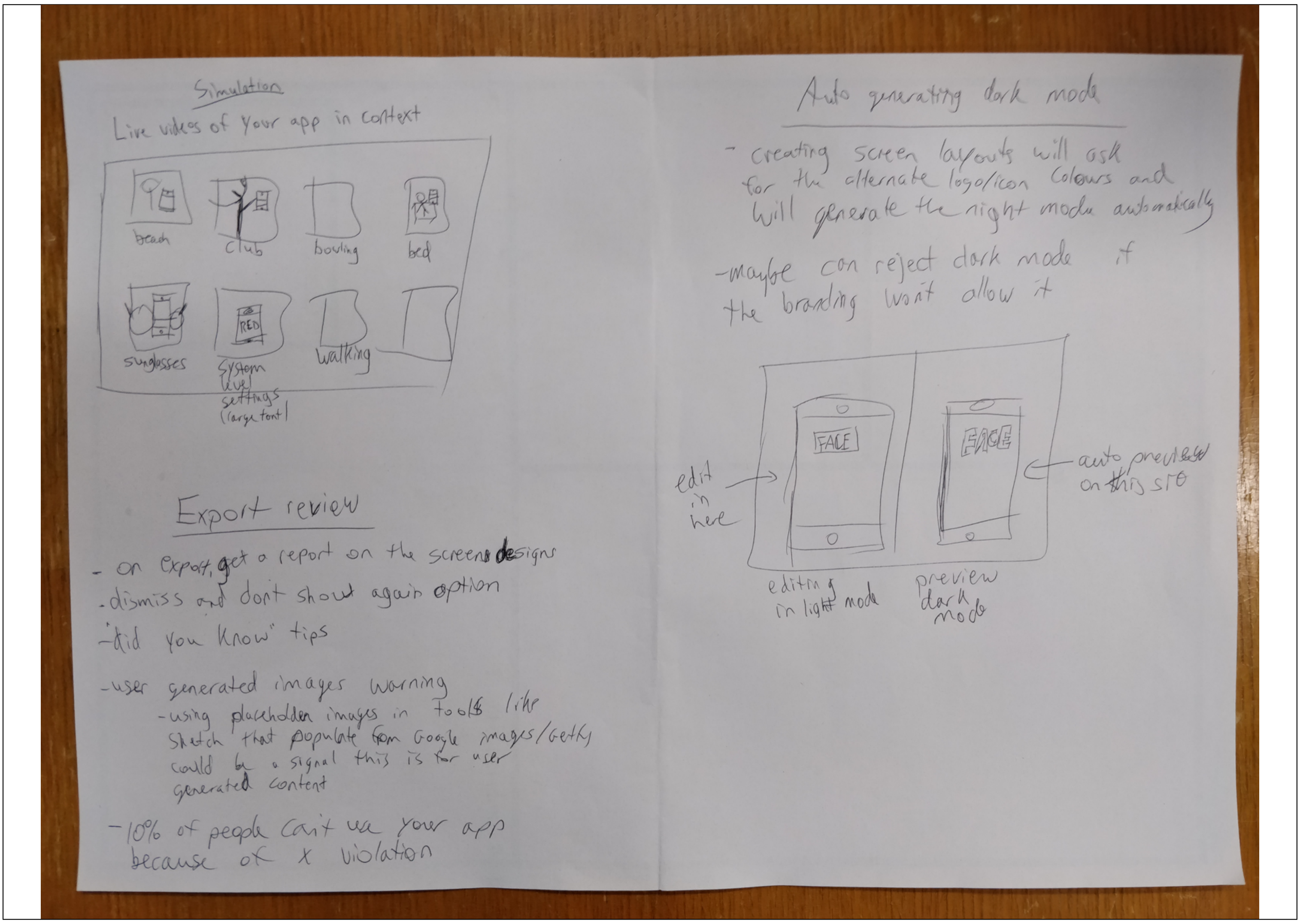
6. Which of the following do you have experience with? (Please tick **all that apply**)

