User Experience Guidelines for Mobile Natural User Interfaces: A case study physically disabled users

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User Experience Guidelines for Mobile Natural User Interfaces: A case study of physically disabled users

By

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DECLARATION:

In accordance with Rule G5.6.3, I hereby declare that the above-mentioned dissertations my own work and that it has not previously been submitted for assessment to another University or for another qualification.

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ABSTRACT

Motor impaired people are faced with many challenges, one being the of lack integration into certain spheres of society. Access to information is seen as a major issue for the motor impaired since most forms of interaction or interactive devices are not suited to the needs of motor impaired people. People with motor impairments, like the rest of the population, are increasingly using mobile phones. As a result of the current devices and methods used for interaction with content on mobile phones, various factors prohibit a pleasant experience for users with motor impairments. To counter these factors, this study recognizes the need to implement better suited methods of interaction and navigation to improve accessibility, usability and user experience for motor impaired users.

The objective of the study was to gain an understanding of the nature of motor impairments and the challenges that this group of people face when using mobile phones. Once this was determined, a solution to address this problem was found in the form of natural user interfaces. In order to gain a better understanding of this technology, various forms of NUIs and the benefits thereof were studied by the researcher in order to determine how this technology can be implemented to meet the needs of motor impaired people.

To test theory, the Samsung Galaxy s5 was selected as the NUI device for the study. It must be noted that this study started in the year 2013 and the Galaxy S5 was the latest device claiming to improve interaction for disabled people at the time. This device was used in a case study that made use of various data collection methods, including participant interviews. Various motor impaired participants were requested to perform predefined tasks on the device, along with the completion of a set of user experience questionnaires. Based on the results of the study, it was found that interaction with mobile phones is an issue for people with motor impairments and that alternative methods of interaction need to be implemented. These results contributed to the final output of this study, namely a set of user experience guidelines for the design of mobile human computer interaction for motor impaired users.

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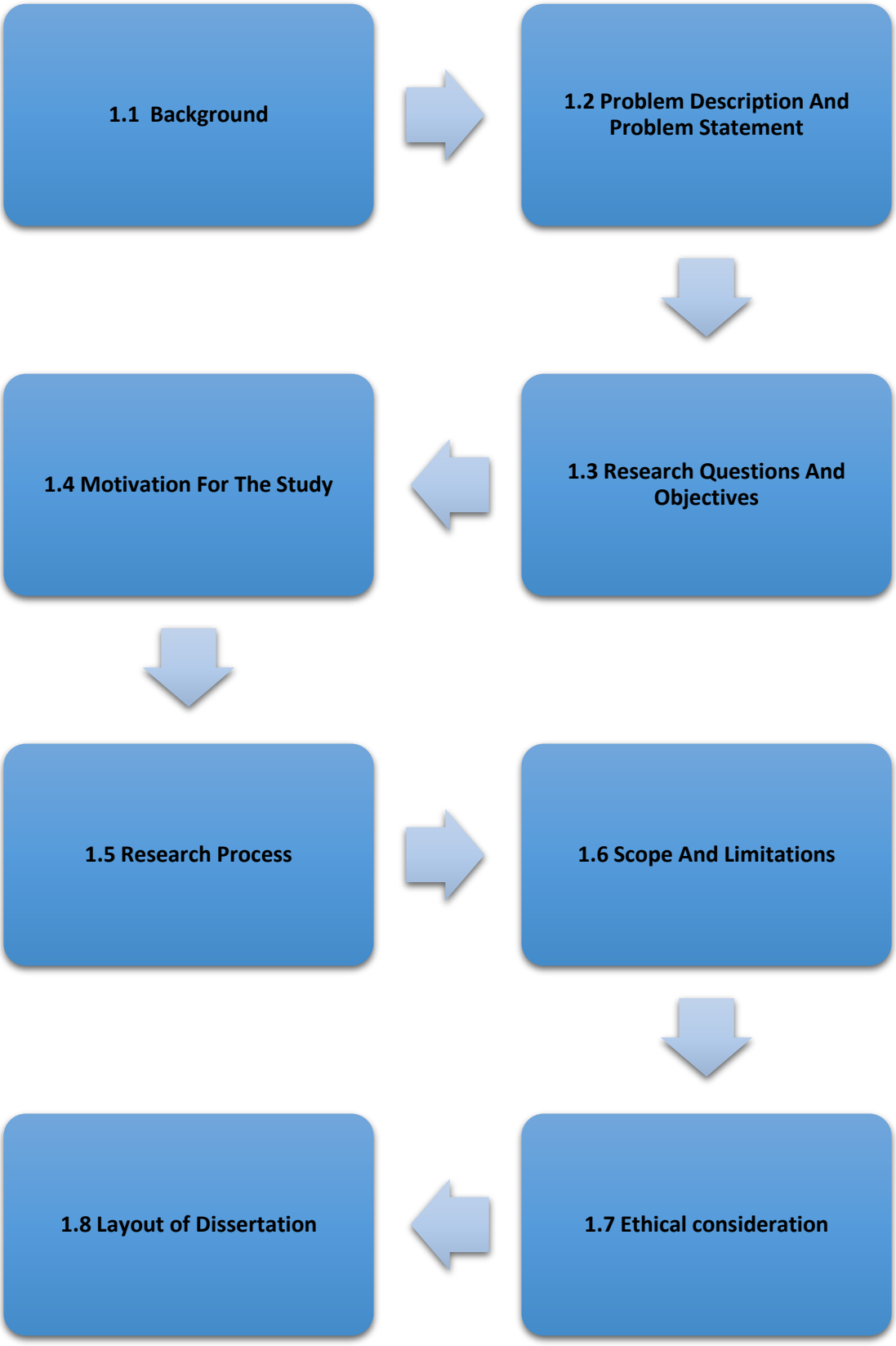
LIST OF ABBREVIATIONS

Abbreviations	Term in Full
CLI	Command Line Interface
CPU	Central Processing Unit
DPSA	Disabled People South Africa
GUI	Graphical User Interface
HCI	Human Computer Interaction
ICT	Information Communication Technology
IXD	Interaction Design
LCD	Liquid Crystal Display
NI	Natural Interaction
NMMU	Nelson Mandela Metropolitan University
NRF	National Research Fund
NUI	Natural User Interface
PWD	People With Disability
RSI	Repetitive Stress Injury
SA	South Africa
SIID	Situationally Induced Impairments and Disabilities
UI	User Interface
UX	User Experience

1. INTRODUCTION



1.1. Background

ICT is a broad field which involves the communication between various devices that enable user access to information by means of telecommunications (TechTerms, ICT, 2010). ICT is implemented within various contexts such as healthcare, education, and then specifically in the workplace. Mobile phones, as an example of a device within ICT, are used by millions of people around the world. More than half of South Africa's (SA) Internet traffic comes from mobile phones (Writer, 2015). Mobile phones provide access to content on the go. Unfortunately, accessibility is not always achieved, especially when the needs of disabled people are considered. This group of people live a challenging life. Disabled people not only lose out in terms of not being able to complete essential daily activities, but they are also excluded from schools and opportunities for work. In Africa school enrolment for the disabled is estimated at no more than 5-10 % (DisabledTravelers, 2013). This results in disabled people lacking the necessary skills, access to training, social confidence, and development of skills, as they are not fully a part of the common community.

In SA the prevalence rate for disability is 7.6%. The Free State and the Northern Cape are home to the highest proportions of disabled people in SA, followed by the North-West and the Eastern Cape. In the Eastern Cape (geographic location of the researcher) 10 % of people are affected by a disability. The Eastern Cape has one of the highest proportions of people suffering from physical disabilities such as motor impairments (Africa, 2011).

One of the major issues for people with motor impairments is access to information, especially when using mobile phones as these users have a unique set of needs that are not always met. Like the rest of the population, people with physical disorders are increasingly using interactive technologies (Meyers & Wobbrock, 2005). Unfortunately mobile phones are not fully suited to the needs of motor impaired people in comparison to non-disabled people. When motor impaired users use mobile phones a list of barriers arise. These barriers contribute negatively to the UX and usability of mobile phones as they affect the user's ability to interact and navigate appropriately.

To address these issues the needs of motor impaired users need to be identified, once these have been identified suitable methods in terms of interaction and navigation need to be implemented. As a result of this access to information and various devices will be easier for motor impaired users since their needs are now catered for or at least considered. This study realises that that various factors exist, each one contributing to motor impaired user's usability and user experience. To counter these factors the goal of this study is to develop a set of guidelines that focuses on the needs of motor impaired users for mobile phone interaction.

1.2. Problem Description and Problem Statement

The methods used for interacting with mobile phones are currently focused on the interaction skills of people who are fully abled. People with motor impairments, like the rest of the population, are increasingly using these interactive devices regardless of the various barriers they face when using these devices.

To address these issues the needs of motor impaired users need to be identified. Once these are identified, suitable methods in terms of interaction and navigation need to be implemented. This study acknowledges that various factors exist, each one contributing to motor impaired users' usability and user experiences. These challenges range from inputting text into a device, or handling the device. This can cause various issues in terms of usability and accuracy.

The problem statement for this research study can therefore be formulated as:

There are limited instructions available pertaining to various strategies which should be implemented in the design of mobile phones and applications to accommodate the needs of motor impaired users and improve the user experience.

1.3. Research Questions and Objectives

This section presents the research questions and objectives for this study. The questions include a main research question followed by sub-research questions with objectives. These are discussed in more detail in Chapter 5.

Main Research Question

- How can the user experience of motor impaired people be improved when interacting with mobile phones?

Sub-Research Questions

- How can the unique challenges motor impaired users face when using mobile phones be addressed?
- To what extent do the accessibility features of mobile phones assist users with motor impairments?
- What are the existing user experience guidelines for motor impaired users interacting with mobile phones?

Research Objectives

- To determine the various challenges motor impaired users face when interacting with mobile phones and to seek methods to address these challenges.

- To determine if accessibility features on mobile phones are useful to motor impaired users and to seek methods of improvement for these features.

- To determine what is currently seen as important aspects when designing mobile phones and mobile applications.

- To create new guidelines specific to motor impaired users using mobile phones.

1.4. Motivation for the Study

Persons with motor impairment also have a need to have access to information. As accessibility is not always taken into consideration, users with motor impairment are often excluded from using devices that will provide access to information in various forms. As their requirements are unique, there is a need for specific user experience guidelines that will also consider these requirements.

1.5. Research Process

Research methodology and design is determined by the reason for conducting the research (Cohen, Manion, & Morrison, 2000). One model of the research process is that of Saunders, Lewis & Thornhill (2009) where they present the research process as an onion with different layers – beginning with one's research philosophy or worldview, which reflects the researcher's beliefs about the nature of research and the world; research approaches, which indicate whether knowledge is created deductively or inductively; and research strategies, which define the type of study selected or the way in which research is conducted. Research choices indicates the way in which researchers may choose to combine qualitative and quantitative techniques and procedures; time horizons reflect the time frame of the research, while techniques and procedures, or research methods refer to the data collection, analysis and interpretation methods used (Saunders, Lewis, & Thornhill, 2009). The details of this research study are outlined in Chapter 5.

1.6. Scope and Limitations

The scope of this research was limited to the geographical area of Port Elizabeth. The research was furthermore limited to the use of one specific mobile handset for the completion of tasks. Convenience sampling was used to select users with motor impairment from a small selection base as a limited number of participants were available to participate in the study.

1.7. Ethical Consideration

The study was conducted at a private facility that houses disabled persons. Permission was obtained to interact with the participants. A staff member of the facility monitored the interaction with the participants to ensure that no participant suffered any discomfort. Each participant was made aware of informed consent to participate and adequate provision was made for resting periods if required.

1.8. Layout of Dissertation

The dissertation is divided into 8 chapters. Chapter 1 introduces the research topic and highlights the problem area. It also outlines the research objectives and associated objectives.

Chapters 2, 3 and 4 are the literature review chapters which provide the contextualisation and background information that form the foundation of the research. In chapter 2, an in-depth discussion is provided of people with motor disabilities. Chapter 3 focuses on mobile human computer interaction which leads into chapter 4, guidelines for mobile human computer interaction. Chapter 5 outlines the research process followed in the study and outlines the components of the case study. Chapter 6 presents the findings and the analysis thereof. Chapter 7 contains the recommended guidelines for the user experience of mobile human computer interaction with chapter 8 concluding the dissertation.

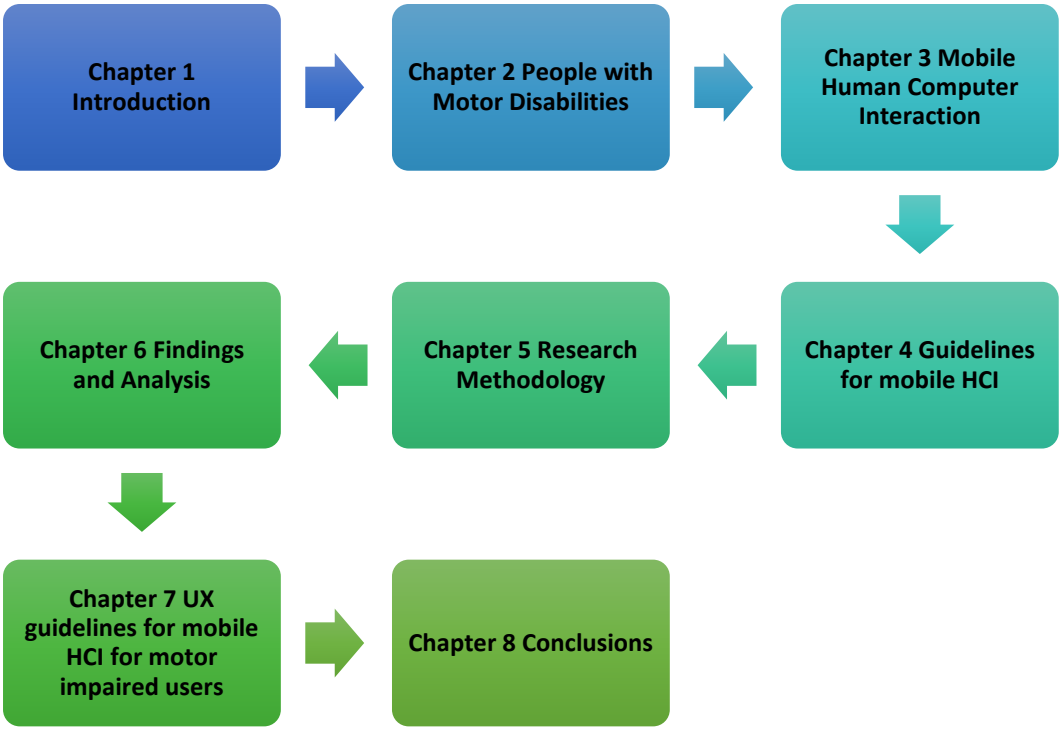
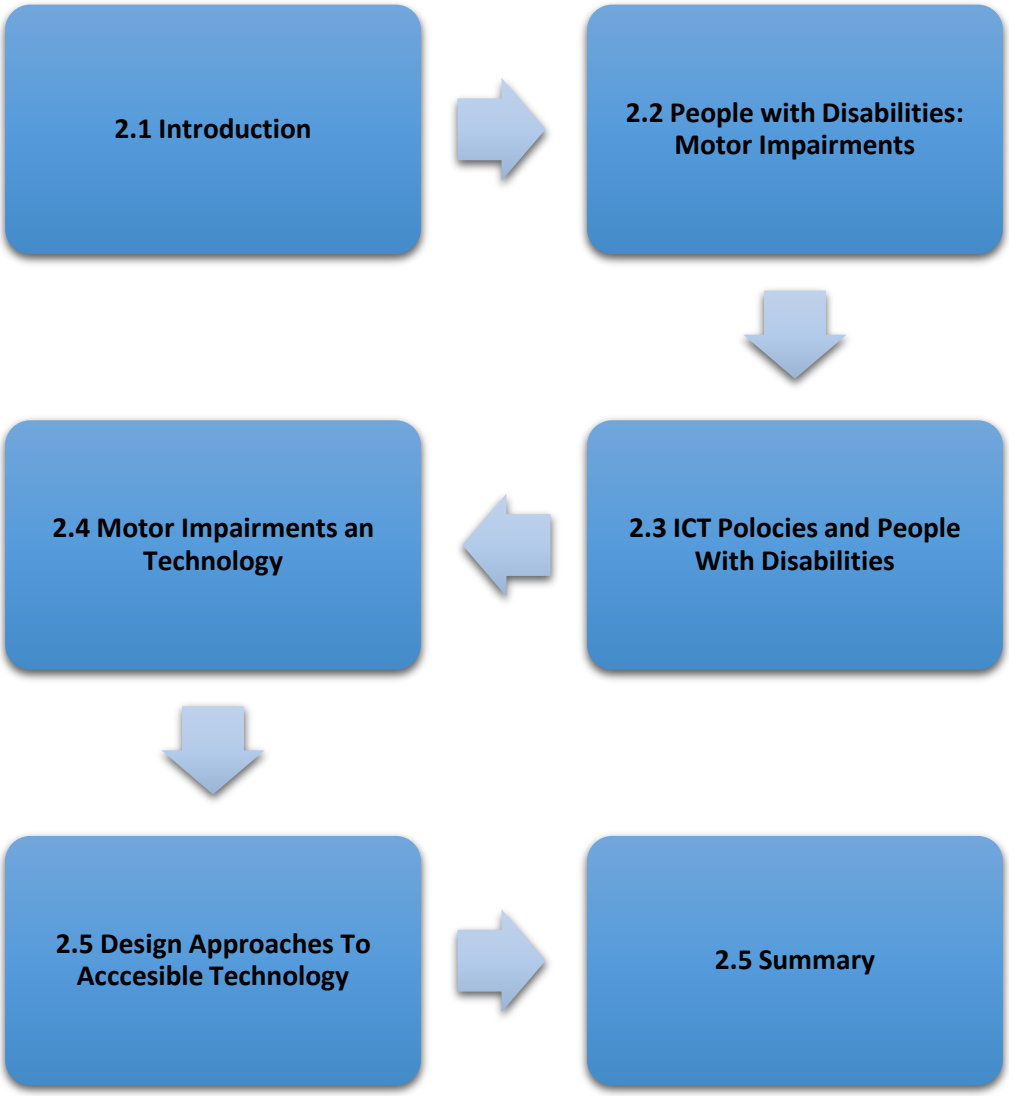


Figure 1.1 Layout of the Dissertation

2. PEOPLE WITH MOTOR IMPAIRMENTS



2.1. Introduction

This chapter seeks to address the following research question:

To what extent do the accessibility features of mobile phones assist users with motor impairments?

With the objective of determining if accessibility features on mobile phones are useful to motor impaired users and to seek methods of improvement for these features.

To address this question, this chapter defines the term disability and focuses on people with motor impairments in Section 2.2. The chapter also focuses on the various challenges that motor impaired people face on a daily basis when accessing information and mobile phones in Section 2.3. Thereafter the chapter discusses various methods that are currently implemented to assist people with motor impairments in section 2.4.

