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An Usability and Universal Design Investigation into Hidden User Interface Navigational Elements

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Abstract

With the trend towards simplicity starting to gain supremacy in digital design, designers are now being forced to adapt. One of the practical areas recommended for them is working within mobile user interfaces' navigational elements. Navigation in mobile applications has a crucial role in interacting with a mobile interface, and there are various opinions on how to implement such a capability best.

Navigation is, without a doubt, a vital element to applications' design. Therefore, designers have to possess the ability to prioritize content without making navigation inaccessible and, in general, sacrificing usability. Mobile application designers have been choosing to hide their navigation mainly in recent times. While many people claim that an application design containing hidden navigation negatively impacts user experience’s metrics. Decreasing discoverability and increasing perceived task difficulty, it is hard not to use them; they are the best of the worst options available.

The experimental work presented in this study looks at some of these hidden user interfaces navigational elements in mobile applications from a usability and Universal Design perspective. This thesis describes an investigative study of hidden navigational elements of mobile applications. For this purpose, two identical prototypes were developed and tested with users, one with hidden navigational elements and visible navigational elements based on time on tasks, task completion and error rate. A questionnaire was presented to get users’ insight about both prototypes on a Likert scale.

The results and findings are that participants preferred prototypes with visible elements and found prototypes with hidden elements challenging to interact with. The interface with hidden elements does not meet the guidelines of WCAG and Universal Design’s principles.

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Acronyms

GUI	Graphical User Interface
HCI	Human-Computer Interaction
ICT	Information and communication technology
UD	Universal Design
UCD	User-Centered Design
UI	User Interface
UX	User experience
WIMP	Windows, Icons, Menus, Pointers
W3C	World Wide Web Consortium
WCAG	Web Content Accessibility Guidelines

1. Introduction

Technology has enhanced and developed around, and we are getting enormous innovations in technology with no time. The advancement in technology and gadgets has enormously modified how people can communicate and exchange information worldwide. Technology and innovation in technology have made communication simpler and faster in the last three decades. Mobile phones were the significant gadgets of the 1990s**.** Regardless of the user's age, these devices got popular and widespread worldwide and are in the majority of the population. The transition from handwritten letters and telegraphs to SMS (Short Messaging Service), E-mail (Electronic Mail), VoIP (Voice over IP), and Video calls has revolutionized every aspect of life from an individual's perspective to a business. Mobile devices are being used to make phone calls, take pictures, use the internet, play games, store information, and do many other things.

Mobile phones are being used by billions of users worldwide, from children to the elderly and people with disabilities. Mobile phones (Hoober & Berkman, 2011) have become an essential part of our daily lives, but even proper standards for mobile user interface design patterns are not there. Apparently, most of the designs are based on the desktop paradigm. Although user interfaces for mobile devices have evolved, mobile applications are being designed with good user experiences. The new trend in the user interface to hide navigational elements has emerged. It can be a good idea to hide elements and navigational menus, but not every user can interact with these interfaces.

Therefore, there is a need to investigate if these interfaces with hidden elements cater to everyone with different abilities and disabilities. There is also needed to find and fill the gap whether or not these interfaces making users' interaction challenging. To determine the knowledge about the effects of hidden navigational elements, this study has been designed. This study aims to overview and investigate if the mobile applications with hidden elements fulfil the usability and universal design guidelines or not. We will use WCAG 2.0 accessibility guidelines and Universal Design's principles to validate the usability and implements of Universal Design's principles in our proposed prototypes. In this study, we present the results of our experimental user interface testing on our proposed prototypes.

1.1 Problem statement

Some interfaces are designed in an inaccessible way that limits the users' interaction with that interface. These interfaces frustrate the user by putting all burden on the user mentally by forcing them to guess and remember the hidden commands in hidden user interfaces to use that interface (usability.gov, 2021b). The problem gets worsen with older people and people with memory disorders. People with situational, temporary, or permanent disabilities and memory loss or short-term memory can confront challenges while interacting with mobile applications with a hidden user interface navigational elements. (uxplanet.org, 2017)

Persons with cognitive impairments and lower technology experience can also struggle with hidden navigational elements in mobile applications. Some situations can limit the interaction with mobile applications (Fuglerud, 2009) and (Vanderheiden, 2000). People may face this problem on the application's interface without a prominent navigational element on the interface. In the absence of visual clues, people may feel challenges to interact with any app. People spend more time searching for their desired commands to interact with the app and struggle, decreasing their experience. Some guidelines by Adobe XD (Babich, 2019) discussed design interfaces that avoid such hurdles and make users aware of all elements in the app. According to these guidelines' navigation should be clear and self-evident to its users. Its emphasis is on providing visual clues, which works as reminders for the users (usability.gov, 2021b). According to their finding, research conducted by Nielsen Norman Group about hamburger menus took a longer time to use the interface with hidden navigation. Moreover, the content discoverability was significantly lower when the navigation was hidden. (Kara Pernice, 2016)

1.2 Significance of the study

Keeping in view the problem mentioned above, the present study has been designed to investigate more into this account for perceptions and practices of useability and Universal Design in mobile applications. This study would be helpful to inform UX/UI designers to adopt more usability and accessibility approaches. This study will provide insight into implementing usability and making mobile applications universally designed to cater to everyone's needs.

1.3 Research objectives

This study aims to consider the usability and accessibility of mobile applications with hidden user interface navigational elements from a Universal Design perspective. The study will implement two prototypes, get users' experience with both prototypes, and investigate their experience based on their feedback about the prototypes.

1.4 Research Questions

According to (Bickman & Rog, 2008), "Your research questions need to be ones that are answerable by the kind of study you can actually conduct." Following are the research questions to be taken into account in the study:

RQ1: Are hidden navigational elements making users frustrated while taking much time to discover hidden elements?

RQ2: How do always visible elements affect user interaction with mobile applications?

RQ3: To what degree do people choose the Interface with the maximum available screen?

1.5 Outline of the thesis

Here, I give a short overview of the contents of each chapter in the thesis.

Chapter 2 Background and related work: In this chapter, I give some background information about the evolution of smartphone GUIs. I also provided a theoretical background to make ground for my research.

Chapter 3 Review of related literature: In this chapter, I present a literature review related to my research and present standards, guidelines and legislation related to mobile phone applications.

Chapter 4 Research Methodology: This chapter discusses the research methods and approaches for this study. The process of data collection and research process are discussed in this chapter.

Chapter 5 Prototype Design Phase: In this chapter, I discuss designing and developing two prototypes for this investigative study.

Chapter 6 Results and analysis: The results and findings from an empirical investigation on two prototypes and questionnaire feedback from participants are presented.

Chapter 7 Discussion: The analysis of findings and discussion are presented in this chapter.

Chapter 8 Conclusion: The study has been summarized, concluded and recommendations presented in this chapter.

Chapter 9 References: All publications which have been referred to in this thesis are listed in this chapter.

2. Background and related work

In this section, we briefly discuss how mobile interfaces evolved from brick phones. Later in this section, we provide a theoretical background for this study.

2.1 Evolution of Mobile User Interface

With the first brick phone, which was the first handphone in 1973 by Motorola (www.edn.com), the new foundations were laid for later modern and lightweight mobile phones. The earliest introduced handphones/mobile phones were quite large and heavy, and similar shapes and functions were often called brick phones (Figure 2.1). These phones were inaccessible and limited to make a phone call only.

Figure 2.1: Brick phones introduced in the 1970s (huffpost.com)

Later in the 1990s, Nokia and Sony Ericsson launched several models of mobile phones lighter and smaller than brick phones. These phones came up with a keypad and a small screen to see the numbers while dialing to make a call. Nokia’s 3310 model got popular and dominated the market for a while (uswitch.com, 2021). That model had a screen to interact with the phone and user interface to perform various functions like making calls, writing and receiving SMSs and playing games with a straightforward User Interface.

The integration of cameras, audio/video players, made these gadgets more powerful. Their user interfaces improved from mono-colour to colour displays with easier access to user interface's elements and easy to interact with features of mobile phones. Companies like Nokia, Motorola, Samsung, and Sony Ericsson started introducing mobile applications with a graphical user interface with the Symbian operating system for mobile devices.

Apple's iPhone (Figure 2.2) changed the scenario with its entrance into the smartphone market in 2007. It introduced the maximum screen use in mobile phones. The popularity of Apple's iPhones was the distinctive introducing features in the mobile phone industry. At that time the mobile phones were reshaping into smartphones with great user interfaces. (Wikipedia) Moreover, it set the stage to introduce mobile smartphone applications significantly increased with the Android platform. Mobile phone application development emerged as an industry.

Figure 2.2: Apple's Introductory model of iPhone (digitaltrends.com)

Mobile phones are coming with big screens to make great use of it with great features offered by mobile applications. Now, mobile phones are dependent on their graphical user interfaces. The journey started from bricked phones reached a stage where mobile phones are completely smart and hardly come with any physical interface.

2.2 Theoretical Background

2.2.1 User Interfaces

The user interface provides a way to interact with any device. Without any user interface, a user cannot interact with the hardware of that device (Figure 2.3). Every device must have a user interface, and when we talk about electronic devices or gadgets like smartphones, they evolved from physical buttons to touch screens with graphical user interfaces. A graphical User interface was introduced with desktop computers to interact with them. Graphical user interface contains Windows, Icons, Menus, and Pointers (WIMP). (En.wikipedia.org, 2021)

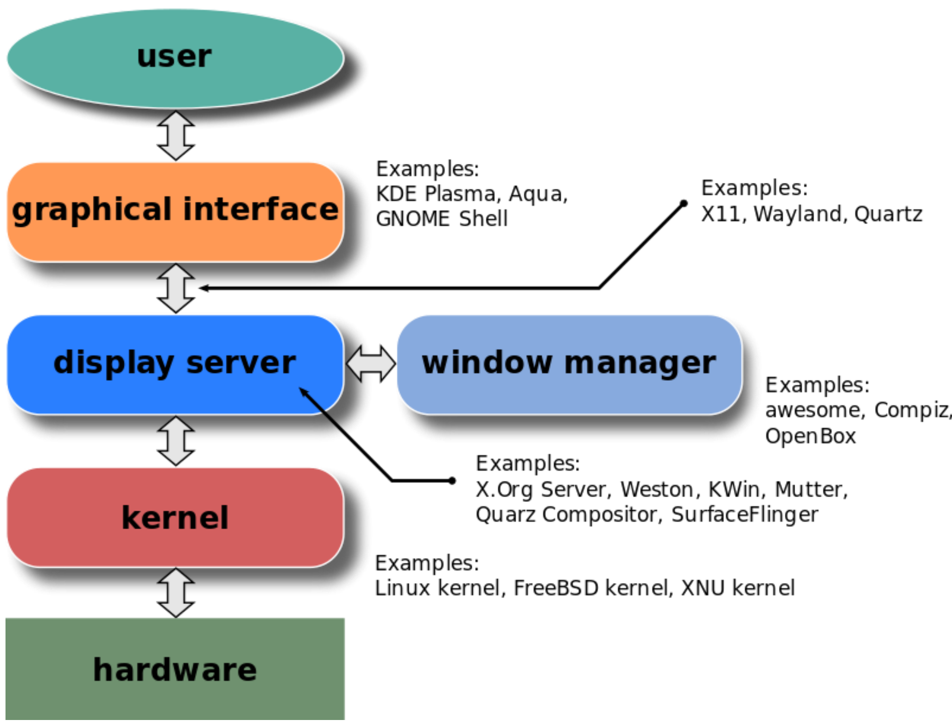

Figure 2.3: Layered schema of Graphical user interface (En.wikipedia.org, 2021)

It is limited to menus and icons in mobile devices but expanded to gestures on mobile touch screens to interact with it (Figure 2.4). Mobile devices took over the benefits of a desktop computer with smart screens and smart and intelligent user interfaces. However, according to (Punchoojit & Hongwarittorrn, 2017b), even the user interface design of these mobile devices has not a proper standard.

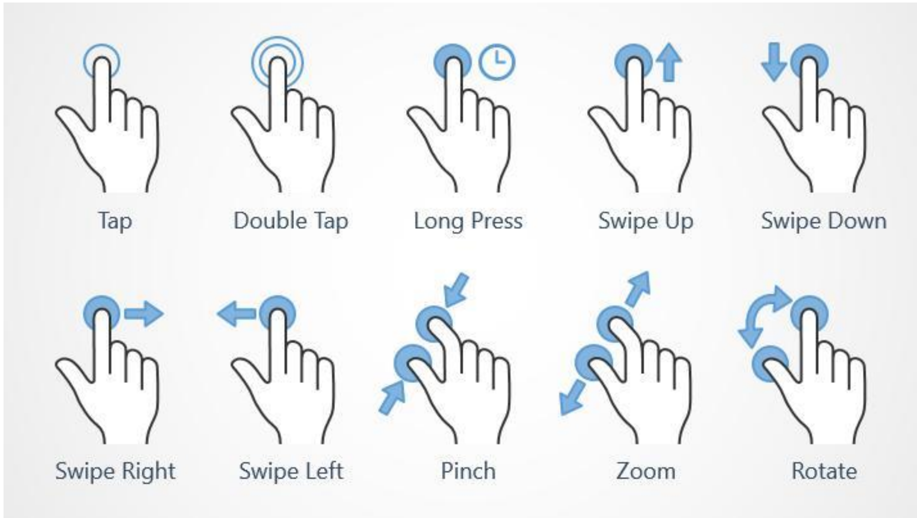

Figure 2.4: Mobile screen touch gestures (cdn.powermockup.com)

2.2.2 Elements of User Interface

A user interface composed of different components includes Input controls, Navigational components, and informational components. Buttons, radio buttons, text fields, checkboxes, list boxes, toggles, etc. categories as Input controls. Breadcrumb, search fields, pagination, sliders, tags, icons, and image carousels are categories under navigational components. Tooltips, progress bar, notifications and message boxes are categories as informational components of a user interface. (usability.gov, 2021b)

2.2.3 Navigational Elements

As we mentioned, Breadcrumb, search fields, sliders, and icons come under the navigational elements of the user interface as these elements are used to navigate through an application or a webpage.

- **Icon**

A small picture on the computer screen or mobile screen represents a function and contain a hyperlink. Icons are used to navigate the system.

- **Slider**

These are known as track bars as they are used to set or adjust some value. Zoom bar is a type of slider.

- **Image carousel**

An image carousel contains a set of images or rotating banners that can act as a slideshow on a web page or mobile application.

2.2.4 Hidden User Interface

A hidden user interface (UI) is a case whereby the user experience of an element is so intuitive that a user interface is not necessary (for example, Smart Guides in Sketch, Adobe XD, and Photoshop — they automatically appear when a layer is moved by the user, to help them align it). Hidden or implicit Human-Computer-Interaction (HCI) or interaction with mobile applications works when the computer or mobile applications are aware of "context" (Pohl, 2011). An example of a real-life case of hidden UI navigational elements can be an automatic sliding door. Since users do not have to open the doors individually, it helps avoid pushing doors when they should be pulled. No signage is needed, no buttons required, the solutions are invisible (and ideally intuitive).

Although surprisingly, people probably use hidden UIs each day without even their realization, which is the beauty of these hidden UI navigation elements. Being more aware of hidden UIs is essential in designing more intuitive UX.

The concept of hidden user interfaces navigational elements has been developing each year with the advancement of mobile phones. As discussed above, the initial mobile phones (in the 1990s) were ridiculously more enormous than the present standard phones and perhaps did not even deserve the description of 'mobile'. One of the main reasons for the large size of these devices was to accommodate UI elements. However, with the innovative and brilliant modern mobile devices, these UI elements can be hidden, reducing the devices to light-weighted and small sizes.

2.2.5 User diversity

Many factors make a user diverse from other users because users have diverse abilities and perspectives. The significant factors are age, functional ability, geography, language, culture, economy, ethnicity, gender and cognitive ability. Every factor has its impact on the use of a mobile device. If we discuss ageing, according to UN World Population Prospects[1], the ageing factor matters as the stats show that more and more percentage of the world population will get older till 2050 (Figure 2.5). This factor is essential while designing web and mobile applications.