- Graphic editors (e.g., Adobe Photoshop, Adobe Illustrator, CorelDRAW) ☐
- Prototyping software (e.g., Axure RP, InVision) ☐
- Visual effects software (e.g., Adobe After Effects) ☐
- Coding environments (e.g., Android Studio, Unity) ☐
- Supported collaboration software (e.g., Lucid Chart, Zeplin) ☐
- Feedback and guidance (e.g., Pendo) ☐
- Physical tools (e.g., pen and paper, whiteboards) ☐

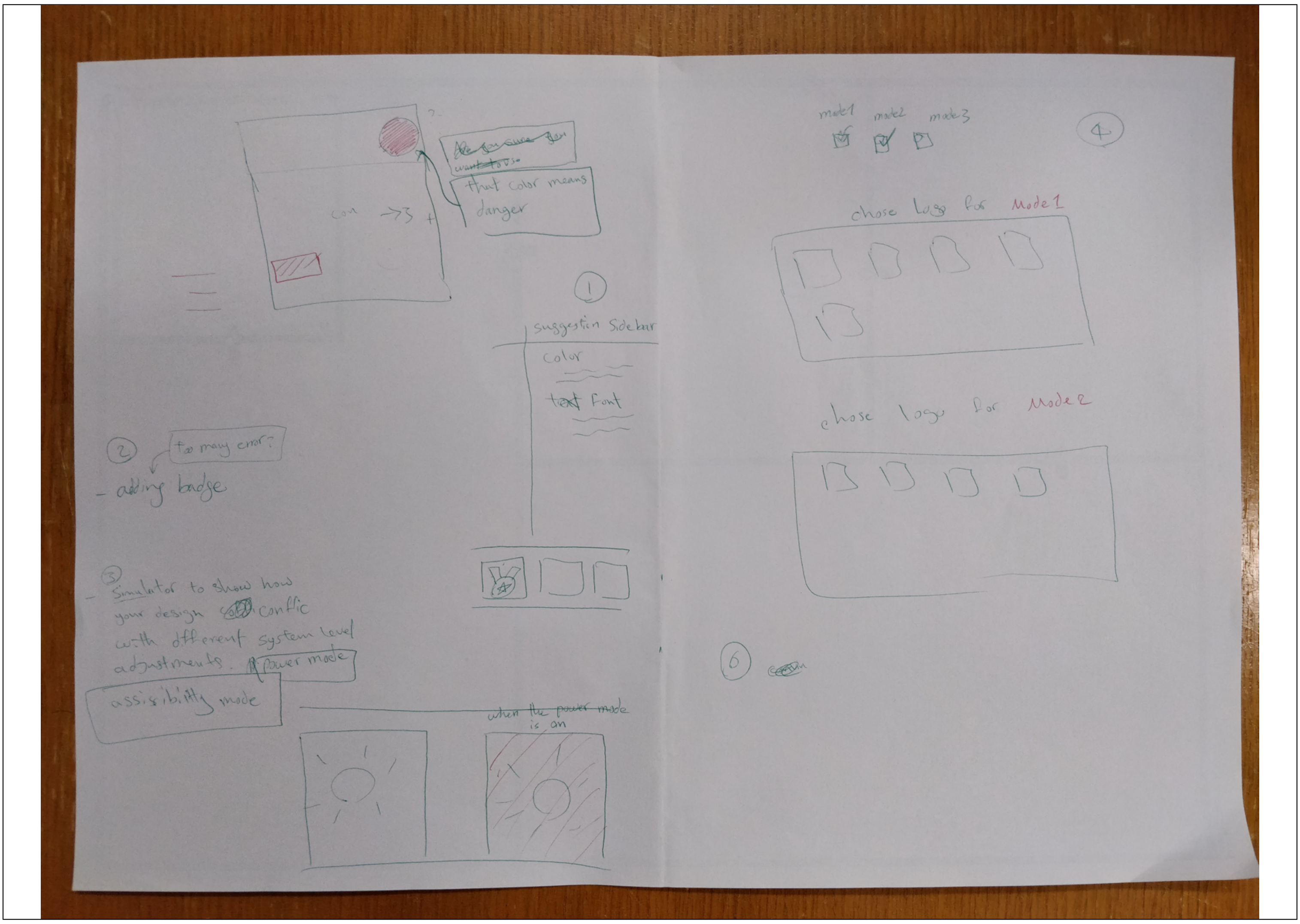
D.29: Study 6 design brief worksheet.