2.2. People with Disabilities

People impaired by a disability have various characteristics and impairments pertaining to them that differs to the characteristics of abled bodied people. The physical differences between abled bodied people and disabled people can be describe through the definition of disability:

"A disability is any condition of the body or mind (impairment) that makes it more difficult for the person with the condition to do certain activities (activity limitation) and interact with the world around them (participation restrictions)" (Prevention, 2015).

As a result of this distinction, people with disabilities are often marginalized within various aspects of society. According to the DPSA (2014) "Disability is the disadvantage or restriction of activity caused by a society that takes little or no account of people who have impairments and thus excludes them for mainstream activity".

Based on the listed definitions, one can derive that first and foremost a person suffering from a disability suffers from some sort of impairment such as restriction on bodily movements and control or the more common inability to see or hear. An imperative point that the DPSA (2014) states is that a disability is regarded as the restriction of activity by society. Based on this point it can be derived that a person is impaired by the context or situation the person is currently in.

A contributor to this marginalization is the fact that a vast list of disabilities exist, each one unique in its own way, which results in most cases that the needs of disabled people are not considered in the production of products and services. On a national scale, the disability prevalence rate is 7.5% (Africa, 2011). In the Eastern Cape 10 % of people are affected by a disability. The Eastern Cape has one of the highest proportions of people suffering from physical disabilities such as mobility impairments (Africa, 2011).

2.2.1. Definition and Types of Motor Impairments

When suffering from a motor disability the affected may suffer from weakness, limitations in muscular control, limitations of sensation, joint problems or missing limbs (Abou-Zahra & Brewer, 2012). Depending on the severity of person's condition various parts of the human body can be affected, including but not limited to:

- The ability to be mobile;
- Lack of coordination and in some cases cognitive skills;
- The ability to communicate;
- Self-care and performing common daily tasks;
- Postural functioning.

In terms of this chapter, motor disabilities is defined in terms of effect it has on the person suffering from the impairment. Based on the definition of motor disabilities and depending on the severity of the impairment, it can be derived that accessibility is a concern as it can be assumed that if one suffers from the inability of mobility and coordination, interacting with input devices or methods of input can be a challenging process. In most cases motor disabilities is a result of an external contributor such as a medical conditions or accidents resulting in physical injury. Table 2.1 contains a list of the most common causes of motor impairments.

Physical disability	*Description*	*Challenges faced*
Muscular dystrophies	Causes the muscle fibres in a person's body to weaken over time. This disability is more common in children and it becomes worse as they grow older (network, 2014).	Loss of use of limbs; Difficulty in speaking.
Amputation	Is the process by which a body part, such as an arm or a leg is removed from the body.	Mobility issues; Basic daily activities, such as brushing teeth or eating.
Cerebral palsy	Is a movement disorder. It results in a lack of the brain's ability to control muscle coordination and bodily movements (DisabledTravelers, DisabledTravelers.com, 2013).	Mobility issues; Basic daily activities, such as brushing teeth or eating; Vision and hearing problems; Seizures.
Acquired brain and spinal injuries	May result from permanent injuries to the brain or spine. These injuries can result in permanent loss of function of one or more limbs (network, 2014).	Mobility issues; Coordination issues; Communication issues.

Arthritis	This type of physical disability refers to a severe case of joint inflammation that affects the person on a long-term basis (Abou-Zahra & Brewer, 2012).	Mobility issues; Loss of strength in joints; Pain.
Repetitive stress injury (RSI)	This is an injury that affects the bones or joints, and it is caused owing to excessive use of the joint by doing repetitive tasks (Abou-Zahra & Brewer, 2012)	Mobility issues; Pain.

Table 2.1 List of various common motor impairments

To identify people with motor disabilities, one could consider the characteristics pertaining to the person impaired by the disability. Various characteristics exist ranging from physical characteristics to mental characteristics. For each person affected by a disability, a characteristic is displayed differently from person to person. The following characteristics can be attributed to a motor impaired person (Kennedy, 2006):

- **Physical characteristics**
  - Lack of coordination and, in some cases, cognitive skills;
  - Difficulty in movement and balance, depending on disability;
  - Deformed, lack of control, or one or two missing limbs.

- **Social characteristics:**
  - Difficulty in socializing with others owing low self-esteem and confidence;
  - Difficulty in accessing public and private infrastructure.

- **Emotional characteristics**:
  - Physical limitations can lead to all sorts of emotions, such as frustration, anger, and disappointment;
  - Unacceptance of the disability, which can lead to grief.

2.3. ICT Policies and People with Disabilities

The policies to follow are regarded as international policies that should be seen as a rule of thumb when considering people with disabilities and ICT. It was found that the policies speaks mainly to the inclusion of disabled people. With regards to South African policies, the CRPD states that accessibility for people with disabilities in ICT is not the focus of all policies, especially for developing countries (i.e. South Africa). The CRPD claims that here focus is placed upon developing an infrastructure for ICT and goals such as decreasing crime and poverty rates (education, 2011). This falls in place with the ACCRA Commitment (2005) where focus is placed upon building ICT infrastructure. In this regard it is evident that from a South African point of view the achievement of the various goals listed by the provided policies are scarce as thousands

of people in SA are withdrawn and excluded from ICT involvement and inclusion as corruption, cost of communication and lack of skills are a few of the many problems SA faces in the ICT sector (Bronkhorst, 2013). This has a negative impact on SA which results in the country falling behind in terms of development.

The Eastern Cape, South Africa (home of the researcher) is province affected by vast rural areas filled with thousands of people affected by poverty, sickness and crime. As mentioned by the ACCRA commitment (2005), in developing countries/areas such as the Eastern Cape ICT services is last concern as there are many other issues that need attention (education, 2011). With regards to ICT, this provides a list of barriers for all people living in these areas especially for disabled people as they already face barriers such as exclusion from the social community. The Eastern Cape has one of the highest proportions of people suffering from physical disabilities such as motor impairments (Africa, 2011). For this reason focus is placed upon people with motor impairments and mobile phones as an ICT device due to the popularity of these devices and the opportunities they provide such as user productivity on the go.

2.3.1. ICTs in Education for People with Disabilities

This is regarded as an international policy that focuses on the rights of people with disabilities in the field of ICT. From a South African context, section 32 of the Constitution of the Republic of South Africa Act, No. 108 of 1996 states that everyone has the right to access information held by the state and another person (Government, 1996). With regards to people with disabilities, for whom accessibility is imperative, the UN Convention on the Rights of Persons with Disabilities (CRPD) states in Article 9 that:

"To enable persons with disabilities to live independently and participate fully in all aspects of life, States Parties shall take appropriate measures to ensure to persons with disabilities access, on equal basis with others, to the physical environment, to transportation, to information and communications, including information and communications technologies and systems, and other facilities and services open or provided to the public, both in urban and rural areas" (UE, 2011).

2.3.2. Model Policy for Inclusive ICTs in Education for Persons with Disabilities

This policy forms part of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and global initiative for Inclusive Information and Communication. The objective of the policy is to promote effective use of inclusive ICTs for learners with disabilities (European Agency for Special Needs and Inclusive Education; Global Initiative for Inclusive Information and Communication Technologies, 2014).

The world Report on disability (2011) estimated that that there are between 93 and 150 million school aged children with disabilities globally (Organization, 2011). Many of these learners are excluded from educational opportunities.

2.4. Motor Impairments and Technology: Mobile Phones

To date, ICT is implemented within various contexts such as healthcare, education, and especially the workplace. Mobile phones, as an example of a device within ICT, are used by millions of people around the world owing to the various benefits that these devices provide to their users. More than half of South Africa's (SA) Internet traffic comes from mobile phones (Writer, 2015). Mobile phones provide access to content on the go. Unfortunately, accessibility is not always achieved, especially when considering the unique needs of people suffering from disabilities, in this case motor impairments. For instance (consider table 2.1), Parkinson's disease can cause limitations in movement and strength which may result in difficulties lifting and grasping objects, when using a mobile phone, holding the device and interacting with content by means of physical input such as typing can cause difficulties. For users suffering from multiple sclerosis interacting with touchscreen mobile phones can extremely challenging as the user may suffer from numbness in the fingers and tremor extremities that may cause unwanted movements when interacting with the device (Choices, 2016). In more severe cases, users suffering from spinal cord injury who have no control over any bodily movements may not be able to interact with a mobile phone at all. One should also take note that in severe cases people suffering poor motor function due to cerebral palsy may have poor vision as a result of the muscles controlling the eye being affected by the disease, this therefore results in the visual aspects of interface design needing additional attention, for example incorporating magnifiers to increase the size of content on screen.

Along with these barriers, a list of other barriers exist. To follow a various barriers will be listed and discussed within categories, namely access to information, aspects of mobile phones, mobile UX strengths and limitations and situationally induced impairments.

2.4.1 Barriers for People with Motor Impairments: Access to Information

This section lists examples of barriers in terms of access to information (Abou-Zahra & Brewer, 2012):

- Websites and web browsers do not provide full keyboard support;
- Insufficient time limits to complete tasks such as filling out online forms;
- Inconsistent and complex navigation methods and page functions;
- Systems used to access information may require complex operation of pointing devices;

- Most methods to access information such as browsers do not support additional methods of input other than a mouse and keyboard;

2.4.2 Barriers for People with Motor Impairments: Aspects of Mobile Phones

The content to follow lists examples of barriers in terms of access to information:

- Physically disabled users may find it hard to interact with mobile phones owing to the device size and the size of buttons used for input (tiresias.org, 2009);

- In some cases, interaction with mobile phones is impossible owing to the user's impairment (tiresias.org, 2009). For example; a user who suffers from Cerebral palsy has very little ability to move may not be able to input commands into the device by means of touch;

- Holding the device can be challenging for users who do not have full control of their hands (SK, C, JO, & RE, 2009);

- Input on mobile phones making use of buttons may require the user to use more strength to complete an input request;

- Usage of physical buttons on a mobile phone may require the user to take more steps to complete a step. This therefore affects efficiency negatively;

- Mobile phones with additional gestures such as swiping and pinching to zoom can be problematic for users who lack fine motor control;

- Mobile phones implementing touch as a form of input can be challenging for users with dexterity impairments as they will be required to aim touch targets on screen to interact with the device;

- Multi-touch gestures can be extremely problematic for motor impaired users considering the fact that in some cases interaction by means of a single touch cannot be achieved.

2.4.3 Barriers for People with Motor Impairments: Mobile User Experience Strengths and Limitations

Mobile phones provide unique opportunities to their users even though they have inherent constraints, such as small screens and variable connectivity. According to the Nielsen Norman Group (2015), these strengths and limitations contribute to the UX of mobile phones in the following manner (Budiu, 2015):

- **Small screen**: Even though mobile phones are extremely portable and convenient because of their small size, when compared to desktop computers and laptop screens, they accommodate less content. For this reason, mobile phone screens are seen as a limitation for mobile phones. Users of mobile phones become subject to higher interaction costs when interacting with the same amount of content as on a laptop, for instance, and they have to rely on short-term memory to refer to information that is not visible on screen. As a result of the screen size of mobile phones, content on screen might be too small and unreadable for motor impaired users suffering from cerebral palsy might be visually impaired as well as a result of the muscles controlling the eyes having poor functionality. In rare cases "People with severe or multiple disabilities may exhibit a wide range of characteristics, depending on the combination and severity of disabilities, and the person's age" (Start, 2015). For example, people that are mentally challenged might experience difficulties in physical mobility, this means that the user has poor cognitive and motor skills. With this said, it is imperative for designers to beware of the fact that when a new design element is placed on screen, it pushes another element off screen or places it below the fold. As a result, interaction requires more mental effort from the user;

- **Portable = interruptible**: Mobile phones are portable, as they can be used by the user on the go in various contexts, and situations. For this reason, users of these devices can be easily interrupted, since they can use the device and be distracted by an external event. Consequently, interaction sessions on mobile devices are usually short and fragmented. When compared to desktop computers with an average interaction session of 150 seconds, the average interaction session on mobile phones is no longer than 72 seconds. This said, it is advised that designers design for interruptions by saving states and by enabling users to save states manually when using a mobile phone. When considering the portability of mobile phones, motion has considerable impact on the user as the device is being used in various environments/contexts that majorly influence of change the user experience (Obrist, Tscheligi, Ruyter, & Schmidt, 2010). With regards to motor impaired users portable devices have a more severe impact depending on the user's disability, for example a user suffering from a spinal cord injury or multiple sclerosis is confined to a wheelchair and depends on it to be mobile. As a result of this the user has to sacrifice one of two tasks i.e. using their hands to control the wheelchair or using their hands to make use of the mobile phone. This negatively effects the user in terms of efficiency and

productivity as the user has to stop the operation of one task to complete the other as opposed to an abled person that can continue the task of walking when inputting text on a mobile phone;

- **Single window**: Many mobile phone manufacturers implement multiple window capabilities on their devices, but the small screen size of mobile phones makes this goal unpractical. Therefore, the design of mobile phones has to be self-sufficient, meaning that any mobile phone task should be achieved on a single application or website**.** Users suffering from brain and spinal injuries may lack the ability to control one or more limbs and suffer cognitively. This means that the user is unable or lacks the ability to process streams of content, this results in the user experiencing a difficult time interacting with the device as the user has to use more mental effort to achieve a task. For a user suffering from brain injuries interaction on mobile phones should take place in a manner that enables the user to interact seamlessly;

- **Touchscreen**: Touchscreens are a great advantage, as they provide seamless possibilities through gestures that represent hidden alternative UIs that make interaction fluid and consistent. Unfortunately, mobile phones implementing touchscreens suffer from low memorability and discoverability. Regardless of the fact that touchscreens provide opportunity for a list of additional functionality it does have its flaws such as too much sensitivity and in some cases the requirement of multi gesture interactions which could be impossible for users suffering from dexterity as they will be required to aim touch targets on screen to interact with the device;

- **Variable connectivity**: To date, cellular networks provide fast connections and seamless connectivity to wireless networks. However, coverage is not always universal or seamless. This requires mobile phones that implement light applications that display as much content as possible. This is a limitation that affects all regardless of one's physical ability;

2.4.4 Barriers for People with Motor Impairments: Situationally Induced Impairments and Disabilities (SIID)

One of the major benefits of mobile phones is the mobility of the device. It enables users to be productive on the go in various situations. Regardless this benefit turns out to be a downfall for mobile phones as well. This is said due to the fact that since a mobile phones are used on the go in various contexts, a list of environmental characteristics influences the user experience of these devices within each context. For users, including those with disabilities, each context change brings a new challenge for the user as they cannot devote their attention completely to the task at hand due to some sort of distraction or environmental changes. This leads to situationally induced impairments and disabilities (SIID). It was found that "mobile users often face demands that compete for the same human resources needed to operate electronic devices" (Miguel &

Nicolau, 2013). According to Sears at al. (2003) these demands, otherwise referred to as contextual factors that induce SIID since these factors influence how users interact with a mobile phone. These factors can be categorized into 3 categories, namely environmental factors, attentional factors, and physical factors. Table 2.2 lists the categories along with various examples within these categories that can influence a user.

Category	**Factors**
Environmental	• Low light, • Glare, • Noise, • Vibration and tremors, • Extreme temperatures, • Change in terrain, • Changes in weather.
Attentional	• Physical obstacles, • Social interactions, • Divided attention, • Abrupt distraction, • Device out of sight.
Physical	• Impending clothing, • Baggage, • Occupied hands, • User movement, • Device movement, • User fatigue, • User posture or grip.

Table 2.2 Various contextual factors impacting on the mobile user experience (Kane, Wobbrock, & Smith, 2008)

These factors may affect a user at any time whilst operating a mobile phone, for example a user might be operating a mobile phone whilst walking in a rainstorm, as an effect of the rain the user is walking faster than normal which causes the user in perform a few mistakes whilst operating the device. Another example might entail a user performing a transaction on their mobile phone, the user is then required to drive a vehicle. Of course the user can perform one of these tasks at a time, but that defeats the goal of user efficiency. From literature it was found that a number of studies focused on the effects of SIID on user accuracy when operating mobile phones:

- It was found that users operating PDA's by means of stylus whilst walking on a treadmill, walking and sitting faced some issues with regards to input as up to 90% of users had to

reduce walking speed to accurately operate the device (lin, Goldman, Price, Sears, & Jacko, 2007);

- Visual performance was affected when users attempted to read and interpret text on a mobile phone whilst walking or changing postural positions (Mustonen, Olkkonen, & Hakkinen, 2004);

- Task performance was affected when users operated a mobile device within in various lighting conditions whilst changing postural position from sitting to walking (Barnard, Yi, Jacko, & Sears, 2007);

- Six participants who took part in a usability study found that it was impossible or extremely challenging to interact with their phones when carrying additional objects in their hands, for example a participant mentioned that interaction with their mobile phone was extremely difficult when carrying shopping bags (Abdolrahmani, Kuber, & Hurst, 2016).

To get around these issues it was found that users had to compensate by sacrificing one of two tasks i.e. operating the mobile phone, walking speed, or postural position. One should take note that these studies were conducted on users that are fully abled. Therefore it can be assumed that if these studies were to be conducted on motor impaired users, the results would've been poorer considering the array of challenges (section 2.4) motor impaired users already face, consider the following:

The experiments found within literature were conducted on human subjects that are fully abled. Each experiment was focused on a different aspects of SIID i.e. walking whilst interacting with a mobile phone and interacting with a mobile phones whilst completing tasks such as carrying shopping bags. Considering the imperative fact that even though these participants fully abled, they are still prone to SIID challenges that affect them regardless of the participant being disabled or not. With this said it can be assumed that if these experiments were conducted on human subjects that suffer from motor disabilities the results could be more or less the same or they could be worse considering the challenges motor impaired users already face with mobile phones.

To mitigate these issues more effort can be placed on enabling mobile phones to adapt to the needs to the user as "Current devices are largely blind to a user's context. It is therefore important for designers to consider incorporating situational accommodations to provide some compensation for these contextual influences" (Kane, Wobbrock, & Smith, 2008), otherwise referred to as contextual UX. This is an area that mobile phones fall short in, if more focus was to be given in this area the UX for all users is more than likely to improve as devices are now more suited to the user's needs.

2.4.5 Barriers for People with Motor Impairments: Conclusion

People with motor impairments, as well as those suffering from other disabilities do not always form part of the common society. It was found that “Since time immemorial, PWDs all over the world are faced with the problem of exclusion and Isolation. This has contributed to their low levels of education therefore exclusion from majority of social services” (ICTs, 2010). In a South African context this statement may apply in the following manner, when considering the following statistics (Africa, 2011):

The Eastern Cape, North West, and the Northern Cape is home to the highest proportion of people suffering from physical impairments such as motor disabilities. Most of these provinces have vast rural areas that have poor access to delivery of essential services such as running water, electricity, and education. Within these provinces approximately one in three people with severe disabilities have some sort of education, Gauteng and the Western Cape has the highest proportion of 9.6%. As a result of the large proportion of uneducated disabled people approximately 62% of these people are jobless. It can be assumed that since such a small group of disabled people are educated, a large amount of uneducated disabled people face exclusion in this regard, resulting in these people lacking the necessary knowledge and skills to access or interact with ICT devices and services. In a South African context this is a major contributor to the poor accessibility of information, considering that people who lack the knowledge and skills to interact with technology will therefore lack access to services such as the internet which is currently the most commonly used method to access information. Another point to consider based on the acquired statistics is that since more than half of disabled people are unemployed, the purchasing of technology for the use of access to information is more than likely to be seen as a waist as the first priority is to use available funds for essential products and services. On the other hand, the remaining number of disabled who are better off, in other words have access to technology are more than likely to face barriers listed in section 2.4.