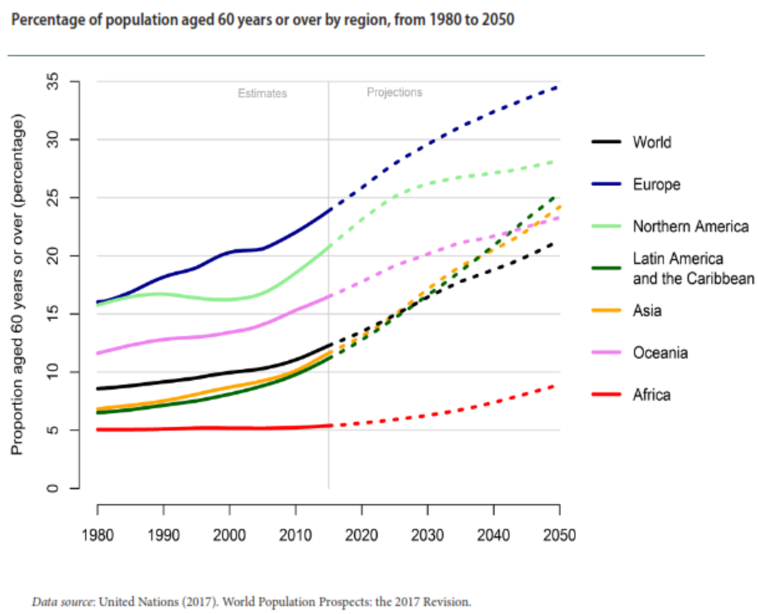

Figure 2.5: Percentage of the world population is going to get older till 2050

Numerous medical issues can prompt actual weaknesses that control mobile access. As (Trewin, 2008) described, those musculoskeletal conditions, for example, joint inflammation and aggregate injury issues, can make development firm and unbearable. Movement problems like tremors, Parkinson, and dystonia influence the capacity to control movement or forestall undesirable movements.

There are often situations or conditions with constraints in the context of mobile devices, and such conditions can limit the access of a user with the mobile device (Fuglerud, 2009). Not every user of a mobile device is facing the same situation or condition as others. A user can go

[1] Data source: United Nations (2017). World Population Prospects: the 2017

through many temporary or permanent situational constraints, such as using a mobile device in the bright light of the sun, use a mobile phone with gloves, people in a situation where the eyes are very busy such as driving a car or when complete darkness is necessary, people who are distracted or stressed under the influence of drugs (Vanderheiden, 2000). These diverse situations can limit a user's interaction with mobile applications.

2.2.6 Cognitive abilities

Many health issues permanent or temporal impairments can impact a user's interaction with an interactive system. The human brain is responsible for controlling the functionality of the body, and when the brain is somehow disturbed by some disorder, its malfunction affects the intellectual ability of a person. According to (Webaim.org, 2021), cognitive disability, also known as intellectual disability, is a nebulous term describing a person who has more incredible difficulty with mental tasks than the average person. People with cognitive disabilities experience mental problems in reading/write, thinking, concentration, formulate ideas.

Cognitive disorders affect human memory functions as a person can experience short-term memory and long-term memory problems. A person with (Webaim.org, 2021) memory problems may also have difficulty with attention or problem-solving. While discussing how human memory works and tips for UX designers (uxplanet.org, 2017) emphasise that memory functions play a vital role in creating clear and usable design layouts.

2.2.7 Usability

Usability can be defined as how easily people can interact and accomplish a particular task. According to ISO-9241-11 standard (ISO.org, 2018), it is defined as "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use".

David McQuillen (Zaib), an ex-Swiss banker and founder of Sufferfest Cycling workout resources, defines *"Usability is about human behaviour. It recognizes that humans are lazy, get emotional, are not interested in putting much effort into, say, getting a credit card and generally prefer things that are easy to do vs those that are hard to do."*

While discussing usability, there are attributes of users which closely attached to usability. These attributes are emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours, and accomplishments (uiuxtrend.com, 2016-2020). Usability is vital in web and mobile applications. A user interacts with the system for the first time how easy it is for the users to accomplish the desired task without any error. Usability involves these conditions (Figure 2.6):

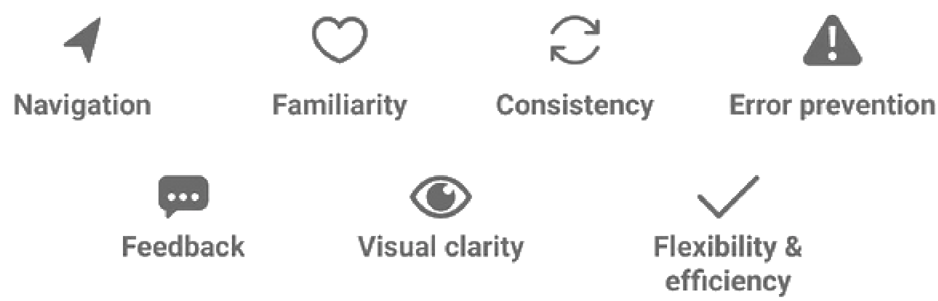

Figure 2.6: Conditions of Usability (public-media.interaction-design.org)

2.2.8 Accessibility

According to the definition of Oxford dictionary, *"accessibility is the quality of being able to be reached or entered or the quality or being easy to obtain or use".* When we think about the web and mobile applications, accessibility is attached itself to web accessibility and mobile accessibility. World Wide Web Consortium[2] (W3C) has been advocating and working for web accessibility and providing standards and guidelines Web Content Accessibility Guidelines [3] (WCAG) to make web applications more and more accessible for everyone to include people even with disabilities.

"The power of the Web is in its universality. Access by everyone regardless of disability is an essential aspect," said Tim Berners-Lee, W3C Director and inventor of the World Wide Web. This statement is also relevant for mobile applications as these applications must be accessible

[2] https://www.w3.org/standards/webdesign/accessibility
[3] https://www.w3.org/WAI/standards-guidelines/wcag/

for everyone. W3C also introduced guidelines and standards (W3C, 2015a) for mobile application accessibility to make mobile applications more accessible for everyone.

2.2.9 Universal Design

Design Pioneer and visionary of Universal Design Ron Mace coined the term “Universal Design” as he (MACE, 2008) described “the concept of designing all products and the built environment to be aesthetic and usable to the greatest extent possible by everyone, regardless of their age, ability, or status in life.”

Universal Design is not a term to differentiate a design that can be good for each arrangement. However, its goal is to include maximum users with different degrees of abilities. According to (Design, 2020), it is unnecessary to assist just a section of the user group. It is anything but a central state of delicate strategy. If the user environment is usable, helpful, and a joy to utilize everybody benefits. By considering the numerous necessities and capacities of the design process, all-inclusive design makes items, administrations and conditions that address people groups’ issues.

Universal Design in designing the user interfaces of mobile applications by making them viable and accessible to the people who have been underrepresented. The rapid reshaping of modern mobile technology has opened many possibilities and opportunities for mobile application developers and mobile application users to make and experience the applications in a more accessible way.

Universal design has seven principles (National Disability Authority, 2020) that have guidelines; for this study, we take into account only those relevant guidelines. The seven principles are as follows:

- “Principle 1: Equitable Use
  The design is useful and marketable to people with diverse abilities.

  1a. Provide the same means of use for all users: identical whenever possible; equivalent when not.

1d. Make the design appealing to all users.

- Principle 2: Flexibility in Use

  The design accommodates a wide range of individual preferences and abilities.

  2a. Provide choice in methods of use.
- Principle 3: Simple and Intuitive Use

  Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

  3a. Eliminate unnecessary complexity.
- Principle 4: Perceptible Information

  The design communicates necessary information effectively to the user, regardless of ambient conditions or sensory abilities.
- Principle 5: Tolerance for Error

  The design minimizes hazards and the adverse consequences of accidental or unintended actions.
- Principle 6: Low Physical Effort

  The design can be used efficiently and comfortably and with a minimum of fatigue.

  6d. Minimize sustained physical effort.
- Principle 7: Size and Space for Approach and Use

  Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility." (National Disability Authority, 2020)

2.2.10 User Experience

"User experience (UX) focuses on having a deep understanding of users, what they need, what they value, their abilities, and their limitations. User experience best practices promote improving the quality of the user's interaction with and perceptions of your product and any related services". (Usability.gov, 2021a)

There are factors that influence UX as Peter Morville (Morville, 2004) represents this through his User Experience Honeycomb

Figure 2.7: User Experience Honeycomb (Morville, 2004)

He notes that “for there to be a meaningful and valuable user experience, information must be:

- **Useful**: Your content should be original and fulfil a need
- **Usable**: The site must be easy to use
- **Desirable**: Image, identity, brand, and other design elements are used to evoke emotion and appreciation
- **Findable**: Content needs to be navigable and locatable onsite and offsite
- **Accessible**: Content needs to be accessible to people with disabilities
- **Credible**: Users must trust and believe what you tell them.”

2.2.11 Prototype

A prototype is an early simplified design or release of an actual product built for testing a development. A prototype is an essential part of a design process because it allows designers to see the product in action to see what works and what does not. If the prototypes reveal any problem, the designer can modify the design and build another prototype (Helmer, 2015). Prototyping has been become an essential part of UX design to design mobile or web applications. “Discussing the difference between the traditional and new ways of prototyping as these technologies, particularly virtual prototyping, can be used to define design specifications for a participatory design. Also, it has been investigated as a design tool for quick evaluations. Users can evaluate the usability of a product interface using virtual prototyping.” (Müller et al., 2016)

In this study, we are making two prototypes of a mobile camera application. The prototype will go through its design process initiated by a paper sketch of a mobile application till the fully functional high-fidelity prototypes. We discuss in detail our prototypes in a separate section.

3. Review of Related Literature

This section presents the related work and review of related literature. The literature review of the hidden UI navigational elements which exponentially boosts user experience will be presented in this report.

The convenience of mobile devices allows them to be used from any place and at any time. According to Isaac (Isaac, 1995), the mobile context involves the environments and conditions of usage — anything that can affect the interactions between the interface and the users, which is particularly significant for mobile since the contexts can change rapidly and constantly. While most designers primarily focus on the colour and other factors of the design, it is also essential to focus on the UI navigational elements to help avoid distractions, enable multitasking, and facilitate use when in motions.

Designed and did experimental (Zheng, Bi, Li, Li, & Zhai, 2018) analysis of marking menus for touchscreen mobile interaction. They proposed their prototype as *M3 Gesture Menu* (M3) on Android, which is initially hidden provided a designated area as its activation button. On pressing and holding the button for 0.5 seconds, the first-level menu pops up and then sliding the finger to an item shows its submenu, which can appear in the same area. However, as a novice user, one has to learn it first as it takes longer to execute than a linear menu.

In a study, “Usability of mobile applications” with the presentation of PACMAD (People At the Centre of Mobile Application Development) usability model, which arguments existing usability models with the context of mobile applications, discussed that memorability is not considered as an essential aspect of usability for mobile application (Harrison, Flood, & Duce, 2013). For easy to learn mobile applications, it may not be considered significant. However, if an application is hard to learn and requires significant time, then memorability must be considered an essential aspect.

An article, *“Usability studies on mobile user interface design patterns: A systematic literature review”* (Punchoojit & Hongwarittorrn, 2017a), discussed that navigation on mobile devices with smaller screen sizes is challenging. For example, when a user clicks on a link on a page, the new page would be loaded, and the process would repeat until the users find the information they need (Punchoojit & Hongwarittorrn, 2017a). Due to smaller screen sizes on mobile devices, this method is more complicated. (Setlur, Rossoff, & Gooch, 2011) and (Setlur, 2010) found an alternative method for mobile devices with context-based icons, "SemantiLynx", to support navigation on mobile devices. SemantiLynx could automatically generate icons that reveal the information content of a webpage. (Böhmer & Bauer, 2010) conducted contextual aware inquiries in different situations and performed different activities to investigate how people arrange icons for their convenience. By designing a prototype that pushes contextual, relevant services to mobile devices.

In a study, (Shrestha & Murano, 2016) designed and developed a prototype for data visualization for people with rheumatoid arthritis. In their empirical, experimental study, they evaluated their prototype and improved it with standards and principles of Universal Design to make the mobile application more accessible and usable. In another study, (Billi et al., 2010) presented a unified methodology by considering both usability and accessibility of mobile applications. Their study discussed and reported some issues by evaluating the MAIS designer, a design tool for generating user interfaces adapted to the characteristics of the target device, such as smartphones.

Lyndon Cerejo (Cerejo, 2012) recommends offering appropriate mobile-only functionality in the user interface (such as image recognition) and hiding other secondary functionalities using the capabilities of the mobile device where possible to ensure that users remain engaged and delighted. Presenting links to the main content and elements instead of placing all of them in the UI prioritized based on the user's requirements. Neil (Neil, 2014), in her publication "Mobile Design Pattern Gallery", presents examples of secondary and primary navigational patterns for mobile, detailing how to hide and prioritize others—enabling users' navigation as the most significant functionality and content to be accessible in few taps as possible. Google's design system, Material Design, created by Google to help teams build high-quality digital experience for Android, iOS, etc. (Material.io, 2021), defines that navigation in mobile applications can have clear task flows with minimal steps and easy to locate controls and clear labelling.

Kara Pernice and Raluca Budiu (Kara Pernice, 2016) from Nielsen Norman Group discussed that people feel challenging to find commands in hidden navigational elements, and they are less likely to use hidden navigation. Their study found that people spent more time performing a task on hidden UI elements than visible elements. Moreover, the hidden navigational elements in mobile user interfaces provide a poorer user experience than visible elements. On the other hand, they highlighted the importance of hiding commands and providing only a hamburger menu. It is due to the commands occupy much screen space on mobiles, and screen space is very crucial on mobile devices. That is why there is a challenging situation for user interface designers to try to use as little space as they can and hide elements in a hamburger menu.

Nick Babich (Babich, 2019) emphasizes that the user interface is an essential part of software because users can interact with the software with the user interface. The user interfaces should be designed in a way to be comfortable to use and reduce cognitive load. Nick Babich proposed four golden rules for user interface design and highlighted that the navigation in applications should be evident to users. For an exemplary user interface design, the UI designer should provide visual clues that can remind users to perform an action and navigate smoothly through an interface. While using an interface, a user should not think or ask himself, “Where am I?” As with poorly designed application interfaces and without proper or prominent navigation, it is challenging for the user to complete any action. Google Material Design (Material.io, 2021) always follows its design guideline to provide a visible navigation menu icon to open and close the menu.

An online article about how human memory works and tips for UX designers (uxplanet.org, 2017) writes about interfaces with too many options and demand to remember too many options can create tension and get users irritated even if they aren’t able to describe the reason for unpleasant emotions. This article provides many tips to make user interfaces more accessible for everyone. It suggests that do not make users memorize many items at once and do not present too many elements for the choice together. The most important tip for the UX designers and significantly related to this study is “do not hide the core elements of navigation” otherwise, with a complex interface, a user has to struggle to find and memorize the patterns of reaching the elements. Alan Cooper highlighted the issue with navigation way back in 2001 in his article “Navigation is not fun”, which is very realistic in mobile application design. According to him, “A well-designed business program must make its structure and organization as clear as possible. Users do not want to waste time-solving the mystery of where resources and information are hidden.” (Costa, 2021)

3.1 Standards and Guidelines

World Wide Web Consortium (W3C) is an international body under this body, and member organizations work to develop web standards. It introduced guidelines and standards (W3C, 2015a) for mobile application accessibility to make mobile applications more accessible for everyone. We take account of standards and guidelines from W3C related to mobile devices and which needs to be considered while designing and developing applications for mobile devices.

3.1.1 WCAG 2.0 and W3C Mobile Accessibility Guidelines apply to mobile

These are Mobile Accessibility Guidelines by W3C, which apply to mobile devices.

Guideline 3.3 Touchscreen Gestures (W3C, 2015b)

“Many mobile devices are designed to be primarily operated via gestures made on a touchscreen. These gestures can be simple, such as a tap with one finger, or very complex, involving multiple fingers, multiple taps and drawn shapes.