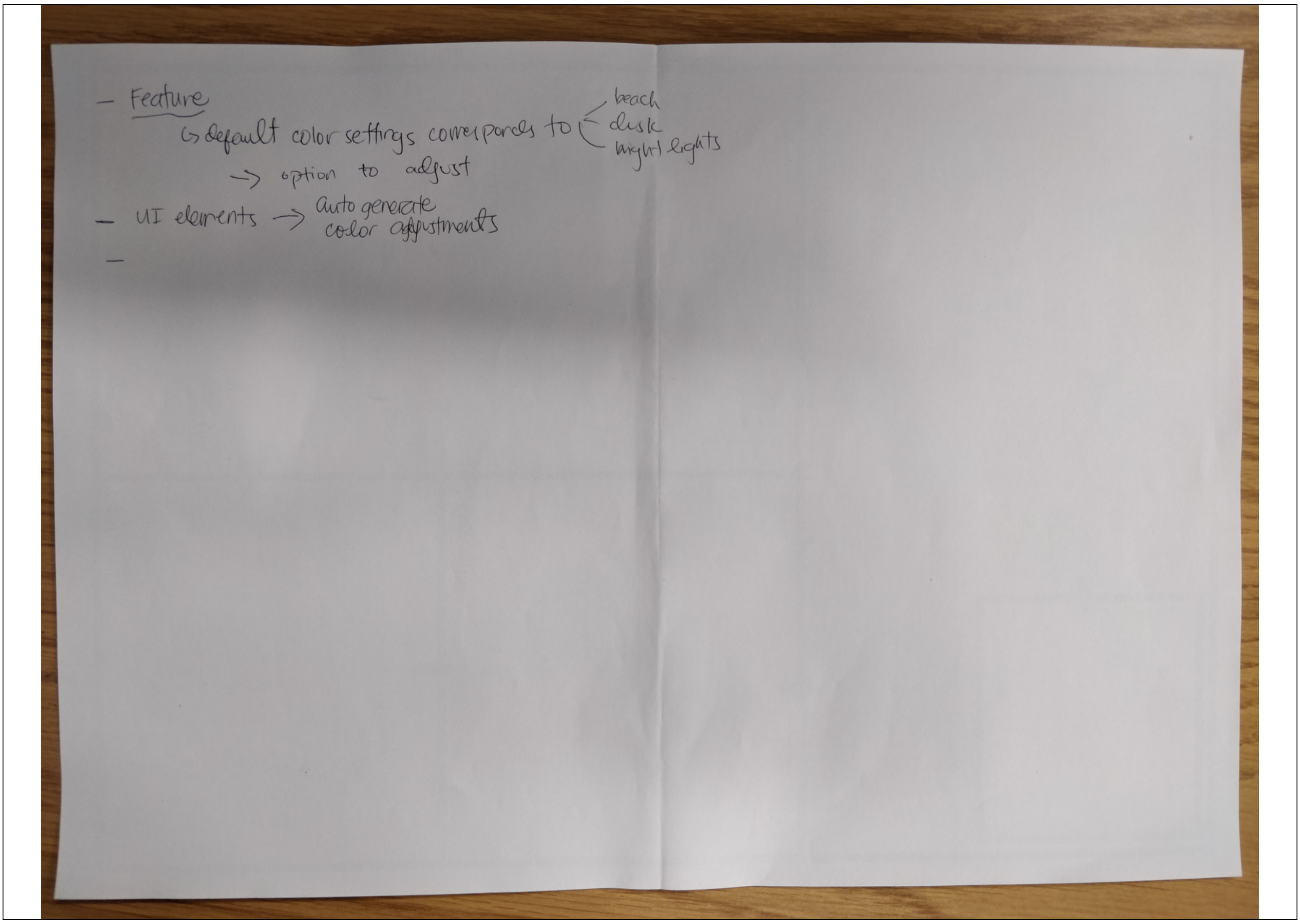
D.29: Study 6 design brief worksheet.