With regards to mobile phones, these devices have become more complex as interactions range from simple taps to the more complicated multi-touch gestures, swipes, timed taps, and repeated taps. Incorporating these interactions into mobile phones requires users to possess motor control. With this being said, when considering the needs of users suffering from motor impairments interaction with content on mobile phones can turn out to be an impossible task resulting in a negative result for the user. Based on a usability study to test the usability of touchscreen smartphones for users with physical disabilities the following results was found (Trewin, Swart, & Pettick, 2013):

- 15 of the 16 participants owned a mobile phone, where only 3 of the participants owned a smartphone;

- 69% of the participants felt that a smartphone would be very useful in their daily lives if it was easy to use;

- 50% of the participants felt that a smartphone requires a lot of visual effort to use, 56% felt that it requires a lot of mental effort, and 19% felt that it required a lot of physical effort to use;

- Of the 16 participants 10 were able to use two hands to operate a smartphone;

- With regards to tapping content on screen, only 49% of the participant's touches started and ended on target. Performing tasks such as swiping through content and multi touch gestures was particularly seen as a difficult task.

Considering the barriers listed in section 2.4 and the results found the usability study by Trewin, Swart, & Pettick (2013), it is evident that a range of barriers exist, each one preventing the user from achieving their intended goal. With this being said one can ask what needs to be done to improve mobile accessibility for motor impaired users? To answer this question two points should be considered, firstly should the capabilities of motor impaired users be adapted to the device or should the device be adapted to the user's needs?

The section to follow provides an overview on the 2 approaches and seeks to determine which method will be more effective.

2.5 Design Approaches to Accessible Technology

Providing accessible technology is a challenging task considering that there is a wide range of users, each one different to the other. With regards to mobile phones, accessibility is extremely imperative since this is technology that is used on the go in various contexts. For users with disabilities, accessibility means being able to make use of a product or service as effectively as a fully abled person (InternetSociety, 2012). Unfortunately, as discussed accessibility is not always achieved when considering the needs of users with disabilities, i.e. motor disabilities. Lazar and Jaeger (2011) state that "Although the range of potential barriers to persons with disabilities in the online environment is extensive, there are ways to develop and implement technologies so that persons with disabilities are included. There are known and achievable means to address the access barriers listed above. However, many developers of Web sites and related new technologies simply do not consider persons with disabilities when they create or update products" (Lazar & Jaeger, 2011). As mentioned two possible approaches exist to address the issue of accessibility for people with disabilities:

- Extending and adapting the capabilities of disabled people by means of assistive technology (AT);

- Extending and adapting the features and capabilities of mobile devices by means of accessibility features.

The sections to follow provides an overview on the 2 approaches in an attempt to determine which approach is more effective.

2.5.1 Design Approaches to Accessible Technology: Assistive Technology

Assistive technology refers to a product or device that is used to maintain, increase or improve the functional capabilities of disabled people (Rouse, 2011). By providing impaired people with assistive tools they can compensate for the impairments they experience. The aim of assistive technology is extend the capabilities of the user by means of physical tools. For example, a user suffering from Parkinson's disease, has poor motor skills and the inability to control their arms and hands. As a result of the user's impairment, interaction with a mobile phone or PC by means of the user's hands cannot take place. To overcome this issue the user can make use of a pointing device which is held in the user's mouth or head (head strap), see figure 2.1.

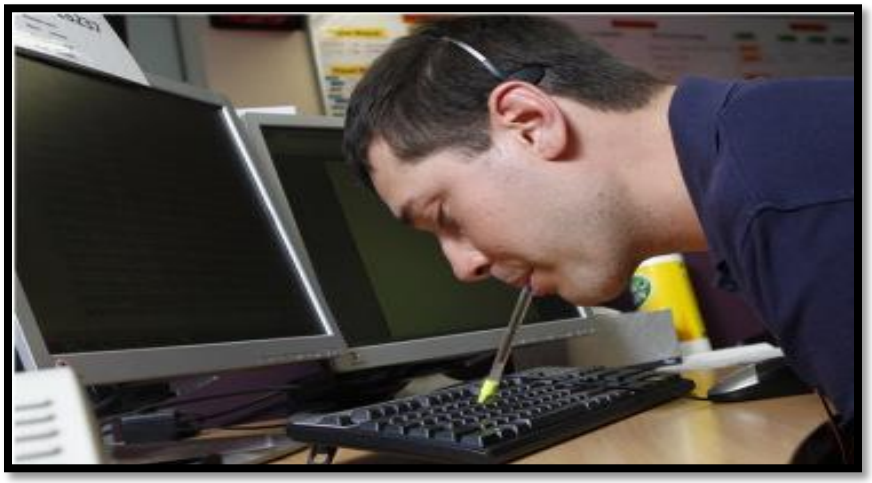


Figure 2.1 User making use of a pointing device to interact with a keyboard

When implemented correctly assistive tools or technology provide the following benefits (Development, 2012):

- Promote independence as it enables the disabled to perform tasks they were unable to do before;
- Decreases the need for educational support since disabled users are able to teach themselves in terms of interaction, instead of having to be assisted to interact with a device or perform a task;
- improves the productivity of disabled people in the workplace and the social environment;

- Increases accessibility to information for disabled people since access and interaction with technology is easier.

Depending on the situation and context, assistive technologies can be extremely empowering for motor impaired users as it enables them the ability to perform tasks they were previously unable to pleasantly achieve. According to Vanderheiden (2010) an advocate of Universal Usability, different strategies may apply to the design of accessible technology (Vanderheiden, 2010):

- Change the individual;
- Provide the user with tools they can use;
- Change the environment.

With this being said, assistive technologies seek to change the individual by means of extending the user's ability via physical tools. This is not always the best approach for a list of reasons, one of them being that users might feel ashamed to make use of assistive technologies. For example, a motor impaired user who has limited dexterity is in a public environment surrounded by many people, the impaired user needs to operate their mobile phone and has to do so by means of a pointing device held in the user's mouth. In society this is not often regarded to as a common method to completing the activity of mobile phone operation, this might therefore result in the user of the pointing device getting unwanted attention which may lead to the user feeling ashamed or embarrassed. It has been found that "Stigmatization has also been suggested to be associated with assistive technology (AT) usage for persons with acquired disabilities in later life" (Parette & Scherer, 2004). To be stigmatized refers to being disgraced or ashamed, often this is a result of using AT's which in some cases leads to users abandoning their devices. This then results to the user dropping back into phase one again, i.e. difficulty with interacting with content on a device and experiencing a poor user experience (UX).

2.5.2 Design Approaches to Accessible Technology: Accessibility Features

An accessibility feature is a built in feature of an operating system, mobile phone, or a browser that aims to enhance the capabilities of the device by providing easier access in terms of usability and UX. When compared to AT, accessibility features take the lead considering that "they integrate accessibility to the mainstream technology instead of leveraging a separate solution for users with disabilities access" (Naftali, 2014). In other words accessibility becomes part of the device features, this means that the user gains the benefit of better access as they do not need additional tools to achieve the goal of interacting with content. For example, a benefit of a NUI is that it enables users to interact with content by means of interaction modalities that are natural and inherent to the user, this implies that the user is able to interact with content via methods that the user does not have to learn how to make use of for example touching an icon on a mobile phone touchscreen.

Since there is a variety of mobile phone manufacturers that exist, each one implementing their own set of features, the scope of this study will focus on the use of operating system (OS) Android accessibility features. To follow a list of common accessibility features from the Android OS (version 5.0) will be briefly touched on (Devine, 2014):

- **Magnification Gestures**: this feature magnifies the entire UI. This feature can be accessed by triple tapping anywhere on the device screen, users then navigating by means of two finger panning and pinch – to – zoom for zooming I or out, see figure 2.2;

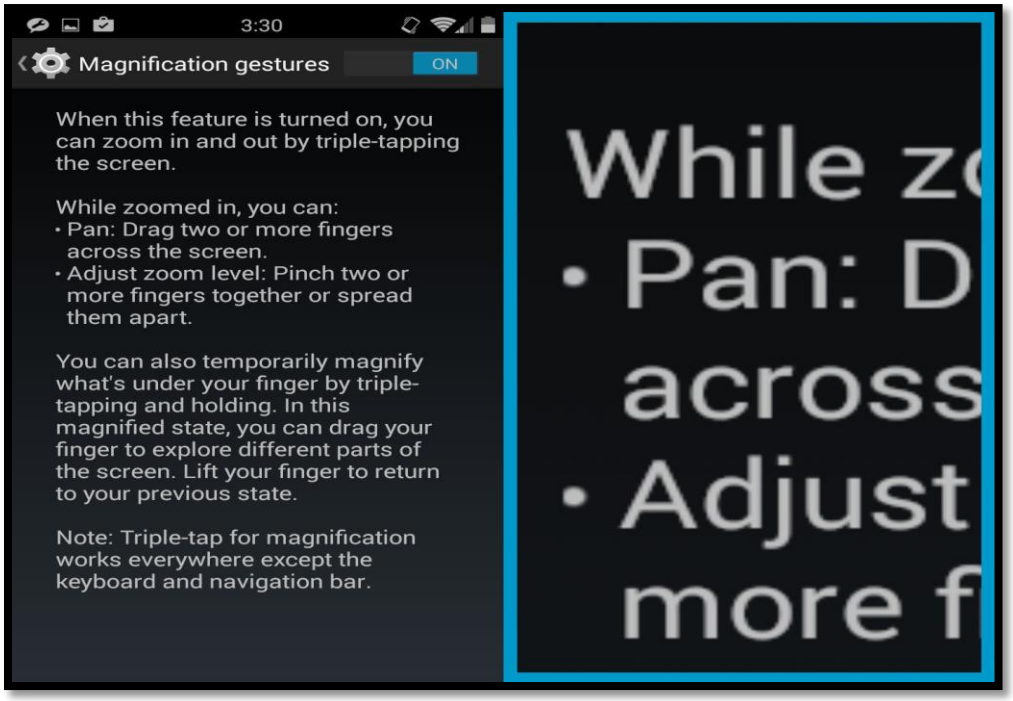


Figure 2.2 Android magnification gesture to enlarge the UI of the mobile phone

- **High contrast text**: this feature highlights text that is naturally more difficult to read, such as small fine text. For example white text might be highlighted with a darker colour to improve visibility, see figure 2.3;

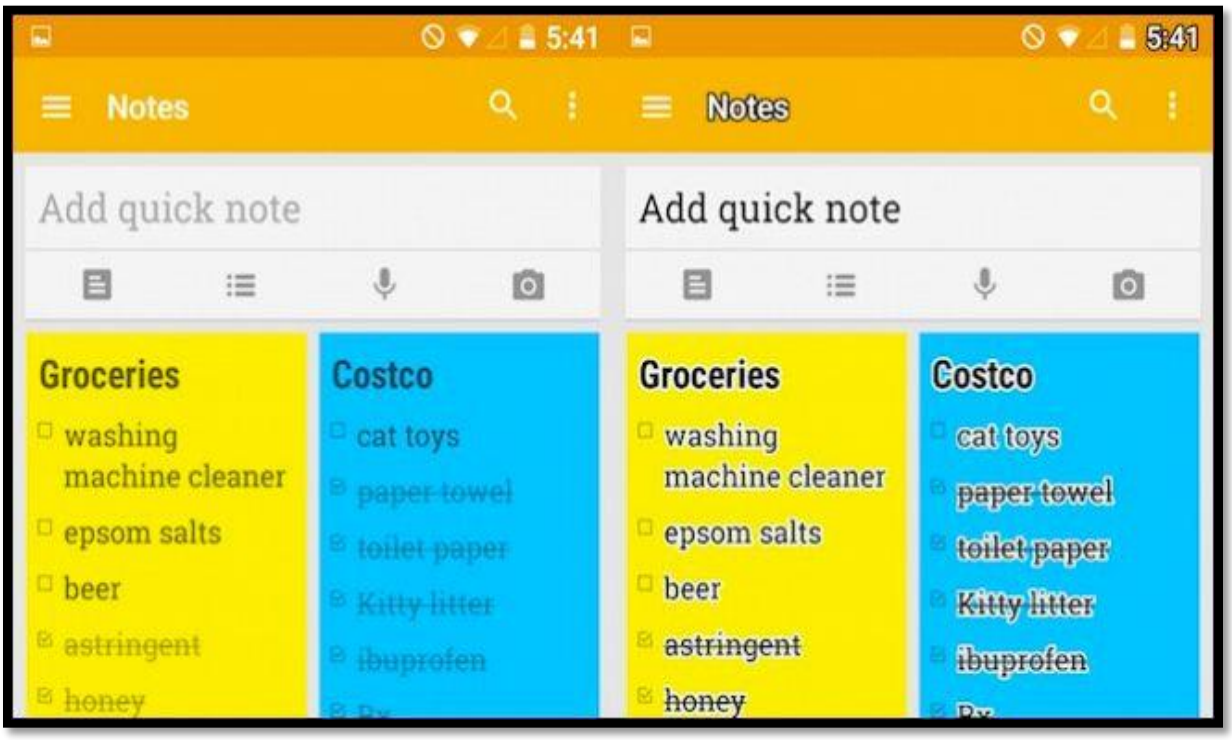


Figure 2.3 Android high contrast feature highlighting invisible text on screen.

- **SWPE**: is a convenient way for users with dexterity impairment to enter text on the device. It enables users to swipe their fingers or pointing device along the keyboard to enter text, see figure 2.4.

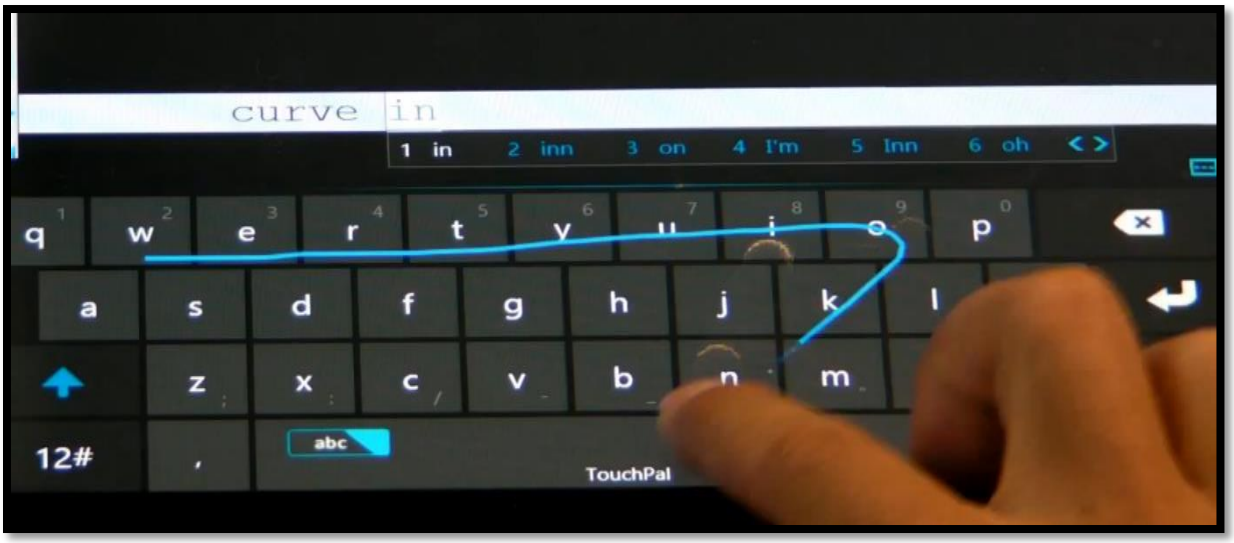


Figure 2.4 Android SWYPE text entry feature

- **Touch and hold delays**: for users with dexterity issues, touching actions might be slow and delayed. This feature enables users to change the duration required to different settings, see figure 2.5.

Figure 2.5 Android touch and hold delay being accessed and operated by a user.

- **Voice recognition**: Quadriplegics and people with limited dexterity rely on voice commands for interacting with interactive devices, such as mobile phones. Voice commands are used to make phone calls, write text messages, and to complete various other mobile tasks;

- **Auto Text**: This feature makes messaging possible for users with limited hand movement. Auto text replaces particular text with predefined words to reduce the number of keystrokes needed to interact with the device;

- **Other**: For users with movements limited to the fingers, sensitive touch-screen phones will benefit them. For users who struggle to hold a mobile phone, various applications are made available by adding anti-shake functionality to the device;

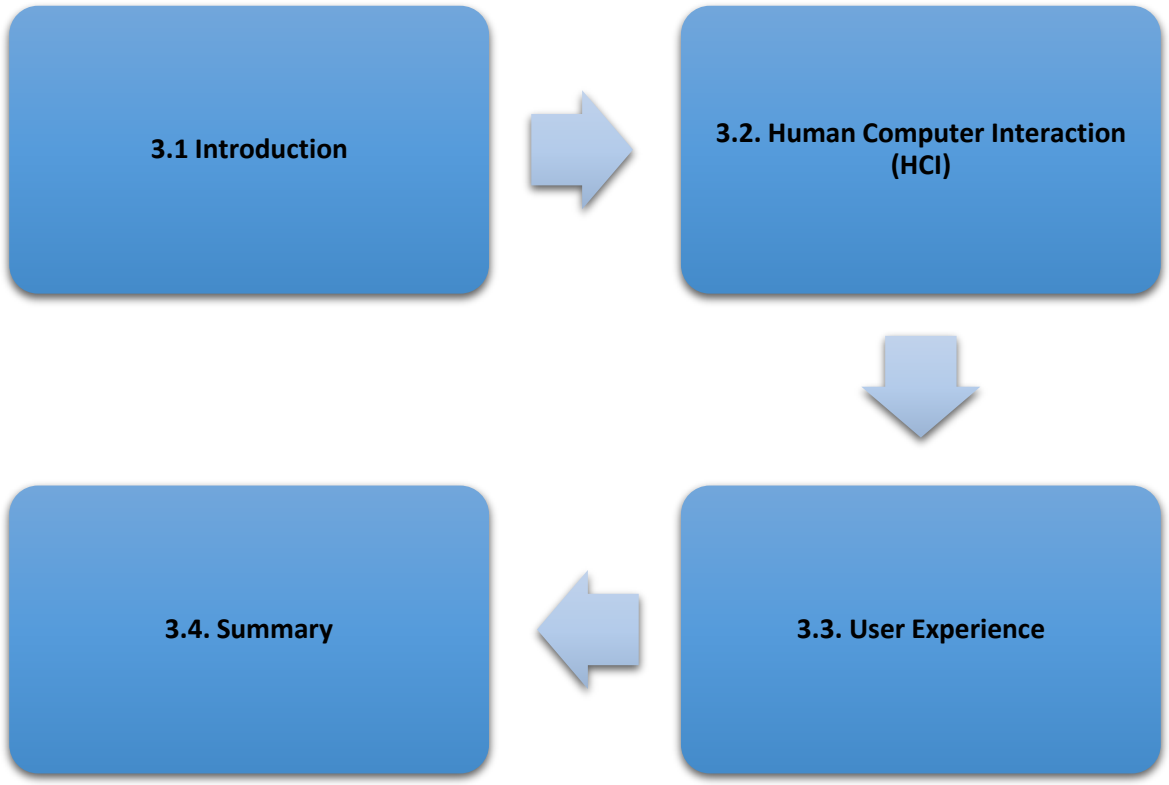
Regardless of the inherent aspects of accessibility features, there is always room for improvement. As mentioned, touchscreens are extremely sensitive as a result of this when accessibility features are in operation, high error rates are still in play. This is due the fact that users are still required to touch down on the screen whilst pointing at icons, completing double taps, and multi- touch operations. This doesn't move the user away from the original issue as the user is still facing the existing problem. Trewin et.al (2013) found in a usability study that "the

assistive features that participants wanted to use often demanded too high a level of dexterity, either in accurate timing, precise targeting, the use of multiple fingers, or sensitivity to extra touches" (Trewin, Swart, & Pettick, 2013).