- Some (but not all) mobile operating systems provide work-around features that let the user simulate complex gestures with simpler ones using an on-screen menu.

Some best practices when deciding on touchscreen gestures include the following:

- Gestures in apps should be as easy as possible to carry out. This is especially important for screen reader interaction modes that replace direct touch manipulation by a two-step process of focusing and activating elements. It is also a challenge for users with motor or dexterity impairments or people who rely on head pointers or a stylus where multi-touch gestures may be difficult or impossible to perform. Often, interface designers have different options for how to implement an action. Widgets requiring complex gestures can be difficult or impossible to use for screen reader users. Usually, design alternatives exist to allow changes to settings via simple tap or swipe gestures.

- Activating elements via the mouseup or touchend event. Using the mouseup or touchend event to trigger actions helps prevent unintentional actions during touch and mouse interaction. Mouse users clicking on actionable elements (links, buttons, submit inputs) should have the opportunity to move the cursor outside the element to prevent the event from being triggered. This allows users to change their minds without being forced to commit to an action. In the same way, elements accessed via touch interaction should generally trigger an event (e.g. navigation, submits) only when the touchend event is fired (i.e. when all of the following are true: the user has lifted the finger off the screen, the last position of the finger is inside the actionable element, and the last position of the finger equals the position at touchstart).

Another issue with touchscreen gestures is that they might lack onscreen indicators that remind people how and when to use them. For example, a swipe in from the left side of the screen gesture to open a menu is not discoverable without an indicator or advisement of the gesture.

Guideline 3.5 Placing buttons where they are easy to access

- Mobile sites and applications should position interactive elements where they can be easily reached when the device is held in different positions.
- When designing mobile web content and applications, many developers attempt to optimize use with one hand. This can benefit people with disabilities who may only have one hand available; however, developers should also consider that an easy-to-use button placement for some users might cause difficulties for others (e.g. left- vs right-handed use, assumptions about thumb range of motion). Therefore, flexible use should always be the goal.
- Some (but not all) mobile operating systems provide work-around features that let the user temporarily shift the display downwards or sideways to facilitate one-handed operation." (W3C, 2015a)

3.1.2 WCAG 2.0 techniques that apply to Mobile

Navigable: (W3C.org, 2015)

"Guideline 2.4 Provide ways to help users navigate, find content, and determine where they are. This guideline works closely with Guideline 1.3, which ensures that any structure in the content can be perceived, a key to navigation as well.

Advisory Techniques for Guideline 2.4

- Limiting the number of links per page
- Providing mechanisms to navigate to different sections of the content of a Web page
- Making links visually distinct
- Highlighting search terms" (W3C, 2015a)

3.2 Legislations and regulations

There are legislations and regulations which protect the rights and responsibilities of individuals.

According to the Convention on the Rights of Persons with Disabilities (CRPD) and its Article 4- General obligations (United Nations, 2016):

"States Parties undertake to ensure and promote the full realization of all human rights and fundamental freedoms for all persons with disabilities without discrimination of any kind based on disability. To this end, States Parties undertake:

e) To take all appropriate measures to eliminate discrimination based on disability by any person, organization, or private enterprise.

f) To undertake or promote research and development of universally designed goods, services, equipment, and facilities, as defined in article 2 of the present Convention, which should require the minimum possible adaptation and the least cost to meet the specific needs of a person with disabilities, to promote their availability and use, and to promote universal design in the development of standards and guidelines.

g) To undertake or promote research and development of, and to promote the availability and use of new technologies, including information and communications technologies, mobility aids, devices and assistive technologies, suitable for persons with disabilities, giving priority to technologies at an affordable cost.

h) To provide accessible information to persons with disabilities about mobility aids, devices and assistive technologies, including new technologies, as well as other forms of assistance, support services and facilities." (United Nations, 2016)

Directive (EU) 2016/2102 of the European Parliament and of the council of 26 October 2016 (Official Journal of the European Union, 2016):

"Requirements for the accessibility of websites and mobile applications:

1. In the context of this Directive, accessibility should be understood as principles and techniques to be observed when designing, constructing, maintaining, and updating websites and mobile applications in order to make them more accessible to users, persons with disabilities.

2. The Member States shall ensure that public sector bodies take the necessary measures to make their websites and mobile applications more accessible by making them perceivable, operable, understandable and robust". (Official Journal of the European Union, 2016)

Norwegian law for prohibition of discrimination on the grounds of disability (Discrimination and Accessibility Act (Government.no, 2013)

"According to regulation for Universal Design of information and communication technology (ICT) solutions:

Article 1: The purpose of the regulation:

The purpose of this regulation is to ensure the universal design of information and communication technology without causing an undue burden on businesses. Universal design means that the design or adaptation of the leading solution in information and communication technology is such that it can be used by as many as possible.

Article 4: Requirements to the design of ICT solutions:

Net-based solutions must, as a minimum, be designed in compliance with standard Web Content Accessibility Guidelines 2.0 (WCAG 2.0) NS/ISO/IEC 40500:2012 at the A and AA level, with the exception of guidelines 1.2.3, 1.2.4 and 1.2.5, or with corresponding standards." (Government.no, 2013)

4. Research Methodology

This section discusses and explains the research methods and which method and approach we will use to evaluate the usability and practice of Universal Design's principles in the proposed user interface of both prototypes. We will also explain why we are using a specific research method and how we collect and analyze data for discussion. Furthermore, we will describe the research approach, the experiments, testing, test level satisfaction feedback with a questionnaire for both prototypes.

4.1 Quantitative Research

The quantitative research method deals with numerical data or metrics such as task completion rate, time taken to perform a specific task. This type of research is data-oriented research used to quantify the issue or problem by usable statistical data. Researchers use measures and metrics to formulate facts and uncover patterns in research. This method is used to give answers to the questions "How many and How much?" In quantitative analysis, researchers ask close-ended questions which can be quantified. The data in this method offers an indirect assessment of the usability of a system (Budiu, 2017). In quantitative research (van Raan, 2013) within the field of technology implies the use and development of advanced data-analytical methods and techniques. Suphat Sukamolson (Sukamolson, 2007) explains that "there are several types of quantitative research. For instance, it can be classified as 1) survey research, 2) correlational research, 3) experimental research, and 4) causal-comparative research. Each type has its own typical characteristics".

4.2 Qualitative Research

The qualitative research method is widely used to get observational findings, insights, opinions, perceptions, and behaviours. In the field of human-computer interaction (HCI), this method is used to understand the users' needs, preferences, concerns and attitudes (Lazar, Feng, & Hochheiser, 2017). In qualitative research, researchers ask open-ended questions in surveys and questionnaires to get more insight into individuals. The data in this method offers a direct assessment of the usability of a system. (Budiu, 2017). According to (Lazar et al., 2017), "the most important issues in designing a qualitative study are how much you should attempt to pre-structure your methods as structured approaches can help ensure the comparability of data across sources and researchers can answer variance questions usefully”.

4.3 Hybrid Research

Hybrid research can be a combination of quantitative and qualitative research methodologies. It is more evolved than just a combination of quantitative and qualitative research methods as a combination of two or more than two research methodologies. The motivation behind using hybrid research is to establish a better understanding of results. It is used to get most of both research methods. (gutcheckit.com, 2019)

4.4 Approach for study

For this study, we adopted a quantitative research approach. We adopted this approach because our user testing will produce some results in numerical forms, such as task completion rate and time taken on tasks. Quantitative research has an advantage over qualitative research, which is statistical significance. According to (Cohen, Manion, & Morrison, 2002), quantitative research is described as utilizing empirical methods. As empirical statements are conveyed in numerical terms. “Quantitative research is also useful to quantify opinions, attitudes and behaviours and find out how the whole population feels about a certain issue.” (Sukamolson, 2007)

In quantitative analysis, when the data are presented firmly, they come with specific protection against randomness. Usually, mathematical instruments such as confidence intervals as statistical significance will tell us how likely the data reflect the truth or whether they may be just an effect or random noise. Perhaps an artefact of the specific participants that we happened to recruit or of the conditions in which the study was run. (Budiu, 2017)

According to (Olsen Jr, 2007), usability comes to mind while deciding to evaluate interactive systems. As (Ivory & Hearts, 2001) discussed, formal usability testing methods could be applied when the user interface design or prototype has been implemented. Similarly, the heuristic technique is suitable in the early design phase. Further (Ivory & Hearts, 2001) explains the results of these evaluations can be different if different evaluators evaluate the same interface.

As technology advances, the research needs to adopt new research methods (Lazar et al., 2017). There are many research techniques around, and adopting any specific research technique is a crucial decision. There are various methods to evaluate or test user interfaces.

4.4.1 Empirical evaluation

Empirical evaluation deals with testing with users. This type of evaluation is composed of evaluation and usability testing forms like questionnaires, interviews, focus groups, performance measurement, thinking-aloud protocols, field testing and user logs. “The empirical approach has been playing a vital role in the HCI field. The validity of experimental research in the field of HCI is well-grounded. Significance testing allows us to judge whether the observed groups' means are truly different. However, this approach has some shortcomings, like it requires a well-defined and testable hypothesis. In HCI experiments, it is difficult to control all potential factors and create experimental conditions.” (Lazar et al., 2017)

4.4.2 Heuristics evaluation

The second method, Heuristic evaluation, is proposed by Jackob Nielsen (Nielsen & Molich, 1990). An evaluator must walk through various scenarios to find errors in these scenario-based rules. “This evaluation method has advantages like it is an inexpensive, quick testing tool and can be used before other usability testing methods. However, It does not involve the users’ opinion in the testing. It depends on more than one UX expert evaluator to get precise results. Another shortcoming is that it cannot be used alone to achieve accurate usability testing” (Team, 2021). In a study, (Doubleday, Ryan, Springett, & Sutcliffe, 1997) was not satisfied and opposed that the heuristic method claimed by Nielsen is a rapid way to identify a high percentage of errors on an interface not be as successful as it claimed.

4.5 Research method

Within the domain of quantitative research, we used empirical research to perform experimental user testing on our prototypes and then gather participants’ insight on the Likert-type scale. Empirical research uses empirical evidence which can be analyzed quantitatively. Using empirical research as a quantitative method has many benefits. It allows to perform experiments and, based on those experiments, get measures/metrics for statistical significance, and later get an in-depth insight of participants about their experience with the tested system, as in our case, there are two prototypes. Empirical studies (Weibelzahl & Weber, 2002) are beneficial at identifying design errors in systems and wrong hypotheses, but they do not propose new theories or approaches directly. While discussing the limitations of an empirical study that its hypothesis testing procedure is responsible for a significant limitation. Further, they suggested that an explorative study requires some hypotheses about possible impact factors, so it must be combined with theoretical grounds to yield valuable results.

This study adopts empirical research because of its experimental nature based on observation and measurement of phenomena. According to (MacKenzie, 2012), human-computer interaction is vast with considerable empirical research. We mainly see in social sciences where only observational methods as opposed to experimental procedures.

4.5 Research design and data collection

We have designed two identical prototypes of mobile camera applications with different user interfaces for our experimental research. Prototype 1 has hidden navigational elements, and Prototype 2 has visible navigational elements. This study is a within-group (within-subject design) where participants have to perform the same tasks on two identical prototypes. Our research is based on an experimental investigation into usability and universal design for our prototypes, and it will help to understand how our participants interact with our proposed prototypes. We evaluate the interfaces of both prototypes. According to Lazar (Lazar et al., 2017), actual experiments have these characteristics:

- “It is based on at least one testable research hypothesis and aimed to validate it.
- The dependent variables are typically measured through quantitative measurements.
- The results are analyzed through various statistical significance tests.
- It should be designed and conducted with the goal of removing potential biases.

- It should be replicable with different participants samples, at different times, in different locations, and by different experiments. " (Lazar)

4.5.1 Measures/metrics

According to Lazar, "in HCI research, the basis for measuring interface usability is still relevant for a long time. These metrics/measures are based on a task-centred model, where specific tasks can be separated, quantified, and measured. The metrics can be task correctness, time performance, error rate, time to learn, retention over time and user satisfaction" (Lazar et al., 2017). For statistical analysis, we have Prototype 1 and Prototype 2 as independent variables and Time on tasks, Task completion, Number of errors and User satisfaction dependent variables. To test both prototypes, we set some measures on which we will analyze the results. Following are the criteria for our study:

- Time on tasks
- Task completion
- Number of errors
- User satisfaction

4.5.2 Hypothesis

H1: We assumed that all participants would be able to perform their tasks more efficiently on prototype 2.

H2: We assumed that all participants would take more time to complete tasks on Prototype 1.

H3: We assumed that Prototype 1 is prone to error than Prototype 2.

H4: We assumed that most participants would prefer to use Prototype 2.

4.5.3 Tasks

After setting the mode for research, the next step is to set tasks for test on prototypes. These tasks are one sentence carrying specific actions that need to be performed by the participants during testing. According to (McCloskey, 2014) the tasks should be realistic, actionable and without clues on how to perform the steps. For our usability testing on prototypes, we made the following five tasks which will be tested on both prototypes:

- Capture a picture
- Adjust "Zoom Level"
- Turn off "Flash"
- Open "Settings"
- Adjust "Auto White Balance" AWB

4.5.4 Procedure of interface testing

As discussed already, the experimental nature of empirical research in the research methodology section, we guide the participants throughout the testing and ask them to perform tasks. While performing tasks, we used a Microsoft Excel Sheet (10.4 Appendix -D) to record their actions whether they could complete a task or failed to complete a task during testing.

4.5.5 Research ethics

Research is mainly concerned with gathering data from people, which also raises privacy issues. During the study, researchers ask their participants to participate in testing prototypes, surveys, and questionnaires. As Oliver discussed, “The research community is becoming increasingly more sophisticated in the manner in which it considers such ethical issues, and there appears to be a growing concern with the ethical dimension of planning and implementing research.” (Oliver, 2010)

Ethical guidelines underline to collect less sensitive user data as possible. There is a need to protect users against discrimination, abuse, exploitation, or deception during research. The information about what the study is about and what the researcher is trying to get from people must be clearly defined and presented before the study. The informed consent form needs to be sent to them and explained before research to have their consent.

In this study, we are not collecting any personal data which can directly or indirectly identify a person's information or background. We will use the Google Forms questionnaire (10.3 Appendix -C), which can be completed anonymously so that no information about the participant will be vulnerable. To comply with the Norwegian Personal Data Act [4] and guidelines for using personal information in research (Datatilsynet 2005b), We provided an information sheet (10.1 Appendix -A) about the study and what we are going to ask them to do. We developed and documented an informed consent form (10.2 Appendix -B) that will be retained protected. No personal data or any information will be collected without the permission of our participant's consent.

Norwegian Center for Research Data (NSD) [5] provides guidelines to store and protect data. For this study, we did not ask permission from NSD because we did not ask or collect any personal details or vulnerable data from our participants.

4.5.6 Consent form

Before any research to get consent from the potential participants is very important in research ethics. A consent form (10.2 Appendix -B) has been made and sent to all our participants before testing to get their consent before testing and getting their feedback. This form provides information about study and testing to our potential participants.

4.5.7 Post-test questionnaire

After testing on prototypes by our participants, a post-test questionnaire form (10.3 Appendix -C) was sent to our participants. This form is an online Google form document containing six questions for each prototype based on Likert type scale carrying 1-5 values. This post-test questionnaire form will be used to evaluate our proposed prototypes by using the Likert scale. The explanation of 1-5 values is as below:

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[4] https://www.legislationline.org/download/id/5546/file/Norway_Personal_Data_Regulations_2013_en.pdf

[5] https://www.nsd.no/en/

Strongly Disagree	=	1
Disagree	=	2
Neutral	=	3
Agree	=	4
Strongly Agree	=	5

4.5.8 Participants

After discussing the research design and process, we discuss our participants. Our proposed prototypes are mobile applications. We adopted user testing on prototypes, which requires the genuine involvement of real users to perform practical tasks that the testing is intended to achieve. Without testing with real users, accurate results cannot be yield. We outline a group of participants in this study and collect feedback to validate our analysis. There were 20 (10 males and 10 females) participants with different age groups (20-60). Each session lasted for 20 minutes, and it included an introduction, a list of tasks, and a short questionnaire. Each participant completed a questionnaire on their experience with the prototypes anonymously with their consent.