D.29: Study 6 design brief worksheet.



D.29: Study 6 design brief worksheet.



D.30: Study 6 video feedback sheet.

Participant ID: ____

Feedback

1. Interface adaption – The designer is prompted to indicate which SVIs they want to design for. The interface adapts as necessary.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

2. Pre-select alternative modes – The designer is prompted to indicate which SVIs they want to design for and is then asked to upload assets for each context.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

3. Notification of issues 1 – The designer is notified of a potential issue and they are provided with guidance to fix the problem.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

D.30: Study 6 video feedback sheet.

Participant ID: ____

Feedback

4. Notification of issues 2 – The designer is notified of a potential issue. Guidance to fix the problem appears when the warning is selected.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

---

5. Notification of issues 3 – The designer is notified of a potential issue by feedback in the sidebar and guidance to fix the problem is available.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

---

6. Notification of issues 4 – The designer is notified of a potential issue by feedback in the sidebar and shown a simulation of the problem.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

D.30: Study 6 video feedback sheet.

Participant ID: ____

Feedback

7. Notification of issues 5 – The system highlights problems with the design and the designer can adjust the severity of SVIs they are designing for.

	Strongly Disagree 1	2	3	4	Strongly Agree 5
This feature would fit within my typical design workflow					

	Strongly Disagree 1	2	3	4	Strongly Agree 5
This feature is important if I was designing for SVIs					

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8. SVI simulations 1 – The system simulates increasing brightness. The designer can adjust the severity of the SVI to assess their design's robustness.

	Strongly Disagree 1	2	3	4	Strongly Agree 5
This feature would fit within my typical design workflow					

	Strongly Disagree 1	2	3	4	Strongly Agree 5
This feature is important if I was designing for SVIs					

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9. SVI simulations 2 – The system simulates night mode. The designer can adjust the severity of the SVI to assess their design's robustness.

	Strongly Disagree 1	2	3	4	Strongly Agree 5
This feature would fit within my typical design workflow					

	Strongly Disagree 1	2	3	4	Strongly Agree 5
This feature is important if I was designing for SVIs					

D.30: Study 6 video feedback sheet.

Participant ID: ____

Feedback

10. SVI simulations 3 – The system provides the designer with a realistic simulation of their design as it would appear in different situations.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

11. SVI simulations 4 – The designer can view potential system conflicts and is offered an improved design that retains editable layers.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

12. Design exploration 1 – The designer is provided with a set of tools that lets them quickly explore alternative designs. Fully editable versions can be saved.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

D.30: Study 6 video feedback sheet.

Participant ID: ____

Feedback

13. Design exploration 2 – The system provides constrains and guidance, while offering the designer as much freedom to explore the alternative design.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

14. Auto-generate alternative mode 1 – The system constructs an alternative version (e.g., dark mode) besides the design the designer is currently working on.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

15. Auto-generate alternative mode 2 – When the designer is finished with their design they can ask the system to automatically generate editable alternative modes.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5

D.30: Study 6 video feedback sheet.

Participant ID: ____

Feedback

16. Export review – When the designer is finished and exporting their designs, they can prompt the system to output a review of potential problems.

	Strongly Disagree				Strongly Agree
This feature would fit within my typical design workflow	1	2	3	4	5

	Strongly Disagree				Strongly Agree
This feature is important if I was designing for SVIs	1	2	3	4	5