2.6 Summary

This chapter determined the term disability, in an attempt to determine what a disability entails it was found that a vast list of disabilities exist. Within a South African context it was found that a large number of people suffer from physical disabilities such as motor impairments. For this reason the chapter/study focuses on people with motor impairments. The chapter then focused on usage of technology i.e. mobile phones by people with motor impairments. It was found that a list of barriers presents itself to users with motor impairments. To date, these barriers are being addressed by either providing the user with physical tools or implementing additional features on mobile phones. It was then found that issues still presents itself even though one of these methods are in place. To conclude it can be said that additional research can take place to determine how the capabilities of NUI features can be implement in accessibility features to unlock the full potential of device, in return benefiting users with motor impairments.

3. MOBILE HUMAN COMPUTER INTERACTION FOR MOTOR IMPAIRED USERS



3.1. Introduction

This chapter seeks to address the following research question:

How can the unique challenges motor impaired users face when using mobile phones be addressed?

To answer the research question, this chapter seeks to discuss the term HCI in Section 3.2. This discussion includes an overview of the HCI components, and how they apply within this study. The chapter then continues by discussing user experience in section 3.3. This includes user experience for disabled people in section 3.3.1 and concludes on methods to measure user experience.

3.2. Human Computer Interaction (HCI)

When communication or a connection is established between these components, interaction with content is the result, i.e. if objects interact, they have an effect on each other. Considering the components previously listed, when a user (human component) inputs information (interaction component) on a mobile phone (computer component), the final output influences the user experience the user is having. This cycle is referred to as human computer interaction (HCI). Various definitions of HCI exist but for the purpose of this research the following definition will be used:

> *"HCI (human-computer interaction) is the study of how people interact with computers and to what extent computers are or are not developed for successful interaction with human beings."* (Rouse, 2005).

It is derived that in HCI major focus is placed upon the 3 components, especially the human component as the "goal of HCI is to make computers easier to use and more helpful to their users." (Lieberman, 2009). Figure 3.1 depicts how the HCI components play a role in this study. As depicted, the human component for this study comprises people who suffer from motor impairments (physically disabled); the computer component is mobile phones, and the interaction component is the natural interaction which is an interaction modality used to interact with NUIs. A sub-component of the human and computer component is user experience (UX) as UX is the result of users interacting with technology. This study addresses each of these components in order to reach a positive output for this study, which is to promote new forms of technology and interaction in order to enable disabled people to perform functional activities on mobile phones.

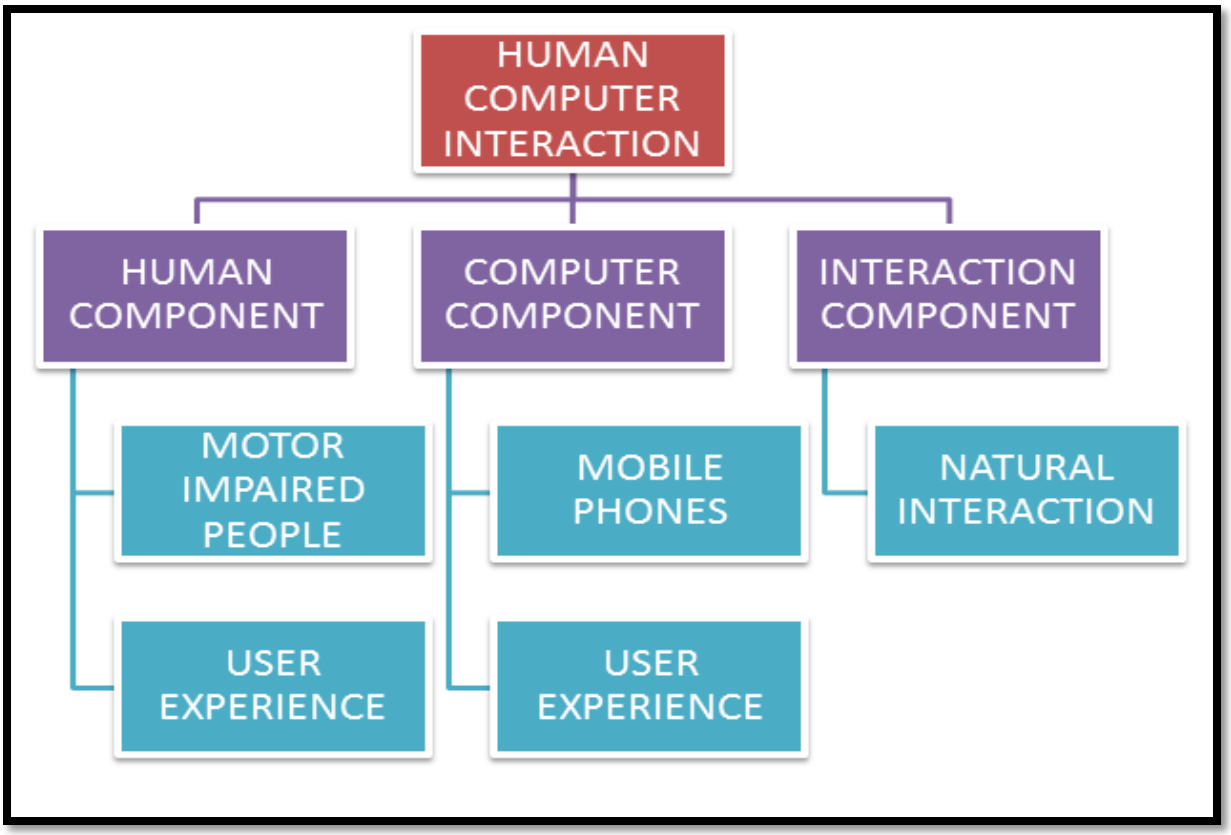


Figure 3.1 Human Computer Interaction Components and Sub Components for this Study

When considering the needs of motor impaired users, the commonly used interaction styles are not suited to the needs of users with motor impairments. Section 2.4 listed barriers that arise when users interact by means of GUIs. To mitigate these issues this study investigates the use of interfaces that enable users to interact in efficient, seamless methods that focus on natural expressions that are inherent to the user, instead of forcing the user to learn new methods of interaction. This form of interaction is referred to as the natural user interface (NUI).

3.2.1. Natural User Interfaces

Standard mobile phones are slowly becoming a thing of the past as new, immersive, and more exciting technologies are being developed with the penetration of smartphones on the rise. A smartphone can be defined as a mobile phone that includes advanced technology beyond making phone calls and sending text messages. This includes abilities such as accessing media and third party applications (TechTerms, 2010). To date, smartphones enable interaction by means of touch, voice, and hand gestures. One can therefore classify the interaction with a smartphones as interacting with a natural user interface as it enables interaction with content by means of natural interaction or direct manipulation of content (Maninis, 2013).

3.2.1.1. What is a Natural User Interface?

A natural user interface (NUI) enable humans to interact by means that are natural to the user such as for example gestures and voice. Natural user interfaces can be defined as:

- " An NUI is a type of user interface that is designed to feel as natural as possible to the user" (Christensson, 2012);
- "The term "natural user interface" is an emerging computer interaction methodology which focuses on human abilities such as touch, vision, voice, motion and higher cognitive functions such as expression, perception and recall. A natural user interface or "NUI" seeks to harness the power of a much wider breadth of communication modalities which leverage skills people gain through traditional physical interaction" (Group, 2009);
- "Natural User Interfaces (NUIs) allow interaction with displayed data in a manner which mimics the physical world. They are enabled by motion or speech recognition devices, and when used properly they are more easily understood by novice users." (Adam, 2011);
- "A natural user interface is a user interface designed to reuse existing skills for interacting appropriately with content." (Blake, 2012);

For the purpose of this research, the following definition of NUI interaction will be used:

Natural user interfaces allow interaction with devices using touch, vision, motion and cognitive functions.

Based on this definition, it can be derived that NUIs seek to take advantage of the user's natural ability to interact with real world objects or other people. It involves direct manipulation of content as opposed to indirect manipulation by means of a mouse and keyboard for CLI and GUI platforms.

The main benefit of NUIs is the natural feeling it provides to the user. Derived from the listed definitions, reuse of the users existing skills is imperative in the design of NUIs and it can be assumed that NUIs do not require the user to adopt new skills to interact with the system. This means that NUIs excel in terms of learnability and discoverability (Blažica, 2013) as users do not have to spend additional time learning how to interact with the system. According to Kurfess (2013) NUIs are focused more on interaction style instead of input modalities. This implies that a considerable amount of focus is placed on interaction design as the goal is to deliver a system that implements natural user interactions ensuring that the user acts and feels natural when using the technology. Daniel Wigdor & Dennis Wixon (2011) expands on this statement by stating that a NUI "is not a natural user interface, but rather an interface that makes your user act and feel like a natural." (Wigdor & Wixon, 2011).

For people with disabilities NUIs provide endless opportunity to provide interactive systems that are more user friendly with regards to the unique needs of disabled users. NUIs can enable motor impaired users lacking the ability to fully use their hands to interact with information by means of hands free interaction, this requires the user the interact with content in a manner that is natural to the user. NUIs have various characteristics pertaining to them, these are outlined below whilst considering the benefit it provides motor impaired users (Wallach & Radvak, 2010):

- **User**: NUIs accept interaction from multiple users with content. One example is the Microsoft Kinect that has the ability to detect and track up to six users at once enhancing efficiency and productivity by allowing for the simultaneous completion of tasks.
    - The Microsoft Kinect is one of many devices that is used for patient rehabilitation. Patients who might have suffered from a stroke and now have loss bodily functions make use of the Kinects capabilities to assist in rehab (Blog, 2014).
- **Interaction**: NUIs involve direct interaction with the software promoting a system that is easier to use and reduces end user anxiety as interaction takes place using inherent methods.
    - One of the main benefits of NUIs is their ability to accept input from natural interaction modalities. For people with motor disabilities this is highly beneficial as the user is able to interact with content through methods that are not labour intensive. An example of this is discussed in section 3.2.1.5.
- **Context**: This refers to the physical surroundings and situations the system is placed in. NUIs are dynamic, as they have the ability to locate themselves in space and time. For example, smartphones make use of gyroscopes and GPS (graphical positioning system) to determine the user's location and react accordingly. Google maps is a good example of this.
    - If implemented correctly NUIs have the ability to adapt to various users' needs which can be beneficial to motor impaired users. For example, NUIs have the ability to accept input from various forms of input, this is beneficial to motor impaired users as the device would be able to adapt to their needs in terms of providing appropriate interaction methods.
- **Posture**: This speaks to the transient collaborative posture allowing the systems to be used on the go. For example, if a user is on the move, the user is capable of interacting with content when needed in an effective and efficient manner that does not completely distract the user from their previous activity and surroundings.

- **Focus**: User experience (UX), exploration, and user's dialogue focuses on providing a pleasant experience to the user. NUIs focus on delivering an experience that is natural to user, an experience that is immersive, and attractive. By presenting the user with a system that is usable and immersive, the user is more than likely to experience a pleasant UX.
    - Since UX is one of the main focus points of NUIs, beneficial results should present itself for all users, both abled and disabled.

3.2.1.2. Various forms and Uses of Natural User Interfaces

Today, various forms of NUI exist, each one meeting the mentioned characteristics in its own unique way, whilst being used in a variety of situations. Table 3.1 provides an overview of the most commonly used NUIs.

DEVICE	INTERACTION STYLE	DESCRIPTION	SITUATION
Tablets Phones	Multi-touch Stylus Voice dial Voice search	Entails gesture manipulation of graphic objects. Realism replaces icons as the user interacts directly with the device (Rouse, 2011) Voice dial and voice search allows the user to interact through voice commands	Tablets and phones are used for everyday use in various situations, such as browsing the Internet or making a phone call. The implementation of NUIs on mobile devices provide space for opportunities in terms of user friendly interfaces for disabled users.
Wii Kinect PlayStation Move	Gestures Voice Motion	Interpretation of human motion. A system tracks human motion and translates these motions into commands (Rouse, 2011)	The Kinect, Wii, and the PlayStation Move are gaming devices that allow users to play video games without any handheld devices. Many of these devices are used to assist rehab patients such motor impaired patients in recovery.
Eye tracking systems	Eye movements	The tracking of eye movements for interaction	Disabled people who cannot use hands for interaction with various devices are able to use their eyes for interaction.
Brain machine interfaces	Neural signals	Makes use of the users' neural signals which are translated by computer software into actions (Rouse, 2011)	Disabled people who cannot use hands for interaction with various devices are able to use their neural signals for interaction

Table 3.1 Various forms of NUIs. This table lists the most common NUIs to date.

3.2.1.3. Benefits of Natural User Interfaces

Based on Table 3.1, three forms of NUIs are used on a daily basis worldwide. This includes touchscreen phones, handheld tablets and the Wii, Kinect for Xbox 360, and PlayStation Move gaming devices. These NUIs are popular because they yield the following benefits:

- **Reduced cognitive load**: users are making use of natural interaction, which requires less mental effort, as opposed to using a mouse and keyboard (Natural User Interface Group, 2011).
    - For motor impaired users suffering from brain injuries the reduction of cognitive load is highly beneficial as user tasks require less mental effort from the user. This results in interfaces that provide easy, fluent access to content.
- **Responsive**: NUIs have a good reaction time. For example, the Samsung tablets on the market are able respond to user interaction in 15 to 40 milliseconds (Samsung, 2012).
    - Having an interface that is responsive contributes to the accessibility of the device. For disabled users, accessibility is extremely imperative as it involves enabling disabled users to interact with devices as easily as abled users (Avila, 2013).
- **Attractive**: An attractive interface makes it more enjoyable for the user and results in an interface that users want to make use of. Most NUIs make use of a more attractive interface to get the user more immersed in the interface.
- **Interactive**: Users are afforded an easy to use style of interaction.
- **Fast and fluid**: Users are able to interact with NUIs fluently, and the interface is able to respond quickly and smoothly to the user's interaction.
- **Full screen and captivating**: most NUIs provide a full screen experience that allows the user to make use of all the capabilities of the device. This allows the user to experience more as the boundaries are broadened.
    - Interactive, fast and fluid designs provide interfaces that are easy to use and achieve user goals. For motor impaired/disabled users this is important as interfaces should be designed in a manner that is understandable and easy to navigate as hand tremors caused by the user's disability can result in the completion of undesired operations.

3.2.1.4. Natural interaction of Natural User Interfaces

Interaction is an imperative component of HCI, as it is the process that entails the user communicating with a system to receive the intended output. Various methods of interaction exist, each form being implemented in a different manner, depending on the technological device. This is an important to note as the method used for interacting with a system has a major influence on the UX of the system/device. This is why interaction design (IXD) plays a major role in the development of a system. IXD "defines the structure and behaviour of interactive systems. Interaction designers strive to create meaningful relationships between people and the products and services that they use, from computers to mobile devices to appliances and beyond" (Booth, 2015). Incorporating the correct IXD means that users are at the focus of the system, the result of this is a user centred system that delivers a pleasant level of UX.

NUIs implement a form of interaction that is immersive, simple, and flexible as the user is able to interact through methods that are direct, enabling the user to interact directly with content. These methods are inherent to the user as humans communicate through gestures and movements that are so common they are understood in various cultures, for example the thumbs up. Natural interaction (NI) is a form of interaction that applies this concept to NUIs. Natural interaction involves "people naturally communicating through gestures, expressions and movements, and discovering the world by looking around and manipulating physical objects" (Valli, 2006). Natural interaction is defined by Valli (2006) according to experience. Based on his definition it is derived that users should be able to with a system just as easy as they would interact with objects in the real world.

3.2.1.5. Natural interaction for Mobile phones

A smartphone is a mobile phone that includes advanced technology beyond making phone calls and sending text messages. This includes abilities such as accessing media and third party applications (TechTerms, Smartphone, 2010). These devices enable users to interact by means of various natural modalities referred to as natural interaction, which is highly beneficial especially for users who are motor impaired as they can make use of effortless interaction styles that are inherent to them. Unfortunately the implementation of these methods on mobile phones still present a list of barriers to motor impaired users (see chapter 2, section 2.4). Reason being that users suffering from motor impairments still have to perform physical actions to interact with content such as hand movements to scroll through a paragraph of information. It was found that "one of the technologies that can help to overcome the limitations of users with special needs (such as cerebral palsy) are all those that do not involve any physical action on the part of the user (hands or fingers)" (Lopez-Basterretxea, Mendez-Zorrilla, & Garcia-Zapirain, 2015). Hands free interaction with mobile phones will be beneficial to disabled users as they are able to interact with the device through interaction styles that require less effort as opposed to the common hand/touch gestures. These methods of interaction includes eye tracking and voice interaction.

- **Eye tracking**: refers to the measurement and tracking of eye activity (Imotions, 2016). Software on the device implementing this method of interaction makes use of these measurements to determine where on screen the user's eyes are pointing and reacts accordingly. For example, a user can look at a button on a screen an blink twice whilst looking at the button, this simulates a user making use of PC mouse to click a button on screen;
- **Voice interaction**: Speech recognition enables technological devices to accept a vocal command and convert it into a format that is understood by the device in order to produce some form of output (Rouse, 2007). This form of interaction enables users to make use of a natural behaviour that is used on a day to day basis. Speech recognition as a form of interaction is extremely beneficial for users who are blind or who do not have full control of their arms and hands.