4.5.9 Avoiding biases in research

The human mind is an unimaginable organizing machine, and it can store a great measure of data. One-way minds can keep such a lot of data is by making alternate mental routes dependent on revised designs. These alternate ways permit people to relate and gather data for faster handling. However, these revised examples of reasoning can prompt wrong or absurd ends that are one-sided — preferring or having a bias against a person or thing. Preferences can seriously impact the research. According to Lazar, “experimenter behaviour is one of the major sources of bias. Any intentional action to influence participants’ performance or preference is unethical in research and should be strictly avoided. ” (Lazar et al., 2017). For this study, it was tried to avoid any bias by taking below mentioned steps:

- We tried to limit our guidance to the participants during the prototype testing to follow their path without any interruption to the design and prototype.
- We tried to remain open-minded throughout the study and treat all information equally to avoid any bias.
- It was made very comfortable for participants to share their feedback and thoughts after experiencing the design.

4.5.10 Testing time division

The testing procedure consists of three steps, as shown below. The total allocated time is 20 minutes, and it is divided into three steps.

1. Welcome/ pre-test brief introduction / signing of consent form 5 min
2. Carrying out the test tasks 10 min
3. Post-test questionnaire 5 min

4.5.11 Test environment and resources

We used different test environments at the participant's convenience to make testing and all the process inline. We used cell phones for prototype testing and did not perform the test on the computer. We used many software and application environments, which is vital to mention here. These are the following:

- **Figma® [6]:** To make wireframes of our prototypes, we used Figma by Figma, Inc., a web-based vector graphics editor and a prototyping tool.
- **Axure [7]:** For designing and testing, we used Axure, software for creating prototypes.
- **Google Forms [8]:** To get feedback from our participants about their experience with the prototypes, we used Google Forms which is used for survey administration freely offered by Google.

[6] https://www.figma.com
[7] https://www.axure.com/
[8] https://docs.google.com/forms

- **Microsoft Excel [9]:** After getting questionnaire response data from the participants, we used Microsoft Excel to compile results. We used it to record testing results also.
- **SPSS:** The data were analyzed statistically with the help of SPSS.

[9] https://www.microsoft.com/nb-no/microsoft-365/excel

5. Prototype Design Phase

In this section, we explain the steps adopted while designing our two prototypes. We name them prototype 1, which is with hidden navigational elements and prototype 2, with shown or visible navigational elements. We will explain and illustrate the steps from paper sketch to final prototype. We also present the technology, tools, and environment to get results for later discussion. The screen images of both prototypes can be found in appendix (10.10 Appendix J)

For this study, we designed two prototypes of mobile camera applications with different user interfaces. The question arises here “Why we chose to make a camera app prototype?” like other applications in mobile, people use camera applications very often in the age of social media. Moreover, every mobile phone has a camera, and a camera app is provided in the primary set of applications. Mobile phones have been shaped into camera phones. The bar chart below shows that 92% of mobile users use their mobile devices to take only photos.

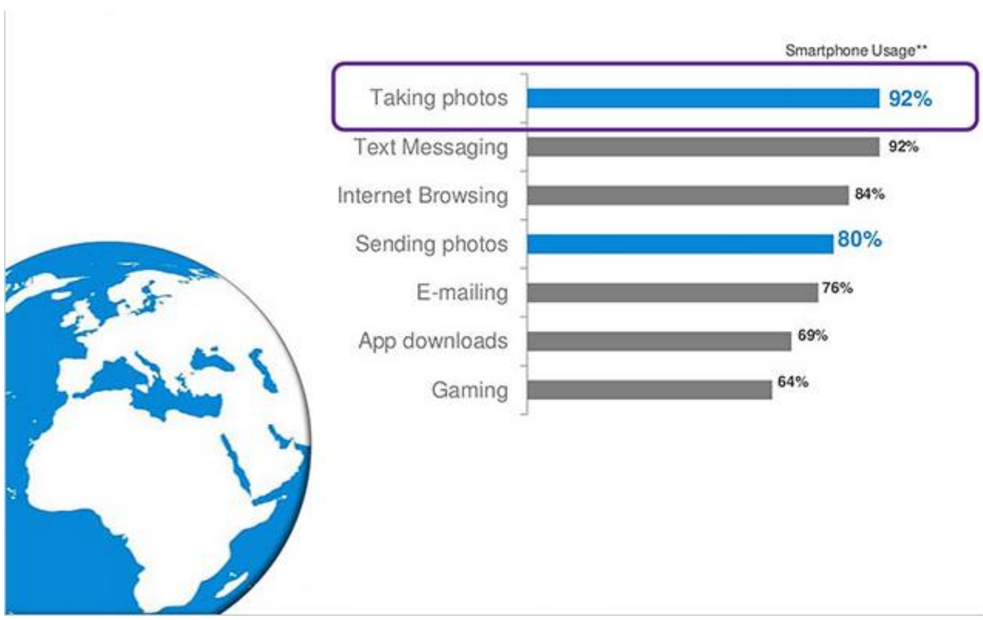


Figure 5.1: Bar Chart showing the percentage of mobile apps usage (https://petapixel.com, 2015)

A mobile application, before its development, goes under many steps. Before making a final app or product, prototyping is an essential and integral part of an app design to get an early taste of the final product. “Prototyping is an experimental process where design teams implement ideas into tangible forms from paper to digital.” (interaction-design.org)

The idea for developing our prototype is to make an application’s user interface so that there will be no clues to use the navigation elements. The commands and options will not be visible on the interface, and a user has to interact with the app by using mobile gestures, i.e., swipe left, right, up and down.

5.1 Paper Wireframes

Paper wireframes and illustrations/sketching are important ways to draw our ideas on paper before using software to build a wireframe on the computer. The advantage of drawing illustrations on paper is, it is an inexpensive, fast way to transfer our idea on paper, and it has countless iterations. Since they take less time to develop, designers tend not to become committed to a specific design early on. To test low-fidelity design for usability in the early stages is called formative testing (Lazar et al., 2017). We started to build our wireframes for our prototypes on paper. Figure 5.2 (a) with hidden navigational elements and in Figure 5.2 (b) is the paper wireframe for prototype 2, which is with visible navigational elements:

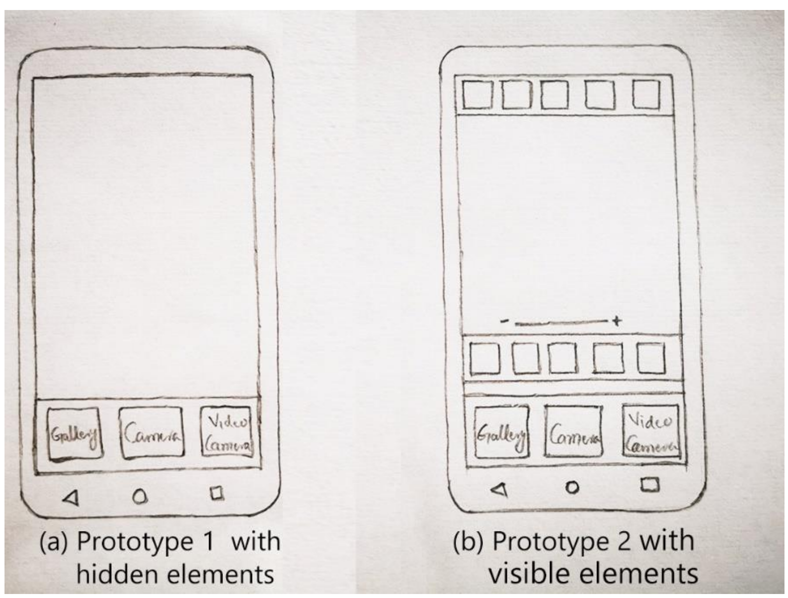
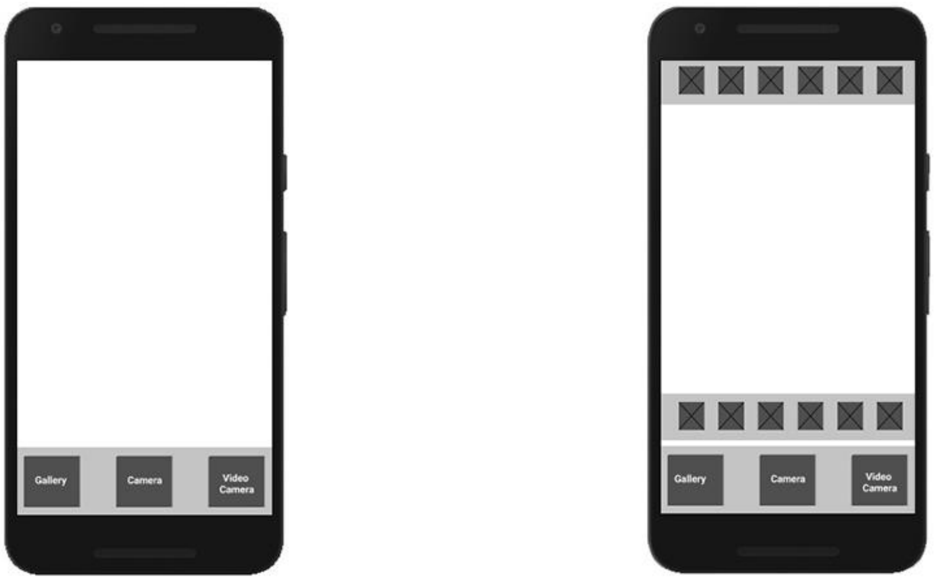


Figure 5.2: Paper wireframes of both Prototypes

5.2 Digital Wireframes

After sketching an idea on paper for our both prototypes, we transferred that sketch into a digital wireframe with the help of web-based environment Figma. The representation of digital wireframes are shown below in Figure 5.3:



(a) Prototype 1 with hidden elements

(b) Prototype 2 with visible elements

Figure 5.3: Screenshot of digital wireframes of both prototypes

5.3 Low-fidelity App flow Prototype

Creating digital wireframes is a great way to have some existence of our initial paperwork. The next step is to build all screens for our prototypes and link these screens with each other to make a flow for the user to interact with the prototype smoothly and make them able to perform required tasks. It is still in the low-fidelity phase without adding high-fi iconography. Usability testing on formal prototypes or high-level design is known as a summative test (Lazar et al., 2017). Figure 5.4, a straightforward layout is linking different screens to complete a user flow on the prototype.

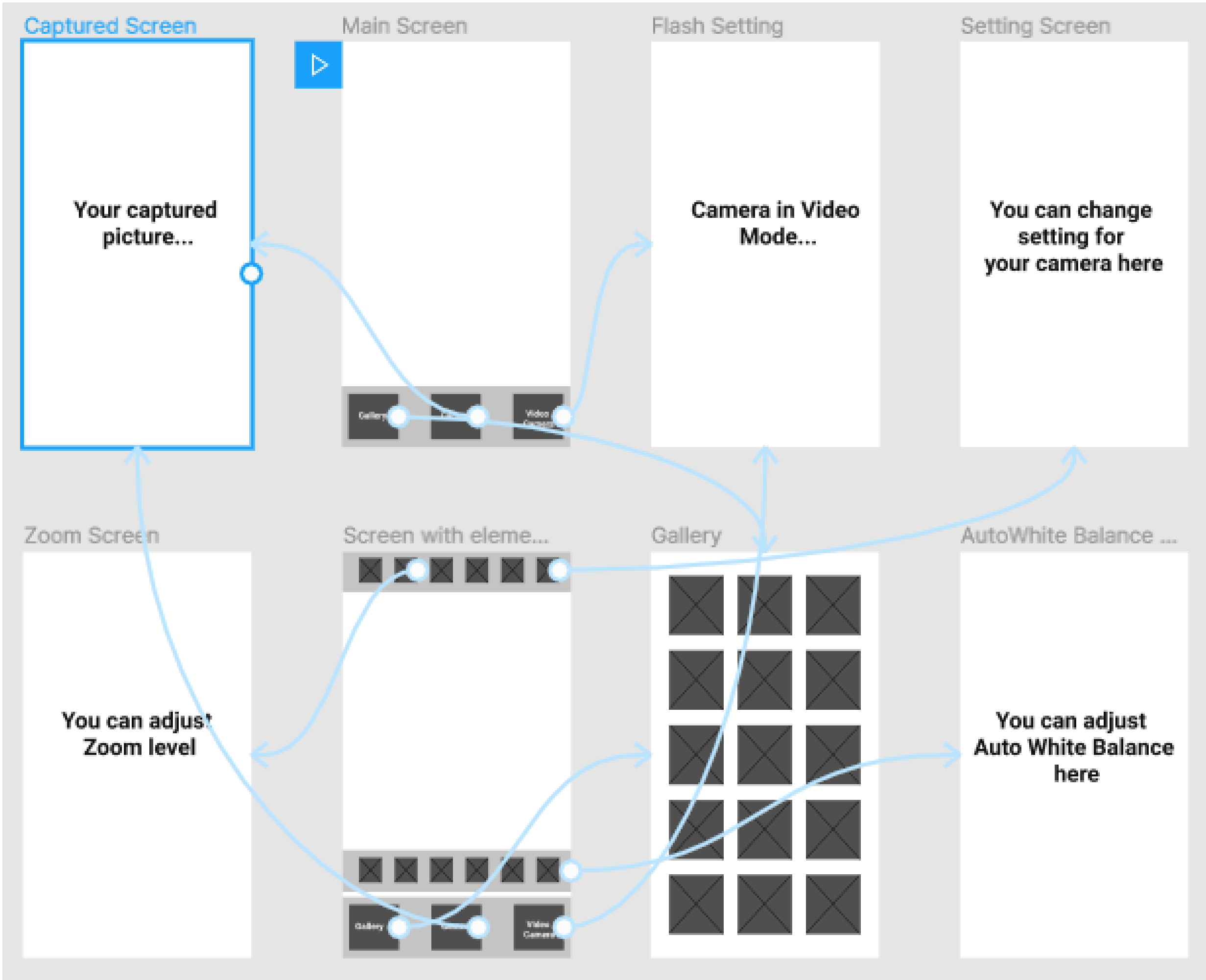


Figure 5.4: Screenshot of Low-fidelity App flow Prototype

5.4 High-fidelity Prototype

High-fidelity prototypes are very closest to the final product, which are helpful to predict how a user will interact with it. Testing on high-fidelity prototypes yields more accurate results (interaction-design.org). We used the Axure application on a computer to build the final version of our prototypes to test with our participants. A screenshot of our prototype during the developing phase is shown in Figure 5.5.

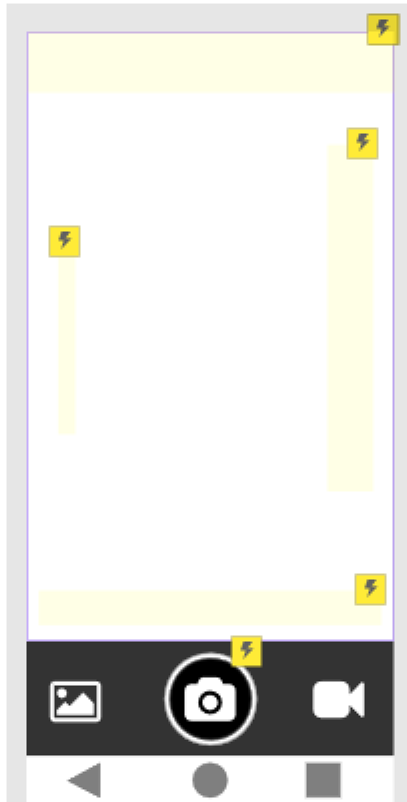


Figure 5.5: Screenshot of the prototype during the development phase in Axure

The final version of our prototypes is shown below in Figure 5.6. Figure 5.6 (a) is a final version of the prototype with hidden navigational elements; as shown in the figure, there are no visual clues to navigate the application and maximum space available for users to use the app. Figure 5.6 (b) is a final version of the prototype with visible/shown navigational elements. As shown in the figure, all menus and commands are visible to the user to interact. In contrast with prototype 1, in prototype 2, much screen occupied by commands on-screen is visible. When the interface is ready to release for users, validation testing can be performed against a set of benchmarks to ensure usability. (Lazar et al., 2017)

(a) Prototype 1 with hidden navigational elements

(b) Prototype 2 with visible navigational elements

Figure 5.6: Screen shot of final and working prototypes

6. Results and Analysis

This section presents the results after testing our prototypes with participants and their feedback and experience with both prototypes. As we discussed in chapter 4 about our research approach, we adopted quantitative research with its advantage of showing statistical significance. Proper determination of statistical techniques and precise understanding of the test outcomes are fundamental for research. (Lazar et al., 2017) We are going to compare two means to get statistical results. The most widely adopted statistical procedure for comparing two means is the t-test. (Rosenthal & Rosnow, 2008) According to Lazar (Lazar et al., 2017), when the same group contributes the two means, a paired-samples t-test can be considered.