To date mobile phone manufacturers have avoided the implementation of all methods as interaction techniques for a list of reasons. According to Yitzi Kempinski, CTO of Umoove which is a company focusing on the development of eye tracking on mobile phones, factors such as instability and computing resources need to be considered (Bleicher, 2013). The mobility of mobile phones means that both movements of the device and the user has to be considered and accounted for. In terms of computing resources, the software needs to be implemented in a way that is invisible to the user, in other words the user should not notice the processing effects of the software on performance. Regardless of this, positive results have been shown when incorporating eye tracking technology into mobile phones (Miluzzo, Wang, & Campbell, 2010). Another device showing positive results for hands free interaction is the Sesame touch free phone. This device is capable of tracking the users head movement to control a cursor and accepts voice commands for easy access (Wood, 2014). Sesame claims that "someone living with paralysis can do anything on its phone that you would normally do with touch: browse the web, send a text, watch YouTube videos, even play Candy Crush" (Olson, 2015). As a result users with motor impairments along with fully abled users benefit from the wide range of accessible hands free interaction methods promote.

3.2.1.6. Natural interaction for Disabled User's (Motor Impaired)

It was found that the importance of natural interaction increases when the subjects are disabled people (Ashraf & Ghazali, 2011). For users suffering from disabilities, Natural interaction is extremely beneficial as they are able to interact with methods that are less demanding on the body, fluent, and inherent to the user. A major benefit for all types of users of successful natural interaction is the reduction of cognitive load (Valli, 2006). Cognitive load refers to the amount of activity that working memory has to attend to at an instance in time. Cognitive load theory in HCI focuses on implementing systems that require less mental processing power that is required by the user to perform tasks, the easier and more pleasant the experience will be for the user. Just like computers, the human brain can only process a certain amount of information at a time,

when all resources are used or when the amount of information exceeds our ability to handle it (Whitenton, 2013), human performance is mitigated in terms of our ability to process the information. Take into consideration, when a computer can no longer handle the users demands, the machine can be easily updated, in terms of the user's ability, designers have to cater for the user's needs in order to accommodate the users abilities and limits. Although the cognitive load can be minimized to a certain extent, it cannot be completely eliminated. The following consideration can be used to minimize cognitive load (Whitenton, 2013):

- **Avoid visual clutter**: the use of any irrelevant information should be avoided, the use of this sort of information slows the user down in terms of performance. NUIs make use of large high resolution devices that in most cases provide more open and direct interaction space for the user.

- **Build on existing mental models**: a mental model is constructed within the conscious mind (Merritt, 2010). To be conscious is to be aware your surroundings. In terms of UX and usability, this means that designers should make use of a consistent design that is recognized by the user. NUIs promote interaction devices that provide natural feelings when interacting with the device. In terms of the design of an interface, this means that the user will be interacting with an interface via methods that is natural to the user.

- **Offload tasks**: look for alternative ways to display information, for example instead of using text use graphics to get the message through to the user. NUIs make use of displays that are high in visuals that enables the user to become more immersed in the tasks they perform.

3.3. User Experience

When using a product or consuming a service various factors contribute to the usefulness of the product. In this context, usability and user experience are often confused as being similar. Below are some definitions of usability to clarify its meaning.

- "Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." (ISO, 1998).

- "Usability' refers to the quality of a system and the process of designing a usable system" (Spencer, 2004).

- "Usability is a quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process." (Nielsen, Usability 101: Introduction to Usability, 2012).

Each one of the definitions speaks to the extent of which a product can be used by the user, considering that the user's goal is to make use of the product to achieve some specific goal. Nielsen (2012) sites the following as usable characteristics:

- **Learnability**: how easy is it for users to complete basic tasks the first time they encounter the design?
- **Efficiency**: once users have learned the design, how can they perform the tasks?
- **Memorability**: when users return to the design after not using it for a period of time, how easily is the user able to remember how to operate the design?
- **Errors**: how many errors do users make, how severe are these errors, and how easily is the user able to recover from the errors?
- **Satisfaction**: how pleasant is it to use the design?

By adopting these five qualities in the design of a user interface, users are most likely to experience a design that is simple and easy to use. If this is the case, users will have the confidence to make use of the system when needed as it performs the tasks the user requires. The user therefore experiences some sort of accomplishment with the use of the system because they are achieving their goals. When one experiences the sense of achievement, pleasant emotions such as joy, happiness, and satisfaction takes place. In other words, the experience a user has with a physical object influences what a user is experiencing emotionally.

In HCI anything the influences on a user's emotions is referred to as user experience (UX). Garrett (2011) describes UX as "the experience the product creates for the people who use it in the real world" Like usability focus is placed on the users and the product in use, but UX answers the following question: "Did the user have as delightful an experience as possible?" (Spool, 2007). Hassenzahl and Tractinsky (2006) claim that UX goes beyond usability when focusing on the following areas (Hassenzahl & Tractinsky, 2006) :

- **Holistic**: usability focuses on the performance of user satisfaction with regards to user tasks and their achievements in the context of use. UX applies an holistic view by aiming for a balance between task orientated aspects and non-task orientated aspects of system use and possession, such as stimulation and self-expression;
- **Subjective**: usability is focused more on objective measures of its components, such as number of tasks completed, task completion time, and error rates. UX is more concerned with the users' subjective reactions to the system at use, their perceptions of the system and their interactions with the system;
- **Positive**: usability is concerned with removing barriers or problems in systems as a method for improving them. UX focus is placed more upon the positive aspects of the system and how to maximize them, such as joy and happiness.

To achieve a pleasant user experience, various UX goals need to be achieved in the design of a user interface. A selected few goals are briefly outlined below (Schrag, 2008)**:**

- **Discoverability**: how long does it take a user to find a feature and how many false finds are allowed? The easier it is for a user to find the needed feature the better the UX.
- **Learnability**: this includes how long it takes a user to learn how to make use of a feature. To achieve a pleasant UX, the user needs to learn how to use the feature quickly by completing a limited amount of tasks such as clicking on a button.
- **Error recovery**: this includes how long it takes a user to recognize that they are in an error state. The quicker it takes a user to recognize that an error has occurred, and the easier it is for the user to get out of the error without losing a large amount of work, the better the UX.
- **Task completion**: this includes the tasks users should be able to complete. Users need to complete their tasks in reasonable time with as little effort as possible.
- **Responsiveness**: this includes the time it takes for the user interface to react to the user's action or input.

With regards to mobile phones and people with motor impairments, UX is not always successfully achieved as the needs of a disabled user differs to the needs of an abled user. When considering the needs of the disabled, Schrag's (2008) UX goals will need to be extended and applied in different manner. For example, a user who lacks fine motor skills will need certain features, such as switching on/off accessibility features to find the user instead of having the user having to look for the feature (discoverability). Ease of use needs to be always achieved, the user should be able to use the device in an efficient and easy manner (learnability). Since the user lacks fine motor skills, the user is more than likely going to perform accidental inputs on the device, therefore methods should be implemented to ignore unwanted operations/inputs (error recovery/prevention). The ability to achieve goals with the device is extremely imperative to any user, for user with disabilities tasks should be completed in an easier manner that requires less steps to accommodate for their disability (task completion) whilst having a UI that responds in an simple an responsive manner (responsiveness).

3.3.1. User Experience for Disabled People

Chapter 2 highlighted the various barriers motor impaired users face when interacting with technologies such as mobile phones. These barriers need to be mitigated as they hinder the users' UX. To deliver in terms of UX for disabled users, accessibility should be at the core of system design and implementation, otherwise referred to as accessible design which is a "design process in which the needs of people with disabilities are specifically considered" (IT, 2015). Following this approach will result in a system that is more than likely accessible by both abled and disabled users. A point to consider, especially when dealing with UX is that like all users,

users with disabilities also have emotions. Therefore it is important to consider the following points when designing for physically disabled users (Tang, 2012):

- Various disabilities exist, they are not homogeneous or of same kind;
- Users with disabilities may not have the same condition;
- Users with disabilities may not communicate the same way;
- Users with disabilities may not use the same tools;
- Users with disabilities may have different preferences.

UX is an extremely broad field with regard to the amount of research that has been conducted in this field. Many researchers have provided a platform for UX with regard to designing new products and services, but a common understanding of UX for people with disabilities is still absent (Lee, Han, Kim, & Bang, 2015). People with disabilities interact with content in a different manner. Therefore, their experiences with a product or service can be completely different to that of a person who is fully abled. For this reason it is noteworthy to consider the fact that the UX for disabled people consists of aspects of interaction that are influenced by assistive technologies, as these are used to aid the user. Unfortunately these devices do have their downfall, as many studies relate to the poor usability and often abandonment of assistive technologies, as mentioned in chapter 2 section 2.5.1. It was found that “lack of participation from the user when choosing the device; its ineffective performance; changes in the user's needs; devices of complicated use; lack of knowledge about the AT; absence of training and improper devices to the user's needs” (Carneiro, Rebelo, Filgueiras, & Noriega, 2015) are some of the main factors that lead to the poor UX of assistive technologies.

To assist developers in the design of products and services for disabled users, a set of UX elements have been identified (see Table 3.2) (Lee et al., 2015). The elements are grouped according to those that have similar characteristics or meanings. When considering the needs of disabled user’s versus the needs of fully abled users, the elements play different roles as they will be applied differently. These elements take various types of disabilities into consideration. However, the importance of the elements can differ according to the types and severity of disability. For example, a visually impaired person is attracted to sound, while a deaf person is attracted to visible objects. Consequently, these elements should be used as a guide in the development of products and services.

Elements		Definitions	Examples or similar concepts
Usability	Accessibility	Degree to which a product enables the user to approach or operate.	Accessible size, input assistance, visibility, audibility.
	Effortless	Ability of a product or service that requires minimal effort to use it.	Efficiency, effectiveness.
	Flexibility	Refers to the product's ability to adapt to various environments.	Adaptability, interoperability
	Informative	Refers to the quality of information that the product provides.	Comprehensiveness, explicitness
	Learnability	How easy is it to use the product?	Memorability, predictability, consistency, intuitiveness
	Simplicity	Considers if the design of the product is simple and uncomplicated.	Modeless
	User support	Can the user use the product easily?	Helpfulness, error prevention, recovery, feedback.
User Value	Attachment	Ability for the user to have a subjective value of a product or service by giving special meanings to it.	Affection
	Customer need	Refers to the amount of satisfaction the user gets from using the product functions	Comfort, convenience, intelligence.
	Identity	Ability of the user to perceive the personality of an individual using the product.	Self-esteem, self-respect, self-satisfaction.
	Independence	Ability of the users to have confidence in their ability to achieve something.	Self-determination.
	Relaxation	Sense of being and feeling relaxed when using the product	Pleasure, fun, enjoyment.
	Sociability	Refers to how much the product makes the user want to become a part of society.	Social emotion, social value, relationship
Affect	Sensory affect	Primitive and direct images from interacting with the product.	Shape, colour, brightness, sense of grip.
	Descriptive affect	Refers to how the users will describe the product based on their experiences.	Delicacy, simplicity, rapidity.
	Evaluative affect	Attitudinal images about the product	Attractiveness, reliability, comfort.

Table 3.2 The UX elements of people with disabilities and their definitions (Lee et al., 2015)

3.3.2. Techniques to Measure User Experience

UX is a broad field that has one goal that is focused on delivering pleasant experiences to users when using a product or service. To measure whether this goal is achieved, various tools and methods are available to evaluate the UX of a product or service. Some common methods for evaluating UX will be briefly touched upon. These methods apply most to UI design (UX, n.d.):

- **Emotion cards:** This method is used to measure the user's experience whilst using the product or service. This method involves a set of cards that present emotions or blank fields. Throughout the evaluation process, the users are requested to document their emotions at a specific moment;
    - Strengths: Quick and easy for both parties (users and researchers).
    - Weakness: Users have to get into the habit of filling in the cards.

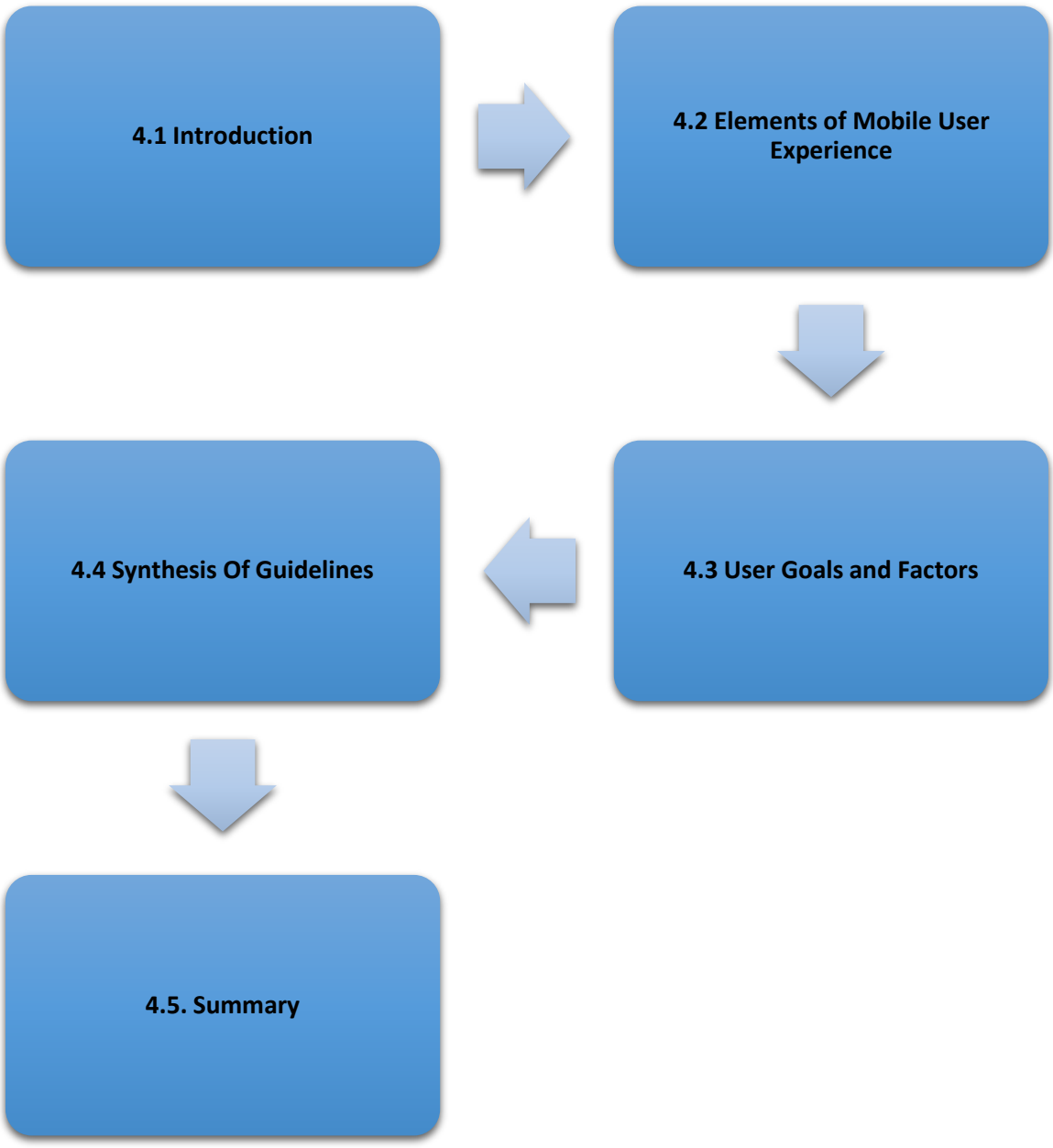
- **Reaction checklists:** Throughout the evaluation process, the user is given a list of possible reactions. The user is then required to select a reaction that applies most to what the user is experiencing at that moment;
    - Strengths: Lightweight and can be done remotely or in a group.
    - Weakness: This method provides summative data only.

- **Mental Mapping:** Users will be requested to complete specific tasks on a design. Once they have done so, they will then select, for example, a famous person or movie that best describes their experience with the device;
    - Strengths: Participants do not have to invent rational reasons for using the product.
    - Weakness: This method is mainly used for assessing visual design and not functionality.

3.4. Summary

This chapter discussed the concepts of human computer interaction, user experience and how these relate to users with motor disabilities. The chapter highlights the need for further research in this space. Despite that, it does provide some guidance on the unique considerations for technology and systems for persons with motor disabilities.

4. GUIDELINES FOR THE USER EXPERIENCE OF MOBILE PHONES



4.1 Introduction

This chapter seeks to address the following research question:

What are the existing user experience guidelines for motor impaired users interacting with mobile phones?

This chapter investigates a list of guidelines such as UI design, usability, UX, accessibility, and mobile phone design guidelines. The purpose of investigating the various policies is to understand their applicability to assist the researcher in deriving a synthesis of guidelines which will be used to determine a list of usability tasks and UX questions to be used in the case study for this study.

This study recognized that to improve the mobile user experience for motor impaired users, alterations would have to be implemented in the following areas (factors):

- **User interface design**: Pertains to the design of the user interface (UI), the part of the system the user interacts with;

- **Usability**: Pertains to how easy it is for a user for a user to interact with a system. This study recognizes that usability is defined by interaction design and navigation design;

- **Accessibility**: Concerns ease of use, for users with disabilities focus is placed on whether a disabled user is able to interact with system as easily as a fully abled person;

- **User experience**: Pertains to the level of satisfaction a user receives when interacting with a system, i.e. what does the user experience emotionally when using the system.

To follow various policies pertaining to the identified areas of interest will be listed and discussed. This discussion will be concluded with a synthesis of guidelines which is based on crucial points found in literature.

4.2 The Elements of the Mobile User Experience

On a daily basis thousands of people contribute to the mobile phone market by purchasing a new device, accessories, and mobile apps, since there is a wide range of products available to consumers. As in every other market, no product is alike. Mobile phones differ from one another as there are a number of competitors in the market, each one designing their own products for the common user. Each user is different from the other. This creates a challenge for designers as they have to try their best to meet various user needs on each device that they design. Various rules and guidelines exist to aid and assist designers in the design of their products.

Unfortunately, mobile phones still have room for improvement, especially when considering the needs of motor impaired users.