We first performed the Shapiro-Wilk test in SPSS to check the normality of our data, whether it is parametric in nature or non-parametric. The results of the Shapiro-Wilk test showed the data is normally distributed so that we can perform parametric tests on it. We also performed Descriptive Statistics, Frequencies for our questionnaire, and Paired Sample T-Testing to analyse our data precisely and present the results. Raw data collected during testing and frequencies (10.8 Appendix -H and 10.9 Appendix -I) of the questionnaire can be found in the Appendix section.

We tested our prototypes with 20 participants (10 males and 10 females) age ranging from 21 to 60; details are shown in (Figure 6.1). Our participants performed 5 similar tasks on each prototype. We recorded the time spent on all tasks collectively on one prototype during testing, i.e., we did not record time spent on each task individually. We also gathered data about task success/failure rate, which we present here.

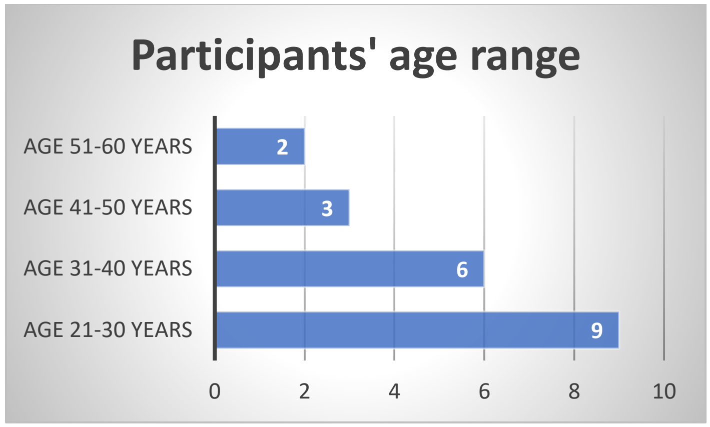


Figure 6.1: Participants' age range

6.1 Time on tasks

Time was recorded as the total time taken by all tasks on each prototype by a participant.

Table 6.1: Descriptive Statistics of Time on tasks

	Minimum	Maximum	Mean	N	Std. Deviation	Std. Error Mean
Prototype1 with hidden elements	0.54	1.34	1.1470	20	.22150	.04953
Prototype 2 with visible elements	0.22	0.47	.3095	20	.06970	.01558

Table 6.1 presents the comparison of the total time taken on tasks on both prototypes. It is evident from the data that participants with the mean value of (1.1470) and standard deviation of (SD=.22150) took more time to complete tasks on Prototype 1 with hidden elements than on Prototype 2 with visible elements with the mean value of (0.47) and standard deviation of (SD=.3095)

Table 6.2: Paired Samples Test Results for Time on tasks

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Prototype1 with hidden elements - Prototype 2 with visible elements	.83750	.20645	.04616	.74088	.93412	18.142	19	.00000000000185897973

Table 6.2 exhibits a more precise comparison of time on tasks between two prototypes. It is evident from the results of T-test that P-value (Sig. = .00000000000185897973) which is (p-value = < .00001) is highly significant against our significance level of (.05). This significant difference between the two prototypes in terms of the total time taken on tasks proves our hypothesis (H2) correct and reject the null hypothesis. The bar chart (Figure 6.2) below depicts the difference in terms of the total time taken on both prototypes.

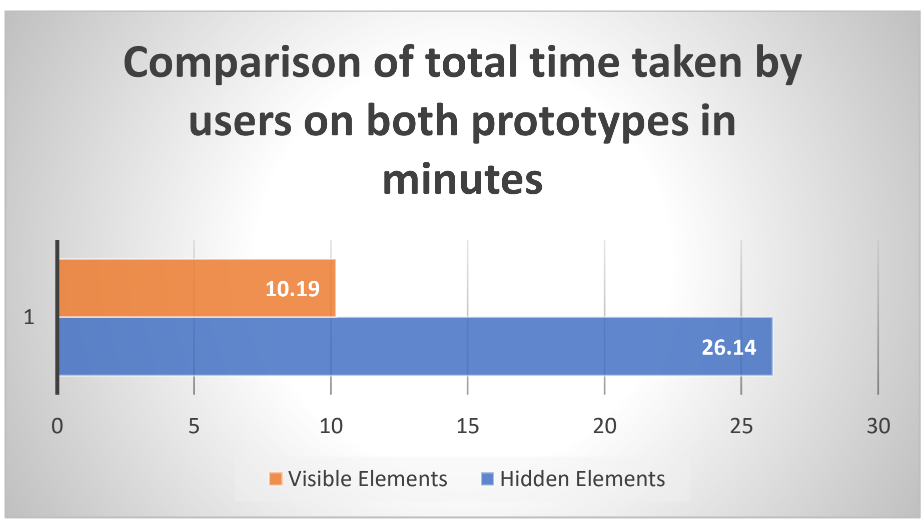


Figure 6.2: Bar chart of time on tasks comparison

6.2 Task completion

There were five tasks for each prototype, and all participants performed the same tasks on both prototypes. We present here the task completion comparison between both prototypes.

It will then be easily understandable which prototype was easier to perform with the number of successful tasks completed.

Table 6.3: Descriptive Statistics of Tasks completion

	N	Minimum	Maximum	Mean	Std. Deviation
Prototype 1 with hidden elements	20	3	5	4.25	.550
Prototype 2 with visible elements	20	5	5	5.00	.000
Valid N (listwise)	20				

Table 6.3 reflects the task completion comparison of both prototypes. The data shows that participants could complete all tasks on prototype 2 with visible elements and performed less successful tasks on Prototype 1 with hidden elements. The difference in mean value (5 and 4.25) and standard deviation of (SD=.000 and .550) for prototype 2 with visible elements and prototype 1 with hidden elements, respectively, supports the difference.

Table 6.4: Paired Samples Test Results for task completion

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper			
Prototype 1 with hidden elements - Prototype 2 with visible elements	-.750	.550	.123	-1.007	-.493	-6.097	19	.0000073119795240

Table 6.4 expresses that P-value (Sig. = .0000073119795240) which is (p-value = < .00001) highly significant against our significance level of (.05). This significant difference rejects the null hypothesis and confirms our hypothesis correct (H1). It proves that prototype 2 with visible elements was more effective in overall fostering more successful task completions than prototype 1 with hidden elements.

Task completion comparison between two prototypes can be seen below in the bar graph.

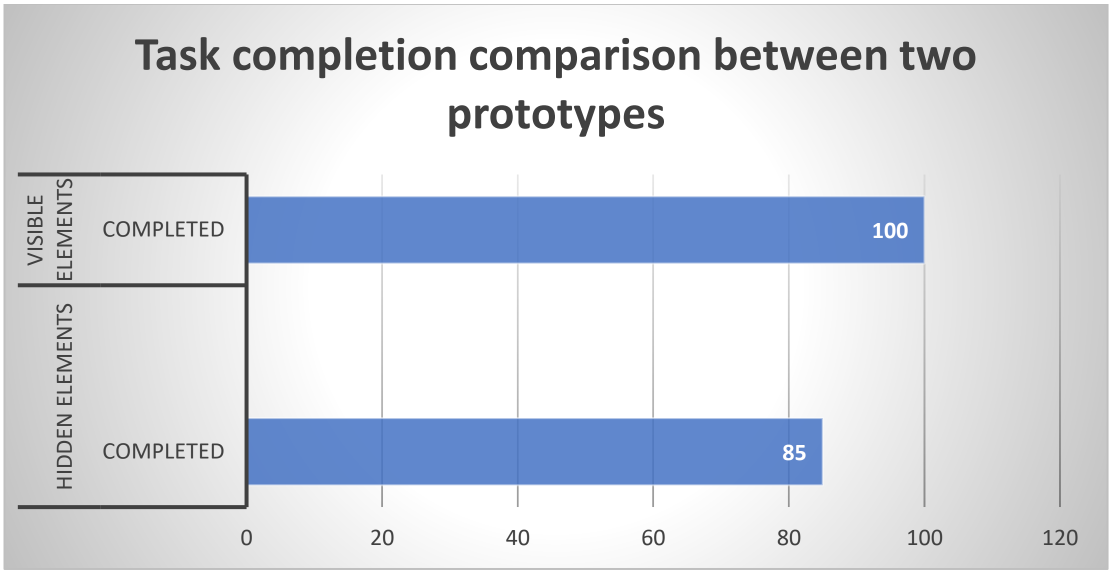


Figure 6.3: Bar graph of task completion comparison

6.3 Number of errors

Errors are mistakes, slips or unsuccessful attempts to complete a task. For testing on prototypes, errors were defined as failure to complete a task. One error in performing a task is counted as a failure. We observed total 15 errors on prototype 1 with hidden elements during testing, and there was not a single error found on prototype 2 with visible elements. The statistical representation of the number of errors on both prototypes is presented below:

Table 6.5: Descriptive Statistics of Task failure

	N	Minimum	Maximum	Mean	Std. Deviation
Prototype 1 with hidden elements	20	0	2	.75	.550
Prototype 2 with visible elements	20	0	0	.00	.000
Valid N (listwise)	20				

Table 6.5 unveils that participants who performed prototype 1 with hidden elements (M=.75, SD=.550) encountered errors or failures compared to the same participants. The same tasks were performed without any failure on prototype 2 with visible elements (M=.00, SD=.000).

Table 6.6: Paired Samples Test Results for task failure

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Prototype 1 with hidden elements - Prototype 2 with visible elements	.750	.550	.123	.493	1.007	6.097	19	.00000731198

Table 6.6 signifies the result of the comparison of both prototypes in terms of task failure. The P-value (Sig. = .00000731198) which is (p-value = < .00001) significant against our significance level of (.05). It rejects the null hypothesis and accepts our hypothesis (H3).

6.4 User satisfaction

A questionnaire was asked to complete to get our participants' level of satisfaction and experience with both prototypes. We used the Likert Scale (Strongly Disagree = 1, Disagree =2, Neutral=3, Agree=4, Strongly Agree =5,) for the questionnaire. We compared the results of statements of both questionnaires for our prototypes one by one. There were six statements for each questionnaire. Below are the results of the questionnaire (10.3 Appendix -C) presented statistically.

Analysis of data of statements of questionnaires

6.4.1 Statement 1: The user interface was easy to interact with.

Table 6.7: Descriptive Statistics for statement 1 of both questionnaires

	N	Minimum	Maximum	Mean	Std. Deviation
Statement 1 for Prototype with hidden elements	20	1	5	2.60	1.353
Statement 1 for Prototype with visible elements	20	1	5	4.40	1.273
Valid N (listwise)	20				

Table 6.7 shows that participants (M=4.40, SD= 1.273) think the interface with visible elements is more accessible than the interface with hidden elements (M=2.60, SD=1.353).

Table 6.8: Paired Samples Test Results for Statement 1 of both prototypes

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Statement 1 for Prototype with hidden elements - Statement 1 for Prototype with visible elements	-1.800	2.308	.516	-2.880	-.720	-3.488	19	.002461570

Table 6.8 reflects that the P-value (Sig. = .002461) which is (p-value = < .002461) significant against our significance level of (.05). This significant difference rejects the null hypothesis and accepts the alternative hypothesis that participants found the user interface with visible elements to be significantly easier to interact with.

6.4.2 Statement 2: It was easy to remember the commands.

Table 6.9: Descriptive Statistics for statement 2 of both questionnaires

	N	Minimum	Maximum	Mean	Std. Deviation
Statement 2 for Prototype with hidden elements	20	1	5	2.45	1.356
Statement 2 for Prototype with visible elements	20	1	5	3.85	1.226
Valid N (listwise)	20				

Table 6.9 exhibits that it was easier to remember commands on prototype 2 with visible elements (M=3.85, SD=1.225) than on prototype 1 with hidden elements (M=2.45, SD=1.356).

Table 6.10: Paired Samples Test Results for Statement 2 of both prototypes

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Statement 2 for Prototype with hidden elements - Statement 2 for Prototype with visible elements	-1.400	2.326	.520	-2.489	-.311	-2.692	19	.014446

Table 6.10 witness that the P-value (Sig. = .014446) which is (p-value = < .014436) significant against our significance level of (.05). This significant difference rejects the null hypothesis and accepts the alternative hypothesis that participants found that the user interface with visible elements significantly easier to remember commands.

6.4.3 Statement 3: The tasks were easy to complete on this interface.

Table 6.11: Descriptive Statistics for statement 3 of both questionnaires

	N	Minimum	Maximum	Mean	Std. Deviation
Statement 3 for Prototype with hidden elements	20	2	5	3.25	1.209
Statement 3 for Prototype with visible elements	20	1	5	4.50	1.147
Valid N (listwise)	20				

Table 6.11 shows that when it was asked “which interface is easy to complete tasks,” participants on prototype 2 with visible elements (M=4.50, SD=1.147) were more satisfied than on prototype 1 with hidden elements (M=3.25, SD=1.209)

Table 6.12: Paired Samples Test Results for Statement 3 of both prototypes

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Statement 3 for Prototype with hidden elements - Statement 3 for Prototype with visible elements	-1.250	1.803	.403	-2.094	-.406	-3.101	19	.005884

Table 6.12 manifests that the P-value (Sig. = .005884) which is (p-value = < .05882) significant against our significance level of (.05). This significant difference rejects the null hypothesis and accepts the alternative hypothesis that participants found the user interface with visible elements to be significantly easier to complete the tasks on it.

6.4.4 Statement 4: It was clear how to find desired option/Command.

Table 6.13: Descriptive Statistics for statement 4 of both questionnaires

	N	Minimum	Maximum	Mean	Std. Deviation
Statement 4 for hidden elements	20	1	5	2.30	1.302
Statement 4 for visible elements	20	1	5	4.10	1.447
Valid N (listwise)	20				

Table 6.13 reveals that participants on prototype 2 with visible elements (M=4.10, SD=1.447) found it easier to find desired commands than on prototype 2 with hidden elements (M=2.30, SD=1.302). The difference between mean and standard deviation indicates the difference strongly.

Table 6.14: Paired Samples Test Results for Statement 4 of both prototypes

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Statement 4 for hidden elements - Statement 4 for visible elements	-1.800	2.505	.560	-2.972	-.628	-3.214	19	.00457

Table 6.14 expresses that the P-value (Sig. = .00457) which is (p-value = < .004568) significant against our significance level of (.05). This significant difference rejects the null hypothesis and accepts the alternative hypothesis that participants found the user interface with visible elements to be significantly clear to find desired commands on it.

6.4.5 Statement 5: It was comfortable with hidden/visible navigational elements.

Table 6.15: Descriptive Statistics for statement 5 of both questionnaires

	N	Minimum	Maximum	Mean	Std. Deviation
Statement 5 for prototype with hidden elements	20	1	5	2.75	1.164
Statement 5 for prototype with visible elements	20	1	5	3.85	1.089
Valid N (listwise)	20				

Table 6.15 presents those participants on prototype 2 with visible elements (M=3.85, SD=1.089) who were more comfortable than the prototype with hidden elements (M=2.75, SD=1.164).

Table 6.16: Paired Samples Test Results for Statement 5 of both prototypes

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Statement 5 for prototype with hidden elements - Statement 5 for prototype with visible elements	-1.100	1.997	.447	-2.035	-.165	-2.463	19	.0235037

Table 6.16 reflects that the P-value (Sig. = .0235037) which is (p-value = < .0235) significant against our significance level of (.05). This significant difference rejects the null hypothesis and accepts the alternative hypothesis that participants found the user interface with visible elements to be significantly comfortable to interact with.

6.4.6 Statement 6: It was comfortable with maximum/less screen used by app interface.

Table 6.17: Descriptive Statistics for statement 6 of both questionnaires

	N	Minimum	Maximum	Mean	Std. Deviation
Statement 6 for Prototype with hidden elements	20	1	5	2.75	1.070
Statement 6 for Prototype with visible elements	20	1	5	3.55	.999
Valid N (listwise)	20				

Table 6.17 reveals the difference between responses against statement 6. Participants on prototype 2 with visible elements (M=3.55, SD=.999) felt comfortable with less screen available and more occupied by commands. In contrast, participants on prototype 1 with hidden elements (M=2.75, SD=1.070) were comfortable with the maximum screen on prototype 1 with hidden elements.

Table 6.18: Paired Samples Test Results for Statement 6 of both prototypes

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Statement 6 for Prototype with hidden elements - Statement 6 for Prototype with visible elements	-.800	1.576	.352	-1.538	-.062	-2.270	19	0.035043

Table 6.18 displays that the P-value (Sig. = 0.035043) which is (p-value = < .035037) significant against our significance level of (.05). This significant difference rejects the null hypothesis and accepts the alternative hypothesis that participants found the user interface with visible elements to be significantly comfortable even with less screen available.

Table 6.19: Preference to use interface

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	With hidden navigational elements	4	20.0	20.0	20.0
	With visible navigational elements	16	80.0	80.0	100.0
	Total	20	100.0	100.0	

Table 6.19 shows the frequencies and percentages of participants' responses. Results revealed that the 4 participants and 20% of the respondents selected prototype 1 with the hidden navigational elements. Moreover, 16 participants and 80% of the respondents selected prototype 2 with the visible navigational elements. Hence, the hypothesis was accepted because the majority of the participants preferred to use prototype 2 with visible navigational elements.

7. Discussion

The primary objective of this study was to investigate and find the usability and universal design practice in hidden navigational elements. For this purpose, it was essential to get users' real interaction with an interface with hidden navigational elements. By implementing our proposed prototypes for hidden navigational elements and visible elements, we come across the issues and barriers faced by the users. The results and analysis presented in the previous chapter helped discuss and answer our research questions for this study.

RQ1: Are hidden navigational elements making users frustrated while taking much time to discover hidden elements?

It is apparent from the results that users spent more time on prototype 1 with hidden navigational elements and spent less time on prototype 2 with visible elements. Users spent more time discovering the hidden elements, which frustrated them, and they tried to find them with different mobile screen gestures without any clue. The considerable difference in time to complete tasks (Table 6.1) shows how challenging it was to interact with prototype 1 with hidden elements. It was observed during the study; users were not happy with the hidden elements.

The precise comparison of time on tasks between prototype 1 and prototype 2 was highly significant (Table 6.2), and it rejects the null hypothesis, and that significant difference supports our assumed hypothesis that H2: All participants would take more time to complete tasks on prototype 1. Discovering hidden elements was a real challenge for the participants.

In response to the question asked in the questionnaire (Table 10.10), “It was clear how to find the desired command,” on prototype 1 with hidden elements, 70% of opinion opposed this statement only 20% opinion was in favour of this statement. On prototype 2 with visible elements, 85% of opinion was in favour of that statement. Similarly, in response to the statement (Table 10.11), “It was comfortable with hidden navigational elements”, 65% of the opinion opposed this statement and 35% opinion was in favour of this statement. However, the opinion of 80% was in favour of the statement that it was comfortable with visible elements.

During testing, it was observed that the participants had a negative impression of hidden elements while discovering desired commands. These challenges and the negative impression left a negative effect on user experience with hidden navigational elements.

RQ2: How do always visible elements affect user interaction with mobile applications?

To answer this research question, we have apparent data after testing with users; users could perform all tasks successfully on prototype 2 with visible elements, in contrast with prototype 1 where users failed to complete some tasks. On prototype 2 with visible elements, the tasks completion ratio was 100%. It is evident from (Table 6.3) that prototype 2 with visible elements was more effective in overall fostering more successful task completions than prototype 1 with hidden elements. Participants did not feel any challenge or hurdle to perform any task on prototype 2. There was a significant difference (Table 6.4) of task completion between the two prototypes, and this significant difference rejects the null hypothesis. It supports our assumed hypothesis H1: All participants would be able to perform their tasks more efficiently on prototype 2.

In response to the statement (Table 10.7), “The user interface was easy to interact with”, 85% of the opinion agreed with the statement, and only 15% opposed it on prototype 2. When it was asked (Table 10.8), “It was easy to remember commands,” 80% of opinion favoured this statement, and only 15% opposed it. In response to the statement “It was comfortable with visible navigational elements”, 80% opinion agreed with it, and 20% opinion disagreed with the statement. The data provided enough evidence to infer that the user interface with visible elements was easy to interact with and did not challenge users.

The results also reveal that participants did not face any error or failure of task on prototype 2 with visible elements. On the other hand, participants faced 15 errors of failure of tasks on prototype 1 with hidden elements. It is evident from the results in (Table 6.6), which reveals the significant difference between the two prototypes in terms of the failure of tasks. The data reject the null hypothesis and accepts our assumed hypothesis; H3: Prototype 1 is prone to error than Prototype 2. It can infer from the results that prototype 1 with hidden elements was not as accessible or user friendly as a prototype with visible elements was.

RQ3: To what degree do people choose the Interface with the maximum available screen?

Based on results, we found that participants preferred prototype 2 with visible elements even though it occupied more screen than prototype 1 where much screen was available. It can be inferred from the results that participants preferred usability and user-friendliness of an interface that was provided in prototype 2 over the maximum available screen.

In the questionnaire, we asked for prototype 2 with visible elements "It was comfortable with commands/options occupied screen by app interface" 50% opinion (Table 10.19) was in favour of this statement, and 25% opinion opposed this statement. The data shows that users were only concerned with the ease of interaction with the visible user interface. Even though the options occupied much screen, they still agreed to feel comfortable with it. Moreover, when as a final question (Table 6.19) in the questionnaire (Figure 7.1), it was asked which interface they would prefer to use, as shown in the figure below, 80% of the participants said they would prefer an interface with visible elements, and only 20% of participants chose to prefer interface with hidden elements. This considerable difference in opinion or preference of participants makes things clear about their experience with both interfaces. It supports our hypothesis; H4: Most participants would prefer to use Prototype 2 with visible elements. It showed that majority of participants had higher user satisfaction for visible navigation elements.

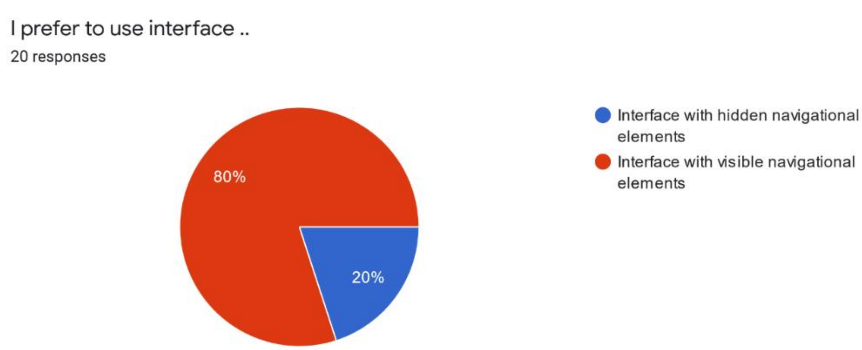


Figure 7.1: Pie chart showing the percentage of preference

Usability and Universal Design practices and WCAG guidelines

The primary purpose of this study is to consider usability and universal design practice in hidden navigational elements. According to Lazar (Lazar et al., 2017), there is a method of usability testing: guideline review. In this method, an expert compares interfaces with a previously written set of interface guidelines. He further explains that these guidelines are probably the best-known sets of guidelines by WCAG created by W3C. A study by (Awale & Murano, 2020) evaluated television app using the principles of Universal Design. In another similar kind of study (Shrestha & Murano, 2016) evaluated Usable Data Visualization for a mobile application in the context of Rheumatoid Arthritis, reviewing principles and guidelines of Universal Design. (Billi et al., 2010) also reviewed the WCAG guidelines to evaluate mobile applications for accessibility and usability.

Universal Design Principle 1: Equitable Use

"Guidelines: 1a. Provide the same means of use for all users: identical whenever possible; equivalent when not." (National Disability Authority, 2020)

Prototype 1 with hidden navigational elements does not comply with this guideline. It can be useable for a specific age group or having certain abilities but cannot be used for other age groups or people with diverse abilities.

"1d. Make the design appealing to all users." (National Disability Authority, 2020)

Prototype 1 with hidden navigational elements does not fulfil this condition to be appealing to all users. However, prototype 2 with visible elements fulfil this condition.

Principle 2: Flexibility in Use

"Guidelines: 2a. Provide choice in methods of use." (National Disability Authority, 2020)

Prototype with hidden elements does not conform to this guideline as it does not provide any choice in the method of use to avoid hidden elements. On the other hand, prototype 2 with visible elements provide all commands on screen to cater for every need of the user.

Principle 3: Simple and Intuitive Use

"Guidelines: 3a. Eliminate unnecessary complexity." (National Disability Authority, 2020)

Our prototype with hidden elements does not follow this guideline to eliminate unnecessary complexity, but it adds more complexity by hiding core menu items and navigational elements. On the contrary, prototype 2 with visible elements eliminates unnecessary complexity by making all the commands/elements visible on the screen to interact easily.

Principle 6: Low Physical Effort

"Guidelines: 6d. Minimize sustained physical effort." (National Disability Authority, 2020)

Prototype 1 with hidden elements maximizes sustained physical effort by repetitive gestures on the screen to find the desired command, making the prototype less efficient and comfortable for the users. On the other hand, a prototype with visible elements minimizes sustained physical effort by making all the elements visible for every user.

WCAG 2.0 and W3C Mobile accessibility guidelines apply to mobile

We mentioned guidelines that apply to mobile in chapter 3.

Prototype 1 with hidden navigational elements does not conform with guideline 3.3 touchscreen gestures. Prototype 1 does not provide any onscreen indicators that remind people how and when to use gestures. However, prototype 2 with visible elements provides elements on the screen to be interacted by using gestures.

WCAG 2.0 techniques that apply to Mobile

Interface with hidden navigational elements does not comply with guideline 2.4, which deals with navigable, which ensures provides ways to help users navigate, find content, and determine where they are located. However, prototype 2 with visible elements comply with this guideline by showing elements on the screen to help users to navigate, find content and determine where they are located easily.

Prototype 1 with hidden navigational elements does not comply with ISO-9241-11 standard of usability of a system. However, prototype 2 with visible elements is more efficient, effective, accessible, and usable for everyone.

8. Conclusion

Mobile applications' Interfaces with hidden navigational elements can be intuitive or make an interface design more composed with maximum screen available. However, these hidden navigational elements only make an interface with low usability and challenging for a user to interact with these interfaces. An excellent looking interface can be a problem for another user.

There is a tradeoff between the maximum screen with navigational elements hidden and the less screen available with visible navigational elements. The more available screen will result in more hidden navigational elements and make it complex or challenging for the users by putting the mental burden on them. On the other hand, more visible elements or options available on the screen confuse users to choose a command from plenty of commands available and occupy much screen. According to Hick's Law in the user experience paradigm, "the more elements people get, the harder it is to make a choice."

The purpose of our study was to explore and investigate the usability and universal design practices in hidden navigational elements in mobile applications. After experimental testing of our proposed prototypes, our empirical study in "Usability and Universal Design Investigation into Hidden User Interface Navigational Elements" found that participants felt frustrated while discovering hidden navigational elements on prototype 1 with the hidden user interface. Our exploratory user testing, questionnaire, and discussion made it evident that the majority felt comfortable using visible navigational elements, and they prefer to use a user interface with visible elements.

This investigative study with experiments and users' insights made this study a case to check the principles of Universal Design, usability, and user experience. It also checked where the hidden navigational elements contradict or violate WCAG 2.0 guidelines. From users' insights, it is evident that the user experience of user interface with hidden navigational elements is not according to usability or accessibility guidelines. This study found that hidden elements made users unhappy with the interface and complex to discover the contents/commands. During the study, it was observed that most users were clueless about hidden elements, and they felt annoyed with gestures to find commands and options.

Our findings highlight that the prototype with hidden elements is more error-prone than with visible elements. However, users did not find prototype 2 with visible elements challenging to perform tasks, and their comfort level was high with visible elements.

To conclude this study, the mobile user interfaces have been evolved from brick phones to highly precise touch screens. Still, even these developed interfaces can be a hurdle to interact with them for people with diverse situations and diverse abilities/disabilities. It can only be avoided by designing user interfaces more self-explanatory and unambiguous. This goal can be achieved by adopting accessibility and usability guidelines from WCAG and compliance with the principles of Universal Design.

8.1 Recommendations and future work

The study was limited with limited participants who were known people, to make a generalized conclusion, further and extensive study is needed. Many aspects left undiscussed in this limited study can be discussed with a large sampling size and go into the depth of this area of study. This study can contribute as a reference for UX/UI designers while designing mobile applications to keep in mind that users come first and follow the accessibility guidelines to ease user interaction with mobile applications. For developing new mobile applications with accessible interfaces, it is essential to follow all guidelines by WCAG and best practices introduced by Google material design. Based on our study, below are few recommendations to enhance the usability of mobile applications.

- Make it possible to provide visual clues for navigational elements if there is a need to hide them to get the maximum mobile screen. It is not a good user experience design to hide core navigation elements to make users find and memorize elements.
- Make the navigational markers obvious by keeping in mind the diversity of users. Moreover, keep the navigational elements and features consistent on every page on mobile applications.

- Make the user interface of mobile applications unambiguous and self-explanatory to make users interaction easy and smooth.

8.2 Limitations

The study has the following limitations:

1. Due to time constraints, the study was limited to Android users only, and this study did not cover iOS users.
2. Due to the current pandemic (COVID 19) situation, it was challenging to reach more people to test prototypes and get their responses.
3. Due to time constraints, it was challenging to include more diverse people (with different age groups, random sampling) for testing. This study was limited to known people living in urban areas and did not include more older people.

8.3 Personal Reflections

At the end of this study, in this part, I am going to describe my thoughts and reflections which occurred during working on this study. The journey from choosing this appealing subject to the end was not easy. However, the journey of working on this topic was very memorable and worthwhile for me. Being ill for a month and having undergone surgery at the beginning of this work disappointed and discouraged me from moving forward. I am thankful to my supervisor (Dr Pietro Murano) for his continuous support and motivation, which put me on track again.

Still, the work could be improved and broader by including more people in the experimental study. Due to lack of time, I had to approach people I knew, and it was hard to make appointments at their convenience in a short time. I would feel more comfortable about the study with more participation and random sampling from urban and remote areas to have more solid depth in this study. I wanted to include people from diverse age groups and with diverse abilities, but I could not make it quickly.

The best side of this study is that I could get a chance to go through relevant studies and broaden my knowledge and experience. I have gone through many articles, research, and relevant literature to understand this research. The suggestions, guidance, and assistance I got from my supervisor (Dr Pietro Murano) were valuable and helped me incite my hunger for more knowledge.

During testing on prototypes, even most known people found it hard to spare their time and then their expressions and frustrations about prototypes. It was observed that the majority was trying to get out of prototype 1 with hidden navigational elements. To work and deal with people and then learn statistics was the most challenging part of this study. Finding relevant research was also challenging in this study.

Overall, working on this thesis broadened my knowledge in this field, but the new skills, especially research skills and dealing with statistics, are valuable additions to my skill set. I am hopeful to use and excel in these skills in future work. I feel more confident and excited about my upcoming career.