Various elements work in unison in order to create the mobile experience. By dissecting the mobile experience into its key components, a conceptual framework for building and evaluating good mobile experiences within the user-centred approach for designing for mobile use is provided (Cerejo, 2012). The sections to follow will discuss each of the elements depicted in Figure 4.1 and elaborate on a set of guidelines per element (Cerejo, 2012):

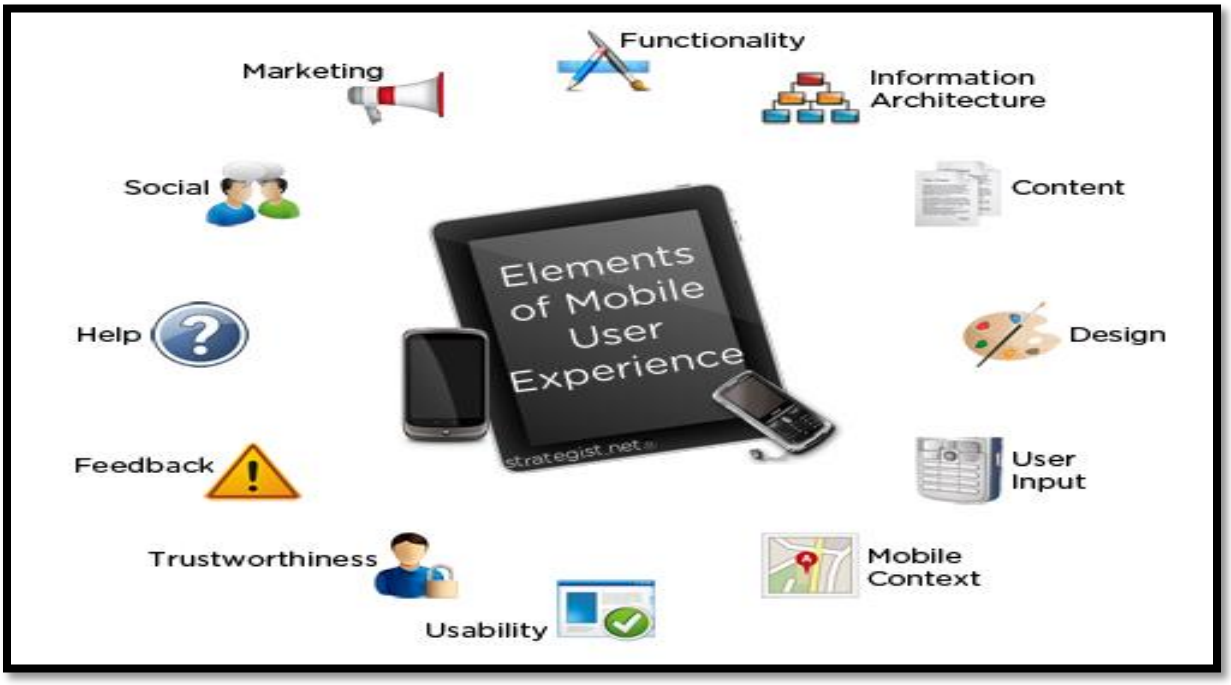


Figure 4.1 Elements of Mobile User Experience (Cerejo, 2012)

Functionality

The term functionality can be described as the various tools and features of a mobile phone that enables the user to perform different tasks and to achieve different goals.

Guidelines:

- Ensure that fundamental features and content are optimized for mobile use;
- Offer mobile-only functionality whilst enhancing functionality by using the capabilities of the device to provide a satisfactory experience to users;
- Offer key capabilities across all channels, on various devices that are mobile optimized.

Information Architecture and Content

Information architecture refers to the way that content and functionality on a mobile phone is organized. It can be seen as the logical structure that assists users in finding information and completing tasks. Content refers to the information that is provided to the user. This can be in the form of text, images, and video.

Guidelines:

- Provide links to main features and content on the landing screen. This screen should be prioritized to the user's needs;
- Users should be able to navigate through the device/application with ease. This means that users should be able to navigate to important content by taking as few steps as possible;
- Organize content in easy to understand, simple layouts that adapt to various screen sizes.
- All content should be mobile appropriate, meaning that content that is accessible by means of desktop computer should be as accessible on a mobile phone;
- Primary content should be easily accessible and presented in a format that is supported on the target device;
- Use multimedia that supports the user's tasks in a mobile context and adds value to the content. For example, an instructional video can be more supportive than a paragraph of text.

Design

The design of a mobile phone includes the visual presentation, interactive experience, and layout of the device.

Guidelines:

- Design for productivity. In other words, designers should design for glance ability and quick scanning, which enables users to perform tasks in a quick and easy manner;
- Layouts should have a fluid and simple design since various devices have different dimensions and screen resolutions (Jain, 2015);

- Design for touch and visual flow. The design of the device should bring the architecture, content, and functionality of the device together to deliver a positive experience;

User Input

User input refers to the user's effort to enter information on the mobile phone. This can be achieved by entering information onto the mobile phone or by making a phone call.

Guidelines:

- Input should be limited to essential fields only. For example, when a user has to enter text, the focus should be on the textbox where information needs to be entered;

- Alternative input mechanisms should always be available to the user with regard to various input techniques;

Mobile Context

The term context refers to the environment and to the circumstances of usage that surround the user.

Guidelines:

- Use device features and capabilities to anticipate and to support the user's context of use. In other words, the mobile phone should try to adapt to the user's needs;

- Apps on mobile phones should adapt to the user's context. For example, depending on the app in use, the app should be able to recognize the time of day and react accordingly;

Usability

Usability refers to the extent that the user is able to use the device. In other words, usability is all about easy to use and understandable systems.

Guidelines:

- Make it clear to the user what the mode of interaction is , and that the user knows exactly where the input and output of the device takes place;

- Do not rely on technology that is not supported by the user's device, such as plugins like Flash, and JavaScript;

- Follow conventions and patterns to reduce the learning curve for users. In other words, make use of a universally consistent design that users recognize and can learn in the blink of an eye.

Trustworthiness and Sociability

Trustworthiness refers to the amount of trust, confidence, and comfort that the user has when interacting with the mobile device. On the other hand, the term social refers to the amount of social belonging and participation that the user gets when using the mobile phone.

Guidelines:

- Do not collect personal information from users without asking the users for permission, for example, asking for the user's location via GPS;

- Create and maintain a presence on social networks in the design of apps. Enable this by incorporating social networking features in the design of apps.

As mentioned, previously listed is a set of guidelines pertaining to the design of mobile phones and applications. It is derived that these guidelines focus on the common user, non-disabled users. This is said due to these guidelines lacking focus on various factors that should be considered for disabled users i.e. motor impaired users. For example none of the listed guidelines focus on the implementation of accessibility features to provide easier access to disabled users. This therefore represented an opportunity to test the applicability of these guidelines for motor impaired users.

4.3 Natural User Interface Principles

The term principle can be defined as the values that represent what is desirable or positive for a person, group, or some sort of object. To follow, are the overriding principles that represent what an NUI should represent. In the absence of specific guidelines, this research will consider the principles as a form of guidelines. There are four principles as listed below (Wallach & Radvak, 2010):

- **Realism:** Most NUIs should have an interface that is simple to use and understand. This means that the design of the interface should be a design that is intuitive to the user. Applications should have a realistic look and feel that is consistent and responsive to the user's interactions;

- **Content is the interface**: The design of the interface should be based around the content that is available to the user, since the user interacts directly with the content, for example, the content of a touch screen device. Users should be able to interact easily with the

content and feel in control of the task at hand. The interface should not be flooded with user controls to assist the user in completing a task. Instead, the user's control should be enhanced by means of direct manipulation. To improve the overall experience for the user, it is imperative that appropriate gestures are used for interacting with content;

- **360 Paradigm**: An NUI should be designed in a manner that it can be used in various situations on various platforms, for various users. It is imperative that an NUI application can adapt to various screen orientations, since there is no user expected orientation;

- **Less is more**: As mentioned, the interface should not be flooded with unnecessary content or user controls, meaning that the content displayed on the screen is needed to complete the task at hand. To encourage this, one should design for discoverability. In order to achieve discoverability in a system or application, step by step exploration should be encouraged.

4.4 User Experience Goals and Factors

This section outlines and presents user experience goals and factors to consider when design the various components that contribute to the user experience.

4.4.1 User Interface Design Guidelines

Nielsen (1995) developed ten heuristics or then user interface design guidelines to guide not only user interface design but also interaction design. Over time, the heuristics evolved into a checklist towards good user experiences. The ten heuristics as defined by Nielsen (1995) are:

- **Visibility of system status:** The system should always keep users informed of what is taking place on screen. This should be done by means of feedback in an efficient manner;

- **Match between system and the real world:** The system should be designed in a manner that is understood by the user. The interface should include phrases and concepts that is natural to user instead of system orientated terms;

- **User control and freedom:** Users should feel in control when using the system. A user should be able to make use of undo and redo functions when necessary;

- **Consistency and standards:** Platform conventions should be followed throughout the design of the system. The user should not wonder whether different situations or words mean the same thing;

- **Error Prevention:** The interface should be designed in a manner that prevents the user from creating errors when interacting with the system. When errors occur, error messages and functionality to assist the user in recovering should be in place;

- **Recognition rather than recall:** Promote ease of use by minimizing the user's memory load. Objects, actions, and option on screen should be visible to the user at all times. Therefore preventing the user from having to remember content on screen;

- **Flexibility and efficiency of use:** Users should be able to interact with the system in an effective and efficient manner. Users should be able to tailor frequent actions;

- **Aesthetic and minimalist design:** Display on screen information that is necessary and needed. Prevent the use or display of unnecessary content, as this will move the users focus away from what is important;

- **Help users recognize, diagnose, and recover from errors:** Assist the user when needed in an efficient manner. Error messages should be displayed in a manner that is understood by the user and assists in error recovery;

- **Help and documentation:** Users should be able to find help when needed, this information should be presented in a manner that is clear and concise.

4.4.2 HCI Principles

There are some important principles that have been derived from decades of research in HCI that apply to design and user research, these principles are as follows (Sauro, 2013):

- **Miller's law of short term memory load**: a psychologist known as George Miller, suggests that most people can only hold approximately seven pieces of information in their short term memory. This law should not be applied to e.g. a list of items or a menu because the selection task does not require users to memorize the information;

- **Fitts' law**: is a mathematical way to determine how long it will take to acquire a target based on its distance and size. When this law is applied to interface design, it means that it takes users longer to point to links and buttons on screen if these objects are small in size or far away from the home position. It forms part of Keystroke level modelling which assists in predicting how long it will take skilled users to complete a task;

- **Hick-Hyman law**: this law deals with the time it takes for a user to make a decision based on the amount of choices available to the user. To reduce this, developers should

subdivide the collection of choices into categories, which eliminates about half of the remaining choices at each step instead of having the user having to consider each choice;

- **Power law of practice**: Newell Rosenbloom states that the time to complete a task decreases linearly with the number of practice trials taken when both are expressed as logarithms. In mathematics, a logarithm is an amount representing the power that a fixed number must be raised to produce the desired number. This is where the learning curve is derived from.

4.4.3 Usability Guidelines

For a system to be usable, the user should be able to achieve their goals in ease when using the system. A system that is usable will meet the following usability goals (Writer, 2013):

- **Speed**: Can the user complete tasks in a n efficient manner;
- **Accuracy**: can the user complete tasks within a minimal amount of attempts;
- **Overall success**: pertains to the percentage of users who are able to complete tasks;
- **Satisfaction**: are users satisfied throughout the process of completing tasks.

A system that applies these goals throughout the design of the system, is more than likely to result in system that is pleasant to use which positively contributes to the UX. Nielsen (2012) states that a usable system should entail the following characteristics (Nielson, 2012):

- **Learnability**: how easy is it for users to complete basic tasks the first time they encounter the design?

- **Efficiency**: once users have learned the design, how can they perform the tasks?

- **Memorability**: when users return to the design after not using it for a period of time, how easily is the user able to remember how to operate the design?

- **Errors**: how many errors do users make, how severe are these errors, and how easily is the user able to recover from the errors?

- **Satisfaction**: how pleasant is it to use the design?

With regards to usability for mobile phone use by users with motor impairments, this study recognized that two key areas of usability can be pointed out, namely user interaction and navigation as they contribute to the usability of a system.

4.4.3.1 Interaction Guidelines

For a system to be usable, users should be able to carry out user tasks in a simple and efficient manner that assists the user in reaching their goal. To achieve this, users need to interact with the system through interaction methods that are understandable and easy to use. Users need to feel connected to the system, where the goal is to "making things that are screen-based, appear real and function in the digital realm as they would in the physical space" (Cousins, 2015). Ultimately developers should aim to implement interaction methods that are as natural as possible, to assist interaction designers various guidelines/principles exist, these should be used as a guide when designing systems. An example of interaction guidelines are (Seys, 2010):

Guideline 1: Match experience and expectations

Implement UI patterns that minimizes the user's learning curve. Aim to match the steps, information architecture and terminology used with the expectations and experiences of the user.

Guideline 2: Consistency

Maintain a consistent design throughout the system, this enables users to learn more quickly and gain easier understanding of the system.

Guideline 3: Functional minimalism

Avoid flooding the user with interactions that are unnecessary, this will lead to distracting the user from the systems primary functions which will negatively contribute to the systems usability. To achieve functional minimalism:

- Avoid unnecessary features and functions;
- Divide complex tasks into sub tasks;
- And limit functions rather than UX, aim for quality instead of quantity.

Guideline 4: Cognitive load

The aim here is to reduce the user's memory load or "thinking load". Interactions need to be implemented in a manner that easy to use and understand. Here users should be able to make use of their current skills to their benefit instead of having to complete actions that requires the user to do the unnecessary.

Guideline 5: Engagement

User engagement is an imperative aspect that contributes to UX. To be engaged in a system implies that the users interest, motivations and goals are put first (Spillers, 2014). If a user has an

engaging experience with a system, a platform is created for the user to be more productive when using the system. The user should feel in control at all times when interacting with the system. Throughout this interaction the user should feel as if they are achieving something whilst being able to see results through appropriate feedback. It is imperative that users should focus on the task at hand, their work, and not the UI.

Guideline 6: Functional layering

Users should not spend unnecessary time looking for information on screen or figuring out how to use the system. The most important and common functions should be the easiest to find, enabling the user to interact in an efficient manner. Focus should be placed on efficiency, this can be achieved by reducing the prominence of infrequently used functions. By implementing functional layering, experienced users are able to able to access advanced functionality without affecting novice users.

Guideline 7: Control, trust and exportability

It is important to implement these 3 elements throughout the design of any system. Allow users to feel in control by using interaction methods that are simple and responds to the user with an expected response. If a user is in control, they will learn to trust the system as they feel protected when interacting with content. Once a user feels they can trust a system, they feel confident and confidence promotes exportability within the system.

Guideline 8: Error prevention, detection and recovery

- Error prevention:
    - Disable functions that are not relevant to the user;
    - Use radio buttons or drop down lists to constrain inputs;
    - Provide clear and descriptive instructions to the user;
    - Display clear warning messages when necessary.
- Error detection:
    - Try to anticipate possible user errors, and provide feedback that verifies users that they have achieved their intended action, and the action they have completed is correct.
- Error recovery:
    - If an error occurs, provide the user with options to go back or redo their intended action;

Guideline 9: Affordance

Affordance refers to the quality of an object that allows a user to perform an action, in other words the control on screen should be a representation of how it should be used. For example a button should represent a clickable object. This can be achieved by:

- Simulating the physical world affordances;
- And keeping consistency throughout the design of the system by following various UI design standards.

Guideline 10: Hierarchy of control

Group elements and controls that relate to each other to form a hierarchy. For example, control to zoom in and out of a map on screen should be grouped together.

4.4.3.2 Navigation Guidelines

User navigation is an important aspect of any interactive system as it enables the user to explore the system and access content. Navigation design should work for both users and system designers as it should be used to lead users to important information within the system. To ensure user friendly navigation, the following guidelines could be applied (Pierce, 2015):

Guideline 1: Embrace predictability

Practice creativity only in areas where predictability is not required. When users need to navigate between screens to gather information, use methods that are simple and efficient. Navigation should be obvious to the user.

Guideline 2: Keep it simple

Navigation methods should be easy to read and understand. Keeping it simple should go hand in hand with predictability, as predictability should only be applied when needed. For example, if the UI is full of grouped menus in an unorganised way, the user will find navigation challenging.

Guideline 3: Do not overdo minimalism

Minimalism promotes UI designs that display as little content as possible, i.e. only displaying content that is necessary. The goal here is to promote white spaces on screen and simplified typography. The concern here is that minimalism should not be overdone as it can lead to navigation that can be deemed useless.

Guideline 4: Keep it consistent

System structure and design should remain consistent throughout the system. This is beneficial for first time users, as they are able to make sense of it in a few seconds. Hereafter the user will expect all interface screens to similar in terms of structure and design. Having a design that changes per screen will result in a frustrated user as the users understanding of how the system operates changes each time.

Guideline 5: Clear hierarchical structure

Menus on screen should have hierarchical structure which includes all categories and clickable sub categories. This information should be presented in an order that is understandable as this gives the user an idea of what is on offer in an efficient manner.

Guideline 6: Make it manageable

Navigation should be implemented in a manner that is clear and concise to the user. Navigation within a system becomes usable when it tells the user where they came from, where they currently are, and where they can go to. Managing user navigation in this manner will make the user feel in control which promotes use of the system.

Guideline 7: Always provide a search bar

Providing users with the ability to search for content on screen enables quick access to information, especially when dealing with large amounts with content on screen.

4.4.4 Accessibility Guidelines

For all users, accessibility is an important element as it promotes ease of use and barrier free access to user content. For users with disabilities, accessibility is extremely important as the goal here is to "use a product or service as effectively as a person without a disability" (InternetSociety, 2012). With regards to accessibility, a disability is not seen as a medical condition but rather as a condition brought upon the person as a result of social barriers, this implies that a disabled person is impaired by objects or situations within society such as a staircase in a building. To defeat this, inclusive design principles need to be applied to the design of products and services so that they can be used by all, such guidelines/principles include (Hausler, 2015):

Guideline 1: Accessibility is not a barrier to innovation

- Designing for accessibility does not mean that the system has to lack in terms of visual appearance;

- Accessibility introduces a set of design constraints that should be used as a guide in the design of any interactive system;

- Accessibility standards should be embraced as any other set of design constraints.

Guideline 2: Do not use colour as the only visual means of conveying information

In some cases uses might find it difficult to distinguish one colour from the other, following this approach will assist users in this regard. Instead colour should be used to highlight and compliment what is already visible to make it standout, this especially applies to important functionality or content on screen.

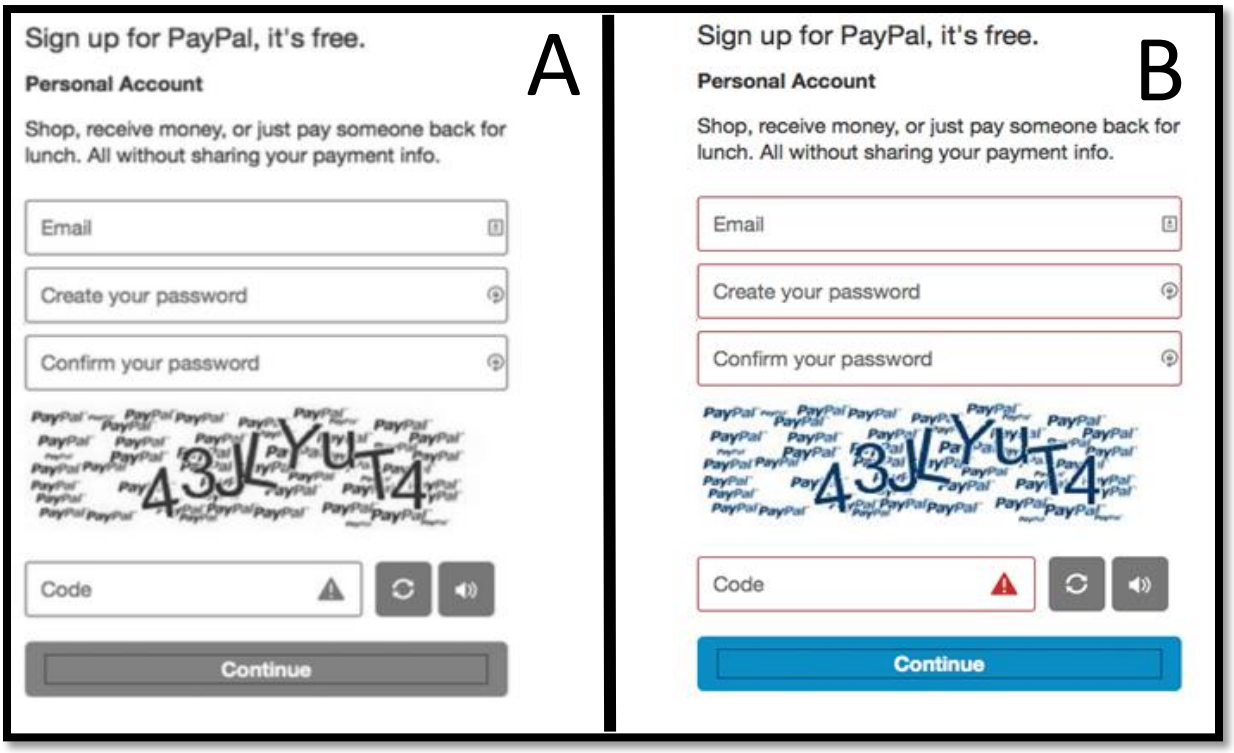


Figure 4.2 A: example of content on screen displayed in grayscale. B: Example of content on screen displayed in colour

Figure 4.2 is an example of how colour should be used to improve interface design, when comparing A to B it is clear that B is more direct and speaks to user by pinpointing or highlighting important content. This can be achieved in various ways by implementing borders, text fonts and tooltips. Various colours can be use, but they should be used on their own.

Guideline 3: Ensure sufficient contrast between text and the background

The background of text on screen should not cause the text on screen to appear invisible, it is advised that the contrast ratio should at least be 4.5 to 1. This approach assists users with poor vision to see and read text on screen. Designers should aim to make use of designs that use high contrasts as they are more vivid.

Guideline 4: Don't make people hover to find things

This mainly applies to people with motor disabilities as they are more than likely to have dexterity issues that will affect the completion of concise interactions such as having to hover of a button on screen. Instead of hiding actions and information through means of hover actions, make use of alternatives such as:

- Secondary actions should be contained inside menus without having to complete hover actions view the content;
- Use a light contrast for secondary icons and darken them on hover;
- Implement tangible items as triggers for large hover items, for example an information icon is a better trigger than blank white space.

4.4.5 W3C Accessibility Guidelines (WCAG 2.0)

The following principles are derived from the World Wide Web Consortium (W3C), an international community that focuses on the development of web standards. The W3C claims that if anyone wants to use the web, content must be perceivable, operable, understandable and robust (WCAG 2.0. guidelines). They state that if any of these principles are not applied, users with disabilities will not be able to interact with content successfully (Caldwell, Cooper, Reid, & Vanderheiden, 2008):

- **Perceivable**: all content on screen should be displayed in a manner that it can be perceived and understood by all users. In other words, users should be aware or realize that there is content on screen;
- **Operable:** all controls and content on screen should be usable and fulfill its purpose. Users should be able to make use of the system in a manner that is simple and understandable;
- **Understandable:** users should have an understanding of how the interface operates. Interacting with content on screen should be done in a manner that is simple in design and easy to make sense of;
- **Robust:** elements on screen should be robust enabling users to interpret content in a reliable manner. For example, content should remain accessible to users using assistive technologies. Note that as technology evolves, content should remain accessible.

The guidelines derived from W3C (2008) are seen as a general rule of thumb that should be applied to the design of web content for accessible use by disabled users. The next section provides an overview of the use of these guidelines for mobile phone accessibility (Patch, Spellman, & Wahlbin, 2015):

- **Perceivable**
  - **Small screen size**: display content on screen that is necessary only, avoid the use of large amounts of content modules and images, focus should be placed on mobile usage scenarios; and content should be sizes and formats that is readable;
  - **Zoom/magnification**: when applied magnification should be applied to the entire screen; magnify lens view under the users finger; magnify browsers viewport; all magnify features should allow users to pan content;
  - **Contrast**: contrast (minimum, level AAA) requires a contrast of at least 4:5:1 or 3:1 for large-scale text; contrast (enhanced, level AAA) requires a contrast of at least 7:1 or 4:5:1 for large-scale text;

- **Operable**
  - **Keyboard control for touchscreen devices**: enable the use of external input devices that can be connected for example via Bluetooth; visually impaired users can benefit from physical keyboards such as separated keys, key nibs and predictable layouts; users with mobility disabilities can benefit from keyboards optimized to minimize inadvertent presses;
  - **Touch target size and spacing:** ensure that touch targets are at least 9 mm high by 9 mm wide; touch targets close to minimum size should be surrounded by a small amount of inactive space;
  - **Touchscreen gestures:** gestures should be easy to carry out especially when using screen reader modes that replace direct touch manipulation with a 2 step process of focusing and activating elements; make use of appropriate methods for mouse and touch interactions to prevent unintentional actions;
  - **Device manipulation gestures:** some mobile applications require input from physical manipulation of the device such as shaking or tilting, for users with disabilities this sort of interaction might not always be possible, therefore alternative methods of interaction should be put in place;
  - **Placing buttons where they are easy to access:** regardless of device positions, all content on screen should be reachable and accessible since mobile phones can be held in different positions; flexible placement of content on screen should be considered as some users might be left or right handed or be unable to use both hands at once;

- **Understandable**
  - **Changing screen orientation:** some mobile applications are required to run in either portrait or landscape orientations and requires the user to rotate their device, this is not always possible for disabled users as their device might be mounted in a fixed orientation such as on the arm of a wheelchair. With this said, developers should aim to develop applications that can be easily used in both orientations without the sacrifice of functionality;
  - **Consistent layout:** since most interfaces might have repetitive content, it should be displayed in a consistent manner. Web pages in a particular view should be consistent in the placement of repetitive content. Note that consistency between different screen sizes and screen orientations is not a requirement under WCAG 2.0;
  - **Positioning important page elements before page scroll:** mobile phones require users to scroll through information, in this regard important information should be positioned so that it is visible without having to perform scroll operations, and this is highly beneficial for users that suffer from poor vision and cognitive impairments. The goal here Is to limit user interaction as much as possible as this speaks to a consistent layout as well;
  - **Grouping operable elements that perform the same action:** controls on screen that perform the same function or navigate to the same screen should be grouped together. This increases the touch target size for all users, especially for users with limited dexterity.
  - **Provide clear indication that elements are actionable:** controls on screen that cause a change in system states should be clearly visible and distinguished from non-action controls/elements. This can be achieved through the use of a combination of shapes and colors for controls on screen;
  - **Provide instructions for custom touchscreen and device manipulation gestures:** various forms of interaction exist, in some cases custom gestures are in place to achieve interaction. For many people, the use of custom gestures and interactions can be difficult to perform and remember. For this reason, instructions should be provided to explain which gestures can be used to interact with the interface and if alternative methods are available. These instructions should be discoverable and accessible;

- **Robust**
  - **Set the virtual keyboard to the type of data entry required:** some mobile phones enable users to customize keyboards on screen. For different actions/requirements users should be able to customize keyboards according to the type of data entry.

- **Provide easy methods for data entry:** text entry on a mobile phone should be done in an easy efficient manner. To achieve this, text entry can be reduced through the selection of menu icons such as radio buttons and check boxes;
- **Support the characteristics properties of the platform:** depending on the features, platforms/applications should adapt to the features of the device. For example, if the zoom function is used, content on screen should wrap appropriately instead of having to scroll horizontally.

4.4.6 User Experience Guidelines

It is required of developers to consider the user's needs in the design and implementation of a product or service should they wish to ensure a positive user experience. To aid developers in the implementation of products and services that deliver great experiences to its users, some sort of guideline should be adopted. The UX Honeycomb was designed by Peter Morville of Semantic Studios in 2004. The Honeycomb represents seven aspects that developers should try to maximize in their applications. See Figure 4.3 for an illustration of the UX Honeycomb.

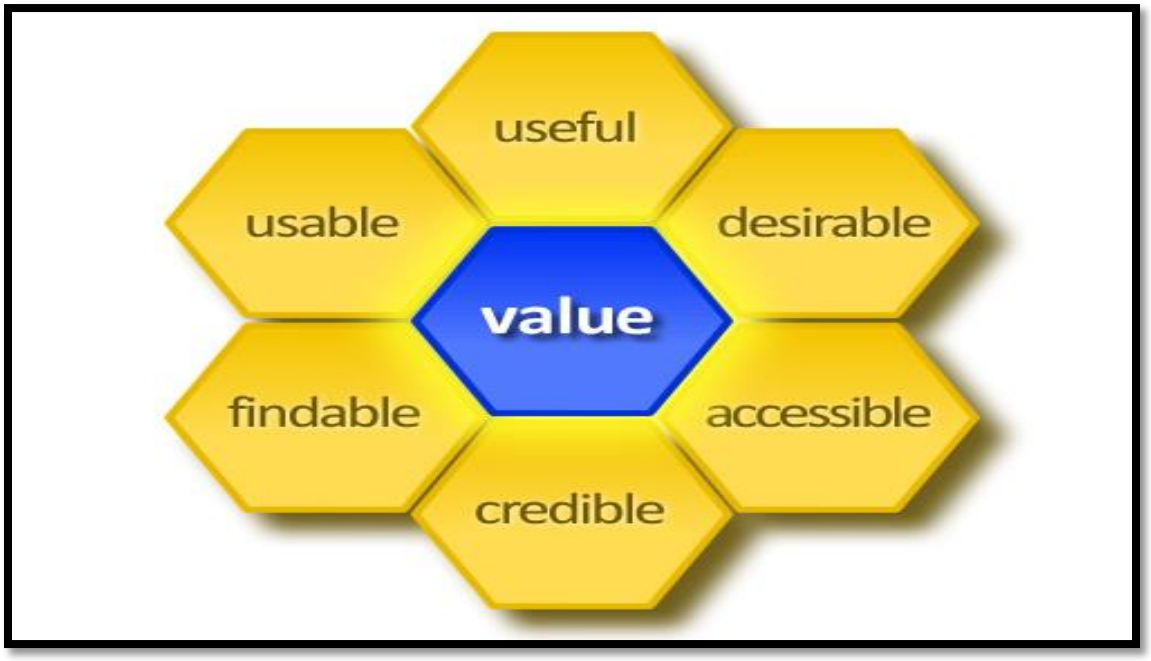


Figure 4.3 User Experience Honeycomb (Semantic Studios, 2004)

To follow, each of the seven aspects will be discussed to provide a better understanding of the concept (Morville, 2004):

- **Useful** – It is imperative that the product or service is useful and suits the user's needs. The product or service should allow users to perform tasks that will aid them in achieving goals that the user wants to achieve through the use of the product or service. For

example, users making use of Blackberry Messenger to achieve the goal of communicating with other users;

- **Useable** – Ease of use is vital. The product or service should be designed in a manner that it makes navigation and performing tasks a pleasant experience for the user;

- **Desirable** – To design a product or service that is desirable, users should feel the need to make use of the product or service. To achieve this, the product or service needs to deliver a pleasant user experience to its users;

- **Findable** – Developers should strive to design navigable applications and locatable objects. This enables users to make use of the product or service with ease;

- **Accessible** – The product or service should be easy to use by all users, including users with disabilities. As a developer, various factors will need to be considered that will aid in making the product or service usable by all users. Factors include: the interaction style to be used, the size of the text in your application, and accessibility features;

- **Credible** – The product or service should convince users to make use of your application. To achieve this, the product or service must fulfil its purpose and provide value to the user;

- **Valuable** – As mentioned, it is imperative that your application serves a purpose and is designed according to what the user desires.

To assist in determining the impact user characteristics have on the UX, a hierarchical approach can be taken such as the hierarchical quality in use and UX evaluation model, see Figure 4.4 (Lew, 2014).

Hierarchical quality in use and UX evaluation model includes various elements that contribute to determining UX for mobile phones. As previously mentioned context plays a major in the UX of a product or service, especially when considering mobile phones due to the mobility of these devices. Contextual factors include the following (Lew, 2014):

- **Activity**: the time a user completes an activity, plays a major role on the users attention span. For example, a user could be completing a task on their mobile phone whilst driving, this will result having to concentrate on two different tasks at once;

- **Time of day**: the time of day can play major role when using mobile devices due variations of natural light which could affect visibility;

- **Location**: the location of the user influences many elements due to their surroundings.

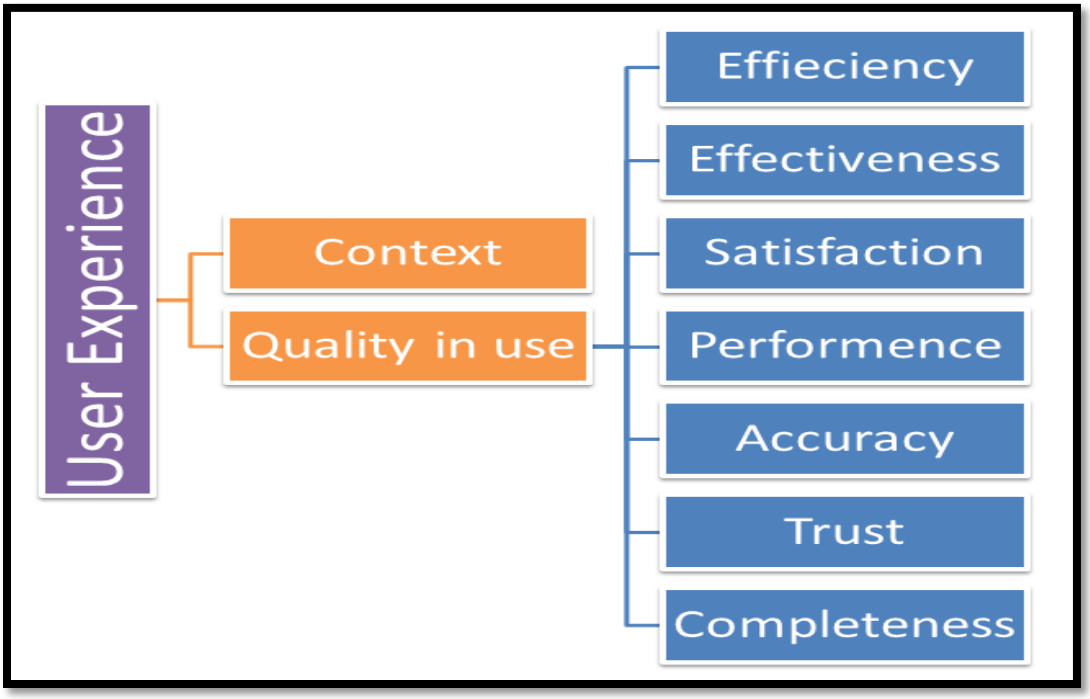


Figure 4.4 Hierarchical Quality in Use and UX Evaluation Model (Adapted from Lew, 2014)

These contextual factors influence the following UX factors:

- **Efficiency**: in UX efficiency refers to the degree to which effort is facilitated. In other words the user should be able to complete interaction with the system in fewest steps possible (Sapounakis, 2011);

- **Effectiveness**: refers to goal achievement, can users complete their desired goals (Thurow, 2014);

- **Satisfaction**: refers to the amount of pleasure the user receives when using a system;

- **Performance**: refers to the time it takes for the user to complete a task (Lew, 2014);

- **Accuracy**: Refers to the way the system responds to the users commands in terms of the results that are delivered. How accurate are the results;

- **Trust**: refers to the user's willingness to risk time, effort, and in some cases money to make use of the system;

- **Completeness**: this refers to the completeness of the system. In other words is the design of the system complete.

4.5 Mobile Phone Guidelines for Motor Impaired Users

The section presents a synthesis of guidelines based on the listed guidelines from literature. The purpose of this section is to present the guidelines that apply to mobile phone use by users with motor impairments. Table 4.1 summarises the guidelines from literature that were taken into consideration for the design of a usability study which was made up of usability testing and a UX questionnaire. Each guideline is listed with the factor that applies to it as mentioned in section 4.1. These guidelines were selected as a result of their applicability to mobile phone design for motor impaired users, in other words these guidelines are imperative when concerning the needs of motor impaired users. It is noticeable that none of the listed guidelines are directed to motor impaired users as there is a lack of this in literature.

Author	**Guidelines**				
Cerejo (2012)	Functionality	Design	Usability		
	Factor: usability, accessibility	**Factor: UI design, UX**	**Factor: usability, UX**		
Wallach & Radvak (2010)	Content is the interface	Less is more			
	Factor: UI design	**Factor: UI design**			
Nielsen (1995)	Guideline 1: visibility of system status	Guideline 3: user control and freedom	Guideline 4: consistency and standards	Guideline 5: error prevention	Guideline 6: recognition rather than recall
	Factor: UX	**Factor: UX, accessibility**	**Factor: UI design**	**Factor: UX, usability**	**Factor: UX**
Sauro (2013)	Milters law of short term memory load	Hick Hyman law			
	Factor: UX	**Factor: UI design**			
Seys (2010)	Guideline 3: functional minimalism	Guideline 4: cognitive load	Guideline 6: functional layering	Guideline 10: hierarchy of control	
	Factor: usability	**Factor: usability, UX**	**Factor: UI design, accessibility**	**Factor: UI design, accessibility**	

Pierce (2015)	Guideline 2: keep it simple	Guideline 3: don't overdo minimalism	Guideline 6: make it manageable		
	Factor: UI design, accessibility	**Factor: UX**	**Factor: usability**		
Haulser (2015)	Guideline 3: ensure correct contrast	Guideline 4: don't make people hover			
	Factor: UI design	**Factor: usability, accessibility**			
W3C (2016)	Understandable	Operable			
	Factor: accessibility	**Factor: usability**			
Morville (2004)	Findable	Usable	Useful	Valuable	
	Factor: usability, accessibility	**Factor: usability, accessibility, UX**	**Factor: usability**	**Factor: UX**	

Table 4.1 Guidelines for usability study evaluating mobile phone use by motor impaired users

4.6 Summary

This chapter discussed a set of guidelines that focuses on the design of mobile phones and UIs in terms of UI design, usability, accessibility and UX. It was found that there is a lack in literature with regards to guidelines that are directed to motor impaired users using mobile devices with regards to the identified factors. This chapter concluded with a summary of guidelines that can be adapted to be used in the evaluation of mobile phone use by motor impaired users. The summarized guidelines are to be used in the usability study as part of the case study for this research study.

5. RESEARCH METHODOLOGY

5.1 Introduction

The research process applied in this study was briefly described in Chapter 1, Section 1.5. This chapter commences with a discussion on human computer interaction research in Section 5.2. Then an outline of the supporting theories regarding research methodologies is discussed in Section 5.3. Once the theories are outlined and argued, the chapter proceeds to describe the research process followed in this study, in Section 5.4.

5.2 Human Computer Interaction Research

This research study is contextualised as a user-focused study that explores the usability of mobile phones when used by users who are impaired by physical disabilities i.e. motor impairments. Thus, the relationship between users and technology is a key aspect of the research study. For this reason HCI research is an important component of this study due to the fact that HCI focuses on the relationship between users a technology to benefit mankind.