9. References

Awale, B., & Murano, P. (2020). A Preliminary Usability and Universal Design Evaluation of a Television App User Interface.

Babich, N. (2019). The 4 Golden Rules of UI Design. Retrieved from https://xd.adobe.com/ideas/process/ui-design/4-golden-rules-ui-design/

Bickman, L., & Rog, D. J. (2008). *The SAGE handbook of applied social research methods*: Sage publications.

Billi, M., Burzagli, L., Catarci, T., Santucci, G., Bertini, E., Gabbanini, F., & Palchetti, E. (2010). A unified methodology for the evaluation of accessibility and usability of mobile applications. *Universal Access in the Information Society, 9*(4), 337-356. doi:10.1007/s10209-009-0180-1

Böhmer, M., & Bauer, G. (2010). *Exploiting the icon arrangement on mobile devices as information source for context-awareness*. Paper presented at the Proceedings of the 12th international conference on Human computer interaction with mobile devices and services, Lisbon, Portugal. https://doi-org.ezproxy.oslomet.no/10.1145/1851600.1851633

Budiu, R. (2017). Quantitative vs. Qualitative Usability Testing. Retrieved from https://www.nngroup.com/articles/quant-vs-qual/

cdn.powermockup.com. Mobile Touch Gestures. In.

Cerejo, L. (2012). The Elements Of The Mobile User Experience. Retrieved from https://www.smashingmagazine.com/2012/07/elements-mobile-user-experience/

Cohen, L., Manion, L., & Morrison, K. (2002). *Research methods in education*: routledge.

Costa, R. (2021, 2021). Navigation design: Almost everything you need to know. Retrieved from https://www.justinmind.com/blog/navigation-design-almost-everything-you-need-to-know/

Design, U. (2020). Universal Design Retrieved from http://universaldesign.ie/What-is-Universal-Design/

digitaltrends.com. Apple iphone. In.

Doubleday, A., Ryan, M., Springett, M., & Sutcliffe, A. (1997). *A comparison of usability techniques for evaluating design*. Paper presented at the Proceedings of the 2nd conference on Designing interactive systems: processes, practices, methods, and techniques, Amsterdam, The Netherlands. https://doi-org.ezproxy.oslomet.no/10.1145/263552.263583

En.wikipedia.org. (2021). Graphical user interface - Wikipedia. In: En.wikipedia.org.

Fuglerud, K. S. (2009). Universal design in ICT services. *Inclusive buildings, products & services: Challenges in Universal Design*, 244-267.

Government.no. (2013). *Regulation for universal design of information and communication technology (ICT) solutions* Retrieved from https://www.regjeringen.no/en/dokumenter/regulation-universal-design-ict/id731520/

gutcheckit.com. (2019, 03-04-2019). Hybrid Research: Combining Qualitative and Quantitative Methods and More. Retrieved from https://www.gutcheckit.com/blog/hybrid-research/

Harrison, R., Flood, D., & Duce, D. (2013). Usability of mobile applications: literature review and rationale for a new usability model. *Journal of Interaction Science, 1*(1), 1. doi:10.1186/2194-0827-1-1

Helmer, D. J. (2015). Prototype. In A. H. Blackwell & E. Manar (Eds.), *UXL Encyclopedia of Science* (3rd ed. ed.). Farmington Hills, MI: UXL.

Hoober, S., & Berkman, E. (2011). *Designing mobile interfaces: Patterns for interaction design*: " O'Reilly Media, Inc.".

https://petapixel.com. (2015). The Importance of Cameras in the Smartphone War. In T. I. o. C. i. t. S. War (Ed.), (pp. The Importance of Cameras in the Smartphone War).

huffpost.com. 1970s Mobile phone. In.

interaction-design.org. What is prototyping? Retrieved from https://www.interaction-design.org/literature/topics/prototyping

Isaac, C. (1995). User Interface Design & User Interface Evaluation. In: The British Computer Society.

ISO.org. (2018). Ergonomics of human-system interaction. Retrieved from https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-2:v1:en

Ivory, M. Y., & Hearts, M. (2001). *An empirical foundation for automated web interface evaluation* (Vol. 1): Citeseer.

Kara Pernice, R. B. (2016). Hamburger Menus and Hidden Navigation Hurt UX Metrics. Retrieved from https://www.nngroup.com/articles/hamburger-menus/

Lazar, J., Feng, J. H., & Hochheiser, H. (2017). *Research methods in human-computer interaction*: Morgan Kaufmann.

MACE, R. L. (2008). The Center for Universal Design. Retrieved from https://projects.ncsu.edu/ncsu/design/cud/about_us/usronmace.htm

MacKenzie, I. S. (2012). Human-computer interaction: An empirical research perspective.

Material.io. (2021). Accessibility. Retrieved from https://material.io/design/usability/accessibility.html#understanding-accessibility

McCloskey, M. (2014). Turn User Goals into Task Scenarios for Usability Testing. Retrieved from https://www.nngroup.com/articles/task-scenarios-usability-testing/

Morville, P. (2004). User Experience Design. Retrieved from http://semanticstudios.com/user_experience_design/

Müller, M., Günther, T., Kammer, D., Wojdziak, J., Lorenz, S., & Groh, R. (2016). *Smart Prototyping - Improving the Evaluation of Design Concepts Using Virtual Reality*, Cham.

National Disability Authority. (2020, 2020). The 7 Principles of Universal Design. Retrieved from http://universaldesign.ie/What-is-Universal-Design/The-7-Principles/#p1

Neil, T. (2014). *Mobile design pattern gallery: UI patterns for smartphone apps*: " O'Reilly Media, Inc.".

Official Journal of the European Union. (2016). *DIRECTIVE (EU) 2016/2102 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL*. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32016L2102&from=en#d1e40-1-1

Oliver, P. (2010). *The student's guide to research ethics*: McGraw-Hill Education (UK).

Olsen Jr, D. R. (2007). *Evaluating user interface systems research.* Paper presented at the Proceedings of the 20th annual ACM symposium on User interface software and technology.

Pohl, C. (2011). The comparison of the explicit and the implicit way of Human-Computer-Interaction on a Smartphone.

public-media.interaction-design.org. Conditions of Usability. In: https://public-media.interaction-design.org.

Punchoojit, L., & Hongwarittorrn, N. (2017a). Usability Studies on Mobile User Interface Design Patterns: A Systematic Literature Review. *Advances in Human-Computer Interaction, 2017*, 6787504. doi:10.1155/2017/6787504

Punchoojit, L., & Hongwarittorrn, N. (2017b). Usability studies on mobile user interface design patterns: a systematic literature review. *Advances in Human-Computer Interaction, 2017*.

Rosenthal, R., & Rosnow, R. L. (2008). *Essentials of behavioral research: Methods and data analysis*.

Setlur, V. (2010). *SemantiLynx: context based icons for mobile web navigation and directed search tasks.* Paper presented at the Proceedings of the 12th international conference on Human computer interaction with mobile devices and services.

Setlur, V., Rossoff, S., & Gooch, B. (2011). *Wish I hadn't clicked that: context based icons for mobile web navigation and directed search tasks.* Paper presented at the Proceedings of the 16th international conference on Intelligent user interfaces.

Shrestha, S., & Murano, P. (2016). A Universally Designed and Usable Data Visualization for A Mobile Application in the Context of Rheumatoid Arthritis. *International Journal of Advanced Computer Science and Applications, 7*.

Sukamolson, S. (2007). Fundamentals of quantitative research. *Language Institute Chulalongkorn University, 1*(3), 1-20.

Team, D. (2021, 2021). Applying Heuristic Evaluation in Usability Testing Retrieved from https://www.designorate.com/applying-heuristic-evaluation-in-usability-testing

Trewin, S. (2008). Physical impairment. In *Web Accessibility* (pp. 37-46): Springer.

uiuxtrend.com. (2016-2020). What is usability. Retrieved from https://uiuxtrend.com/what-is-usability/

United Nations. (2016). Article 4 – General obligations Enable. Retrieved from https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities/article-4-general-obligations.html

Usability.gov. (2021a). User Experience Basics | Usability.gov. Retrieved from https://www.usability.gov/what-and-why/user-experience.html

usability.gov. (2021b). User Interface Design Basics. Retrieved from https://www.usability.gov/what-and-why/user-interface-design.html

uswitch.com. (2021, 19-05-2021). History of mobile phones and the first mobile phone Retrieved from https://www.uswitch.com/mobiles/guides/history-of-mobile-phones/

uxplanet.org. (2017, 06). How Human memory works tips for UX designers. Retrieved from https://uxplanet.org/how-human-memory-works-tips-for-ux-designers-12b14071bdf9

van Raan, A. F. J. (2013). *Handbook of quantitative studies of science and technology*: Elsevier.

Vanderheiden, G. (2000). *Fundamental principles and priority setting for universal usability.* Paper presented at the Proceedings on the 2000 conference on Universal Usability.

W3C. (2015a). Mobile Accessibility. Retrieved from https://www.w3.org/TR/mobile-accessibility-mapping/

W3C. (2015b). Mobile Accessibility: How WCAG 2.0 and Other W3C/WAI Guidelines Apply to Mobile. Retrieved from https://www.w3.org/TR/mobile-accessibility-mapping/#small-screen-size

W3C.org. (2015). WCAG 2.0 Techniques that Apply to Mobile. Retrieved from https://www.w3.org/WAI/GL/mobile-a11y-tf/MobileTechniques/#navigation-mechanisms

Webaim.org. (2021). WebAIM: Cognitive - Introduction. Retrieved from https://webaim.org/articles/cognitive/#memory

Weibelzahl, S., & Weber, G. (2002). Advantages, opportunities and limits of empirical evaluations: Evaluating adaptive systems. *KI, 16*(3), 17-20.

Wikipedia. iPhone 1st Generation Retrieved from https://en.wikipedia.org/wiki/IPhone_(1st_generation)

www.edn.com. 1st mobile phone call is made. Retrieved from https://www.edn.com/1st-mobile-phone-call-is-made-april-3-1973

Zaib, J. What is Usability. Retrieved from https://www.scribd.com/document/469452416/What-is-Usability-docx

Zheng, J., Bi, X., Li, K., Li, Y., & Zhai, S. (2018). M3 Gesture Menu: Design and Experimental Analyses of Marking Menus for Touchscreen Mobile Interaction. In *Proceedings of the 2018 CHI*

Conference on Human Factors in Computing Systems (pp. Paper 249): Association for Computing Machinery.

10. Appendixes

10.1 Appendix -A

Information Sheet

My name is Mubashar Munir, and I am a Master’s student in Universal Design of ICT at Oslo Metropolitan University (OsloMet).

As a part of my master’s studies, I am doing my master project in “A Usability and Universal Design Investigation into Hidden User Interface Navigational Elements”. for this experimental study, I have made two prototypes of mobile camera applications (One prototype with hidden navigational elements and second prototype with visible navigational elements) to check which one is more usable and effective to interact.

The purpose of my study is to find out whether mobile applications with hidden navigational elements have usability issues or these applications are accessible by everyone. To check my prototypes, I have made some tasks to perform on these prototypes. During the testing, I will ask my participants to perform these tasks on both prototypes by using a mobile device. I would appreciate your participation in my study and would be happy to provide more information if needed. The tasks are very simple, and no prior knowledge is needed and it will not check your abilities.

Tasks

- Tasks are listed below:
- Capture a picture
- Adjust "Zoom Level"
- Turn off "Flash"
- Open "Settings"
- Adjust "Auto White Balance" AWB

Procedure

Before the start of testing, I will provide guidelines about the tasks and process. The participant will use mobile device and perform tasks one by one on both prototypes. I will monitor and record the results if the participant can perform all tasks or some tasks in the results sheet and note the time taken on both prototypes.

Mubashar Munir

Master Student

10.2 Appendix -B

Consent Form

You are invited to participate in a usability study of prototypes for the master thesis project. This is a research project being conducted by **Mubashar Munir**, a student at **Oslo Metropolitan University**. It should take approximately 20 minutes to complete.

At the end of the usability study, you will be asked if you are interested in participating in an online questionnaire. No names or identifying information would be included in any publications or presentations based on these data, and your responses to this survey will remain confidential.

PARTICIPATION

Your participation in this study/research is voluntary. You may refuse to take part in the research or exit the study at any time without penalty. You are free to decline to answer any particular question you do not wish to answer for any reason.

CONFIDENTIALITY

Your participation will be used only for research purpose. We do not collect identifying information such as your name, email address, or IP address during the study. Therefore, your responses will remain anonymous. No one will be able to identify you or your answers, and no one will know whether you participated in the study.

Please sign below to indicate that you have read, and you understand the information on this form and that any questions you might have about the session have been answered.

I agree to participate in the study.

I read all the information about this study. I understand that participation in this usability study is voluntary, and I agree to immediately raise any concerns or areas of discomfort during the session with the study administrator.

Date:_________

Please write your name or sign: ____

Thank you!

We appreciate your participation.

Consent form was downloaded from: https://www.agnesscott.edu/irb/files/documents/Sample-Consent-Form-for-Online-Surveys.doc

10.3 Appendix -C

Questionnaire Forms

Thank you for participating in the testing of prototypes. You are invited to participate in a web-based online survey.

We want to hear your feedback so we can keep improving our work on prototypes with a better user experience. Please fill this quick survey questionnaire and let us know your thoughts/experience with the prototypes. (Your answers will be anonymous).

PARTICIPATION
Your participation in this survey is voluntary. You may refuse to take part in the research or exit the survey at any time without penalty. You are free to decline to answer any particular question you do not wish to answer for any reason.

CONFIDENTIALITY
Your survey answers will be used only for research purpose. We do not collect identifying information such as your name, email address, or IP address. Therefore, your responses will remain anonymous. No one will be able to identify you or your answers, and no one will know whether you participated in the study.

* Required

1- What is your age group? *

Age 21-30 years

Age 31-40 years

Age 41-50 years

Age 51-60 years

2- How satisfied were you with the Prototype (With hidden elements)? *

1 = Strongly disagree 2= Disagree 3= Natural 4=Agree 5 = Strongly agree

Statements	**1 = Strongly disagree**	**2= Disagree**	**3= Neutral**	**4=Agree**	**5 = Strongly agree**
The user interface was easy to interact with.					
It was easy to remember the commands.					
The tasks were easy to complete on this interface.					
It was clear how to find desired option/Command.					
It was comfortable with hidden navigational elements.					
It was comfortable with maximum screen used by app interface.					

This question requires one response per row

3- How satisfied were you with the Prototype (With visible elements)? *

1 = Strongly disagree 2= Disagree 3= Natural 4=Agree 5 = Strongly agree

Statements	**1 = Strongly disagree**	**2= Disagree**	**3= Neutral**	**4=Agree**	**5 = Strongly agree**
The user interface was easy to interact with.					
It was easy to remember the commands.					
The tasks were easy to complete on this interface.					
It was clear how to find desired option/Command.					
It was comfortable with visible navigational elements.					
It was comfortable with commands/options occupied more screen used by app interface.					

4- **I prefer to use interface ..**

(Please select one option from below)

Mark only one oval.

1. Interface with hidden navigational elements
2. Interface with visible navigational elements

Online link for questionnaire form

10.4 Appendix -D

Testing Result Sheet

Participant No: ______________________________

Prototype 1 with Hidden Navigation Elements				
S.No	**Tasks**	**Completed**	**Failed**	**Time taken**
1	Capture a picture			
2	Adjust "Zoom Level"			
3	Turn off "Flash"			
4	Open "Settings"			
5	Adjust "Auto White Balance" **AWB**			
	Total=			

Prototype 2 with Visible Navigation Elements				
S.No	**Tasks**	**Completed**	**Failed**	**Time taken**
1	Capture a picture			
2	Adjust "Zoom Level"			
3	Turn off "Flash"			
4	Open "Settings"			
5	Adjust "Auto White Balance" **AWB**			
	Total=			

10.5 Appendix -E

Testing Results

Table 10.1: Tasks completion comparison of prototypes

Tasks Completion Comparison		
Participants	**Prototype 1 with hidden elements**	**Prototype 2 with visible elements**
1	4	5
2	4	5
3	3	5
4	4	5
5	4	5
6	4	5
7	4	5
8	5	5
9	5	5
10	4	5
11	5	5
12	4	5
13	5	5
14	4	5
15	4	5
16	4	5
17	4	5
18	5	5
19	5	5
20	4	5
Total	**85**	**100**

Table 10.2: Task errors comparison of both prototypes

Tasks Errors (Failure) Comparison		
Participants	**Prototype 1 with hidden elements**	**Prototype 2 with visible elements**
1	1	0
2	1	0
3	2	0
4	1	0
5	1	0
6	1	0
7	1	0
8	0	0
9	0	0
10	1	0
11	0	0
12	1	0
13	0	0
14	1	0
15	1	0
16	1	0
17	1	0
18	0	0
19	0	0
20	1	0
Total	**15**	**0**

Table 10.3: Time taken on tasks comparison of both prototypes

Time Taken (in minutes and seconds) on Tasks-Comparison		
Participants	**Prototype 1 with hidden elements**	**Prototype 2 with visible elements**
1	01:25	00:44
2	01:31	00:35
3	01:21	00:47
4	01:27	00:22
5	01:33	00:37
6	01:28	00:34
7	01:16	00:27
8	01:24	00:33
9	01:34	00:26
10	01:12	00:24
11	01:29	00:31
12	01:16	00:24
13	01:05	00:22
14	01:28	00:34
15	01:13	00:27
16	00:55	00:23
17	01:09	00:31
18	01:15	00:36
19	00:54	00:28
20	01:19	00:34
Total	**26:14**	**10:19**

10.6 Appendix -F

Questionnaire Responses (For Prototype 1 with hidden elements)

Table 10.4: Questionnaire for Prototype 1 with Hidden Navigational Elements

Questionnaire for Prototype 1 with Hidden Navigational Elements						
1 = Strongly disagree 2= Disagree 3= Natural 4=Agree 5 = Strongly agree						
Participant	The user interface was easy to interact with.	It was easy to remember the commands.	The tasks were easy to complete on this interface.	It was clear how to find desired option/Command.	It was comfortable with hidden navigational elements.	It was comfortable with maximum screen used by app interface.
1	1	1	2	1	1	1
2	3	4	5	4	4	2
3	4	4	4	3	4	2
4	3	2	4	2	2	2
5	2	2	2	1	2	2
6	2	2	2	2	2	2
7	5	5	5	5	4	2
8	1	2	3	1	1	2
9	1	1	2	1	2	2
10	1	1	2	2	3	2
11	2	1	4	2	2	2
12	2	2	4	2	2	3
13	2	2	3	2	2	3
14	1	2	2	1	2	3
15	4	2	3	2	4	4
16	3	2	2	2	3	4
17	4	4	5	3	4	4
18	5	5	4	5	5	4
19	2	1	2	1	2	4
20	4	4	5	4	4	5

10.7 Appendix -G

Questionnaire Responses (For Prototype 2 with visible elements)

Table 10.5: Questionnaire for Prototype 2 with Visible Navigational Elements

Questionnaire for Prototype 2 with Visible Navigational Elements						
1 = Strongly disagree 2= Disagree 3= Natural 4=Agree 5 = Strongly agree						
Participant	The user interface was easy to interact with.	It was easy to remember the commands.	The tasks were easy to complete on this interface.	It was clear how to find desired option/Com mand.	It was comfortable with visible navigational elements.	It was comfortable with commands/o ptions occupied more screen used by app interface.
1	5	1	5	1	5	4
2	5	4	5	4	4	3
3	5	5	5	5	4	4
4	5	4	5	5	4	4
5	4	5	5	4	4	3
6	5	4	5	5	2	2
7	5	4	5	5	4	4
8	5	4	5	5	4	4
9	5	4	5	4	4	4
10	5	4	5	5	4	4
11	3	3	3	3	3	2
12	5	5	5	5	5	5
13	1	2	1	1	2	2
14	1	1	2	1	1	2
15	5	4	4	5	5	5
16	5	5	5	5	5	5
17	5	5	5	4	5	3
18	5	4	5	5	4	3
19	5	4	5	5	4	4
20	4	5	5	5	4	4

10.8 Appendix -H

Frequencies of Questionnaire (For Prototype 1 with hidden elements)

Table 10.6: Descriptive Statistics for Questionnaire 1

	N	Minimum	Maximum	Mean	Std. Deviation
The user interface was easy to interact with.	20	1.00	5.00	2.6000	1.35336
It was easy to remember the commands even.	20	1.00	5.00	2.4500	1.35627
The tasks were easy to complete on this interface.	20	2.00	5.00	3.2500	1.20852
It was clear how to find desired option/Command.	20	1.00	5.00	2.3000	1.30182
It was comfortable with hidden navigational elements.	20	1.00	5.00	2.7500	1.16416
It was comfortable with maximum screen used by app interface.	20	1.00	5.00	2.7500	1.06992
Valid N (listwise)	20				

Frequencies

Table 10.7: Frequency for Statement 1

The user interface was easy to interact with.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	25.0	25.0	25.0
	Disagree	6	30.0	30.0	55.0
	Neutral	3	15.0	15.0	70.0
	Agree	4	20.0	20.0	90.0
	Strongly Agree	2	10.0	10.0	100.0
	Total	20	100.0	100.0	

Table 10.8: Frequency for Statement 2

It was easy to remember the commands.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	25.0	25.0	25.0
	Disagree	9	45.0	45.0	70.0
	Agree	4	20.0	20.0	90.0
	Strongly Agree	2	10.0	10.0	100.0
	Total	20	100.0	100.0	

Table 10.9: Frequency for Statement 3

The tasks were easy to complete on this interface.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	8	40.0	40.0	40.0
	Neutral	3	15.0	15.0	55.0
	Agree	5	25.0	25.0	80.0
	Strongly Agree	4	20.0	20.0	100.0
	Total	20	100.0	100.0	

Table 10.10: Frequency for Statement 4

It was clear how to find desired option/Command.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	6	30.0	30.0	30.0
	Disagree	8	40.0	40.0	70.0
	Neutral	2	10.0	10.0	80.0
	Agree	2	10.0	10.0	90.0
	Strongly Agree	2	10.0	10.0	100.0
	Total	20	100.0	100.0	

Table 10.11: Frequency for Statement 5

It was comfortable with hidden navigational elements.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	2	10.0	10.0	10.0
	Disagree	9	45.0	45.0	55.0
	Neutral	2	10.0	10.0	65.0
	Agree	6	30.0	30.0	95.0
	Strongly Agree	1	5.0	5.0	100.0
	Total	20	100.0	100.0	

Table 10.12: Frequency for Statement 6

It was comfortable with maximum screen used by app interface.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	1	5.0	5.0	5.0
	Disagree	10	50.0	50.0	55.0
	Neutral	3	15.0	15.0	70.0
	Agree	5	25.0	25.0	95.0
	Strongly Agree	1	5.0	5.0	100.0
	Total	20	100.0	100.0	

10.9 Appendix -I

Frequencies of Questionnaire (For Prototype 2 with visible elements)

Table 10.13: Descriptive Statistics for questionnaire 2

	N	Minimum	Maximum	Mean	Std. Deviation
The user interface was easy to interact with.	20	1.00	5.00	4.4000	1.27321
It was easy to remember the commands.	20	1.00	5.00	3.8500	1.22582
The tasks were easy to complete on this interface.	20	1.00	5.00	4.5000	1.14708
It was clear how to find desired option/Command.	20	1.00	5.00	4.1000	1.44732
It was comfortable with visible navigational elements.	20	1.00	5.00	3.8500	1.08942
It was comfortable with commands/options occupied screen used by app interface.	20	1.00	5.00	3.5500	0.998683
Valid N (listwise)	20				

Frequencies

Table 10.14: Frequency for Statement 1

The user interface was easy to interact with.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	2	10.0	10.0	10.0
	Neutral	1	5.0	5.0	15.0
	Agree	2	10.0	10.0	25.0
	Strongly Agree	15	75.0	75.0	100.0
	Total	20	100.0	100.0	

Table 10.15: Frequency for Statement 2

It was easy to remember the commands.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	2	10.0	10.0	10.0
	Disagree	1	5.0	5.0	15.0
	Neutral	1	5.0	5.0	20.0
	Agree	10	50.0	50.0	70.0
	Strongly Agree	6	30.0	30.0	100.0
	Total	20	100.0	100.0	

Table 10.16: Frequency for Statement 3

The tasks were easy to complete on this interface.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	1	5.0	5.0	5.0
	Disagree	1	5.0	5.0	10.0
	Neutral	1	5.0	5.0	15.0
	Agree	1	5.0	5.0	20.0
	Strongly Agree	16	80.0	80.0	100.0
	Total	20	100.0	100.0	

Table 10.17: Frequency for Statement 4

It was clear how to find desired option/Command.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	3	15.0	15.0	15.0
	Neutral	1	5.0	5.0	20.0
	Agree	4	20.0	20.0	40.0
	Strongly Agree	12	60.0	60.0	100.0
	Total	20	100.0	100.0	

Table 10.18: Frequency for Statement 5

It was comfortable with visible navigational elements.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	1	5.0	5.0	5.0
	Disagree	2	10.0	10.0	15.0
	Neutral	1	5.0	5.0	20.0
	Agree	11	55.0	55.0	75.0
	Strongly Agree	5	25.0	25.0	100.0
	Total	20	100.0	100.0	

Table 10.19: Frequency for Statement 6

It was comfortable with commands/options occupied screen used by app interface.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	0	0.0	0.0	0.0
	Disagree	4	20.0	20.0	20.0
	Neutral	4	20.0	20.0	40.0
	Agree	9	45.0	45.0	85.0
	Strongly Agree	3	15.0	15.0	100.0
	Total	20	100.0	100.0	

10.10 Appendix J

Screen Images for Prototype 1 with Hidden navigational elements

Actual working prototypes have been uploaded as supplementary files in Inspera.

The working prototype can be found online on below mentioned URL.

https://bucu8i.axshare.com .

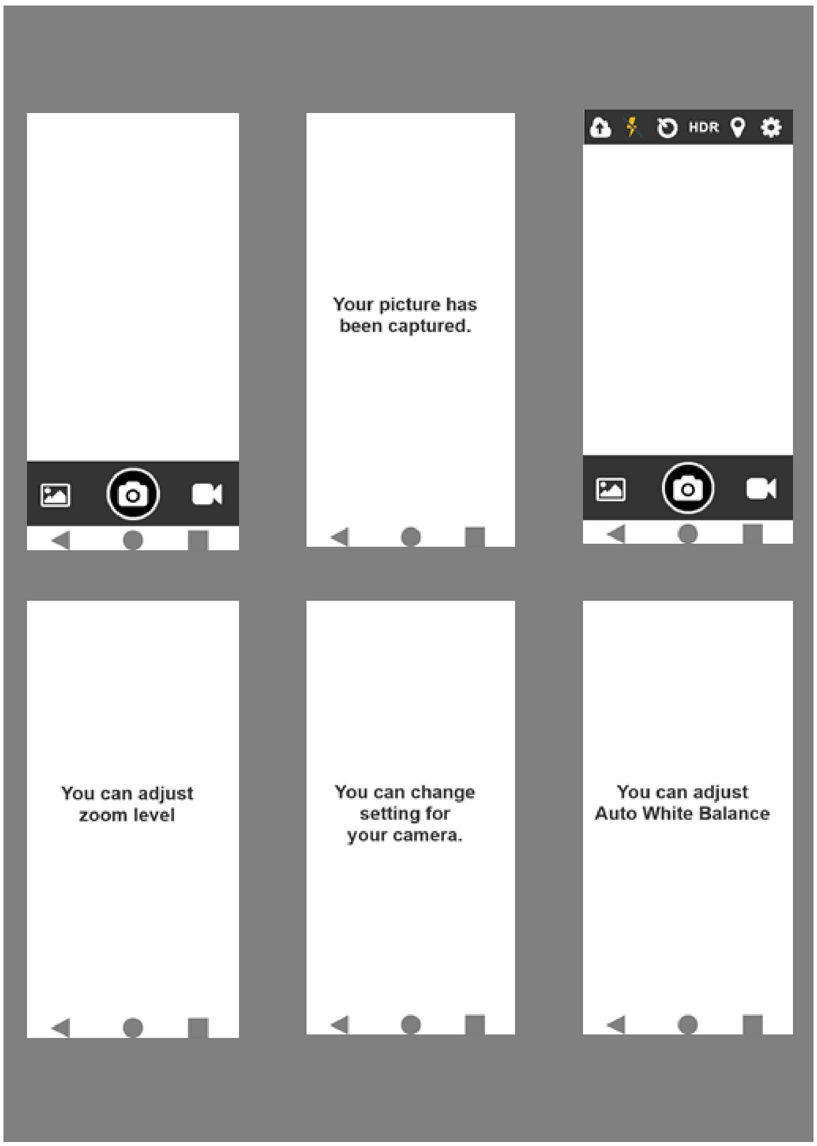


Figure 10.1: Screen images for Prototype 1 with hidden elements

Screen Images for Prototype 2 with visible navigational elements

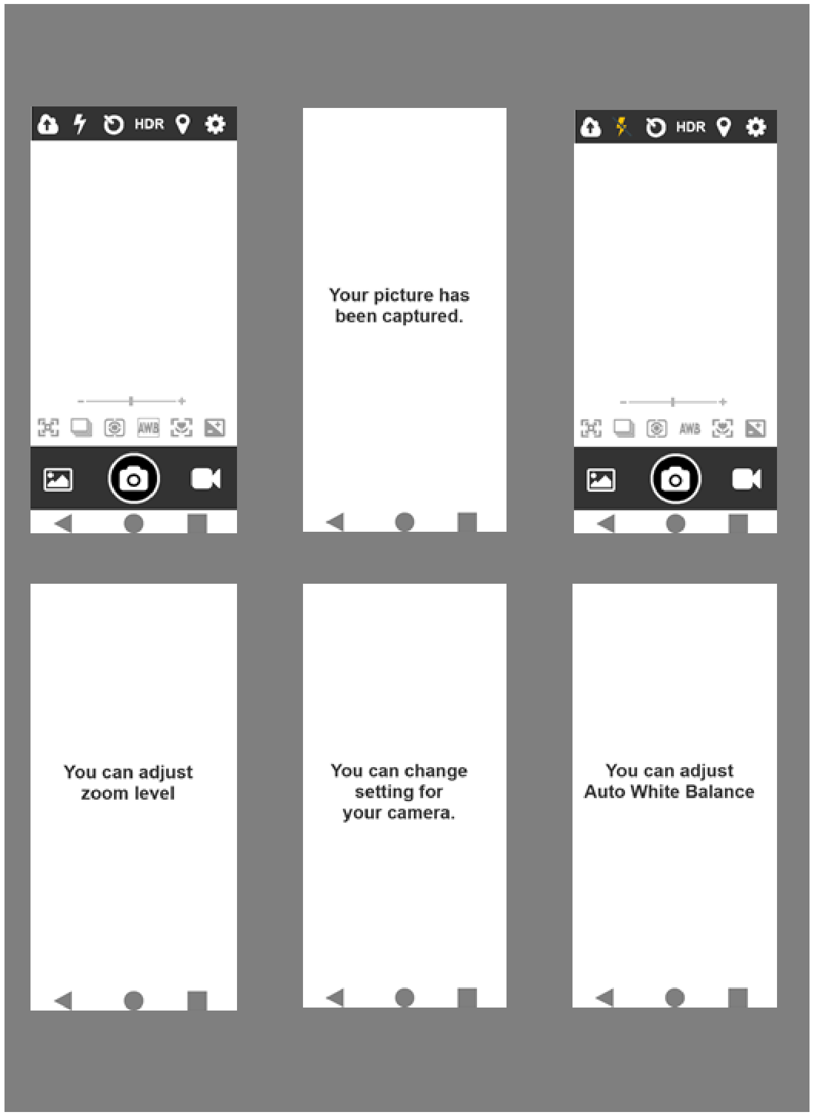


Figure 10.2: Screen images for Prototype 2 with visible elements