HCI research is a multi-disciplinary field informed by computer science, communication, cognitive and behavioural psychology, anthropology, human factors and industrial engineering, sociology and ergonomics, amongst others (Lazar, Feng, & Hochheiser, 2009). Research focuses in HCI have shifted over time since its inception, resulting in the need to adapt existing methods and to develop new research methods as part of the discipline. Consequently, there are many different approaches to research in the field of HCI. Some of these approaches are briefly outlined below.

5.2.1 Psychology

Psychology plays a major role in HCI owing to the fact that it involves the science of the human mind and behaviour (Nordqvist, 2014), in other words, it involves the study of human behaviour, with regards to how human behaviour affected by technology. In HCI humans can be considered as the main component, reason being that if there was no human factor, no interaction with a technological device would exist.

Psychology played a vital role in this study as the study involved human participants testing the accessibility capabilities of a mobile phone. Whilst being tested, the participants were observed by the researcher to assist in determining how the device influenced their overall experience with the device.

5.2.2 Sociology

Sociology can be defined as the study of human nature. This involves the study of social life, social change, and the social causes and consequences of human behaviour (University, 2008). In HCI, sociology involves the impact or changes that take place when technology is a part of the social organization.

As part of this study a set of literature reviews was conducted. One of the literature reviews focused on people with motor impairments to determine the definition of motor impairments, the various types of motor impairments, and the various challenges they face in society and when accessing information.

5.2.3 Computer Science

Computer science is a complex discipline, as it involves the technological component of HCI. This involves computer graphics, artificial intelligence, and computer vision. Computer science, in general, involves the study of the storage, transformation and transfer of information by means of various processors and algorithms (project, 2004).

Technology is one of the major components of this study as research was conducted on the implementation of NUIs for motor impaired users, and the usage of mobile phones by users with motor impairments. An experiment of how users with motor impairments interact with a mobile phone was also conducted.

5.2.4 User Experience Research

User experience (UX) research plays a primary role in HCI research. As mentioned, humans are one of the main contributors to HCI owing to the fact that HCI involves the study of how humans interact with technology. Whilst this interaction takes place, users experience a list of emotions and experiences which contribute to the UX the user is experiencing. In terms of research, UX research involves understanding user behaviours, needs, and motivations through various techniques and methodologies, in order to determine the requirements of the product in use. UX research involves various methods for conducting research (figure 5.1), each one of these methods belong to a dimension namely attitudinal vs. behavioural; qualitative vs. quantitative; or the context of website or product use (Rohrer, 2008). Using the research methods outlined by Rohrer (2008), the study employed specific methods as depicted in table 5.1.

UX Research Method	Attitudinal vs. Behavioural dimension	Context of Product Use	Quantitative vs. Qualitative
Interviews	Attitudinal	Not using the product during the study/method	Qualitative
Usability study	Behavioural	Scripted use of the product	Qualitative
Ethnographic field studies	Behavioural	Natural use of the product	Qualitative

Table 5.1 User experience research methods and dimensions applied within this study

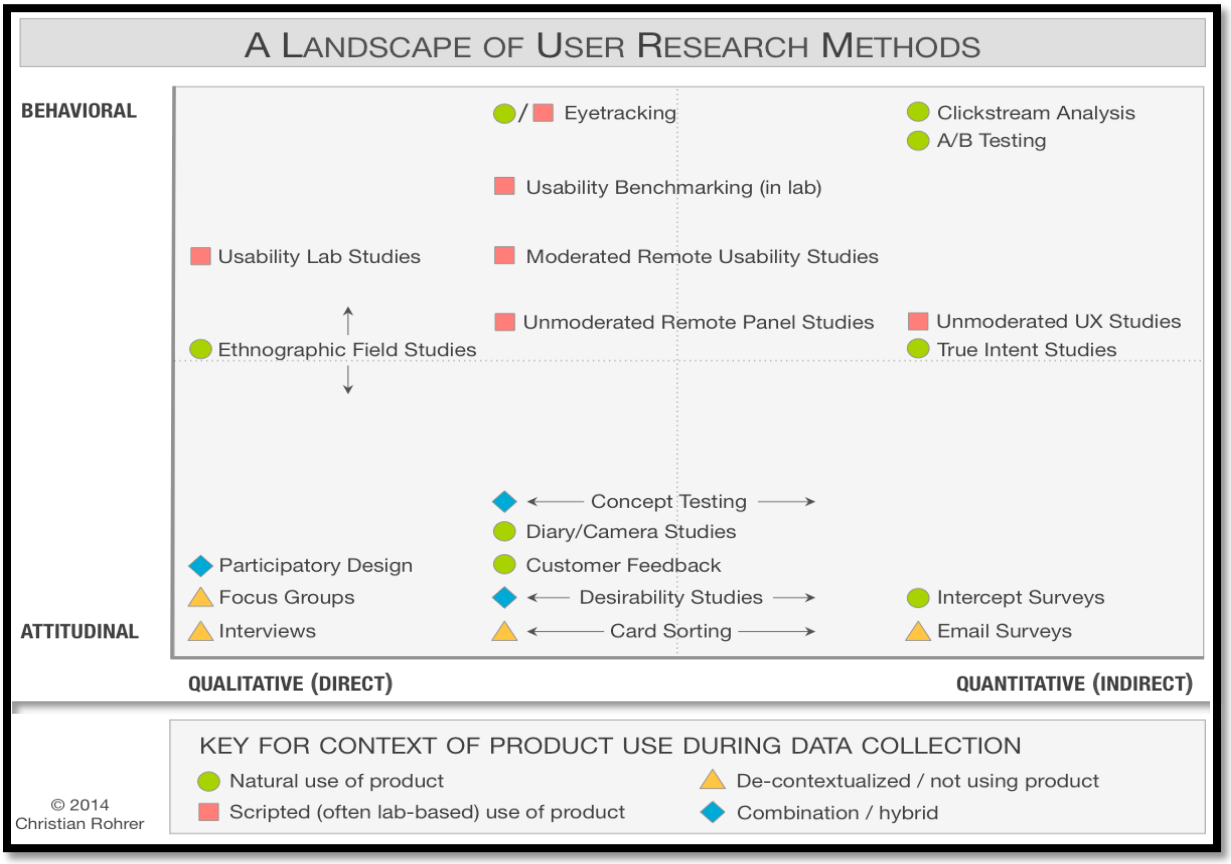


Figure 5.1 User experience research methods (Rohrer, 2008)

The attitudinal and behavioural dimensions distinguishes between what people think and say and what people do. Attitudinal research is used to understand, measure, or inform the change of people's stated beliefs (Rohrer, 2008). This form of research is used primarily in marketing departments. On the other hand, research methods that focus on behaviour seek to understand 'what people do' with minimal interference from the method itself (Rohrer, 2008).

This study is placed more within the behavioural dimension as this study focused on:

- The challenges motor impaired users face when using mobile phones;
- How accessibility features of a mobile phone influences user interaction;

The listed areas of focus involved the participation of human subjects in order to determine how various human traits are effected with such as emotion, efficiency, and productivity.

Within the attitudinal and behavioural dimensions, various research methods can be used. These can be qualitative or quantitative. In qualitative studies the data is being gathered directly, so these methods are better suited for answering questions about how or why to fix a problem (Rohrer, 2008). For example, in the attitudinal dimension a qualitative method would be interviewing, and in the behavioural dimension a qualitative method would be usability studies

(Hey, 2008). In quantitative studies, the data is gathered indirectly. These methods answer questions such as how many and how much (Rohrer, 2008). For example, in the attitudinal dimension a quantitative method would be surveys, whereas in the behavioural dimension a quantitative method would be A/B testing (Hey, 2008). This study implemented qualitative methods in terms of UX research as the aim of the study was to determine "how" motor impaired users make use of a mobile phone whilst data was gathered directly from the users. In terms of answering research questions, in UX research the quantitative and qualitative dimensions are each suited for different approaches.

5.3 The Research process

The sections to follow describes the various layers of the research onion with regards to what it entails and how it was applied in this study as depicted in Figure 5.2.

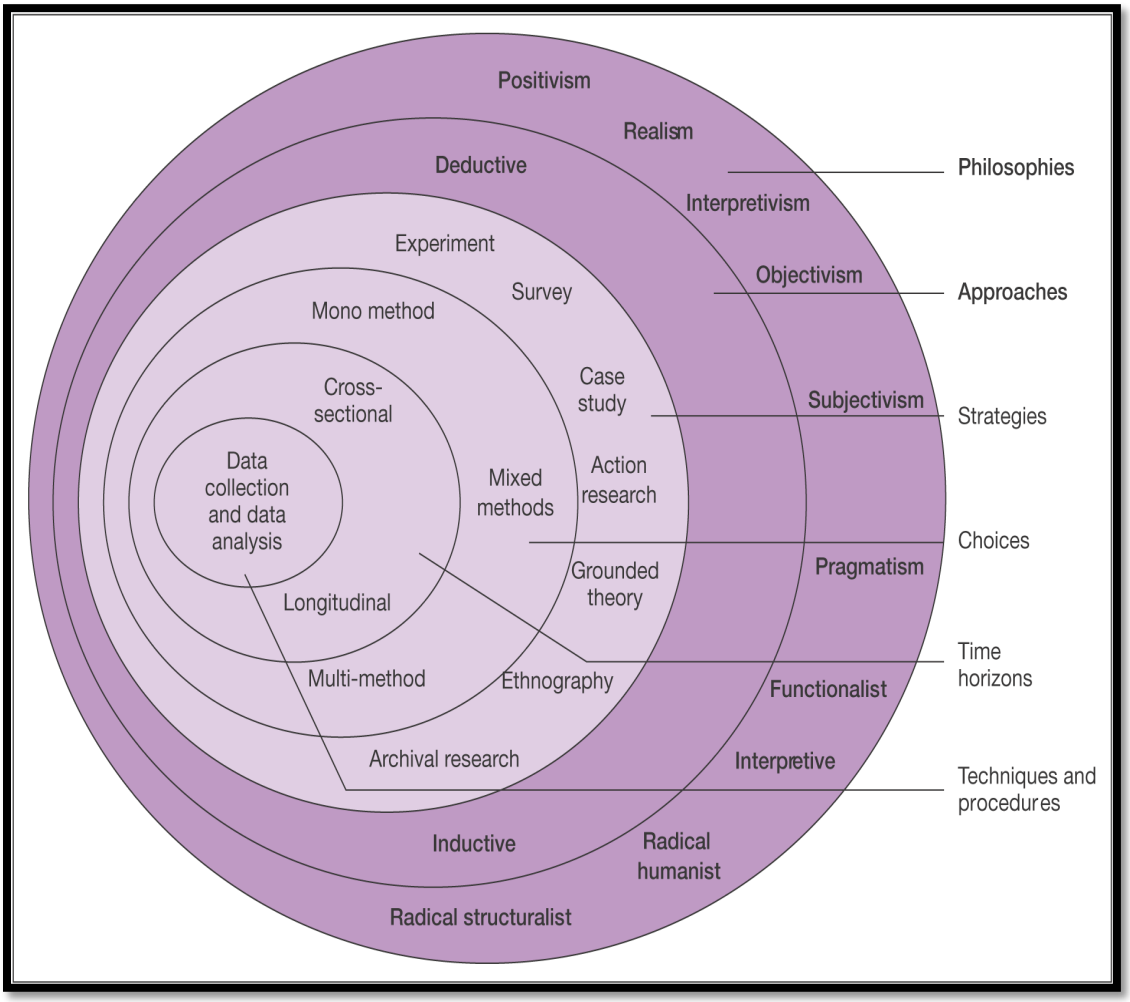


Figure 5.2 Research Onion (Mark Saunders, Philip Lewis and Adrian Thornhill, 2006)

5.3.1 Research Onion: Philosophies

Research philosophy refers to the development of knowledge and the nature of that knowledge (Bandaranayake, 2012). A researcher's philosophy can be referred to as the researcher's personal view of what constitutes acceptable knowledge and the process by which it is developed (Saunders & Tosey, 2012). The research philosophy can be seen to be the process of collecting and analysing data. Within this layer various approaches exist. These are positivism, realism, interpretivism, objectivism, subjectivism, pragmatism, functionalism, radical humanism, and radical structuralism. The most common approaches can be described as follows:

- **Positivism**: refers to philosophical positions that make use of empirical data and scientific methods (Jakobsen, 2013). Using this approach results in the researcher adopting the philosophical stance of the natural scientist (Saunders, Lewis, & Thornhill, 2009).

- **Realism**: realism is associated with scientific enquiry. It states that reality exists independent of the mind (Saunders & Tosey, 2012). In other words, what our senses show us as reality is the truth.

- **Interpretivism**: in Interpretivism it is necessary for the researcher to have an understanding of the differences between humans in their roles as social actors (Saunders, Lewis, & Thornhill, 2009). This approach relates to the study of social phenomena in their natural environment (Saunders & Tosey, 2012).

The research philosophy that was adopted in this study is the phenomenological approach. According to Creswell (2007) a phenomenological study is defined as "a study that describes the meaning for several individuals of their lived experiences of a concept or phenomenon" (W.Creswell, 2007). Following this approach enables the researcher to work closely with the involved participants, study their behaviours and provides an opportunity to gather the necessary humanistic data. This approach was necessary because the study requires the researcher to interact with various participants whilst interacting with the prescribed interaction device for this study (see Appendix H).

5.3.2 Research Onion: Approaches

Two general forms of reasoning exist, namely deductive reasoning and inductive reasoning.

Deductive reasoning involves the development of a theory that is subjected to a rigorous test (Saunders, Lewis, & Thornhill, 2009). The idea is to start out with a general statement or hypothesis and to examine the possibilities to reach a logical conclusion (Staff, 2012). In other words, the deductive approach works from the more general to the more specific. Inductive reasoning involves moving from specific observations to broader generalizations and theories

(Burney, 2008). Following this approach provides a close understanding of the research context and enables a more flexible structure, to permit changes of the research emphasis as the research progresses (Saunders, Lewis, & Thornhill, 2009).

The inductive approach was applied in this study as the research involved the researcher working with various participants. This approach was necessary since an inductive approach creates an environment that provides an understanding of the meaning humans attach to events. This allowed the researcher to gain deeper understanding of what it meant to the participants to interact with a mobile device whilst completing various tasks.

5.3.3 Research Onion: Strategies

The research strategy is the method that aids the researcher in addressing the research issue. It involves a systematic process in which the various research questions are answered. Various strategies exist, and each of these strategies can be used for exploratory, descriptive and explanatory research (Saunders, Lewis, & Thornhill, 2009). The strategies outlined by Saunders *et al.,* (2009) include experiments, surveys, case studies, action research, grounded theory, ethnography, and archival research. This study implemented a single case study as the research strategy. This enabled the researcher to conduct an investigation focused on how new forms of interaction and technologies can be implemented to improve interaction with mobile phones for motor impaired users. A case study was selected for this study. A case study investigates phenomena within its real life context. It can be used in various situations to contribute to our knowledge of an individual, group, organizational, social, political and related phenomena (Yin, 2009). Data is collected from various sources by using different data collection methods such as quantitative or qualitative methods. Two main forms of case studies exist, namely single case studies, and multiple case studies (Saunders, Lewis, & Thornhill, 2009). There are different types of cases study applications and designs and an important aspect of choosing a case study strategy is establishing the number of cases considered in the research. Table 5.2 summarises some of the types of case study designs available to researchers (Baxter & Jack, 2008).

Case study type	Description
Explanatory	Explains causal link in real-life interventions that are too complex for other strategies such as surveys or experimental strategies.
Descriptive	Describes an intervention or phenomenon and the real-life context in which it occurs.

Multiple case studies	Involves the study of more than one case. It focuses on the need to establish whether the findings of the first case occur in other cases, and the need to generalize from these findings.
Exploratory	Explores situations in which the intervention being evaluated has no clear, single set of outcomes.
Single case study	A single case is used where it represents a critical case, or an extreme or unique case. It distinguishes between the phenomenon and its context.

Table 5.2 Various types of case studies (Baxter & Jack, 2008)

5.3.4 Research Onion: Choices

Throughout the research process various methods are used to gather the necessary information. These methods can be divided into mono-methods, multi-methods, and mixed- methods (Saunders & Tosey, 2012). Within these methods either quantitative or qualitative data collection methods can be used. Mono-methods enable the researcher to make use of a single quantitative or qualitative data collection method. In multi-methods, the researcher may make use of two quantitative methods or two qualitative methods. Lastly, with mixed-methods the researcher may make use of both quantitative and qualitative data collection methods. This study made use of multi-methods as more than one qualitative method was used. Using multiple methods enabled the researcher to gather data from various sources/situations therefore allowing the researcher to reach triangulation.

5.3.5 Research Onion: Time Horizons

The time horizon in research methodology highlights the time in which the researcher undertakes the research. The time horizon can either be longitudinal or cross-sectional. Research will be cross-sectional if the study is being conducted on a particular phenomenon at a particular time (Saunders, Lewis, & Thornhill, 2009). Longitudinal studies enable the researcher to focus on a phenomenon as it changes over time (Saunders, Lewis, & Thornhill, 2009).

A cross-sectional time horizon was adopted in this study, as the research involved observing participants during a certain period in time. In other words, participants were being studied whilst using a technological device within a set period of time.

5.3.6 Research Onion: Techniques and procedures

Data collection and data analysis techniques and procedures make up the innermost layer of the Saunders et al (2007) Research Onion. Data collection is an important aspect of any research study. The accuracy of the results collected during the study depends purely on the quality of the data collection process. Inaccurate data collection can impact the study negatively and can lead to invalid results. The sources of data can be categorized into two categories, internal sources and external sources, and data is categorized into primary and secondary data (Utkarsh, 2012).

Data that has been collected for the first time by the researcher is referred to as primary data. This data has not yet been published and it is more authentic and objective, otherwise referred to as raw data. On the other hand, secondary data is collected from a source that has already been published. Two categories of data collection methods exist, namely quantitative and qualitative data collection. This study implemented the following data collection methods:

- **Literature review**: A literature review is the process of reading, analyzing, evaluating, and summarizing of information from various sources about a certain topic. Within this study 4 separate literature reviews were conducted:
    - A literature review to gain an understanding of mobile devices and natural user interfaces (NUI);
    - A literature review to gain an understanding of user experience (UX) and to determine the mobile experiences of mobile phones;
    - A literature review to gain an understanding of the disabled community, scoped down to motor impairments and the challenges they face when using mobile phones;
    - A literature review to gain knowledge on the research methodology and design in order to determine an applicable approach for this study.

- **Interview**: This study implemented a semi-structured face-to-face interviews between the researcher and the participant. Throughout the interview participants were requested to answer a list of questions that were provided by the researcher. Following this approach allowed the researcher to gather personalized data from the participants as each participant had a different experience with mobile phone for the experiment.

- **Questionnaires**: A questionnaire is a tool for collecting and recording information about an area of interest. It contains a list of elected questions which are intended to be answered by various participants. Two forms of questionnaires exist, namely self-administrated questionnaires and interviewer- administrated questionnaires. Self-administrated questionnaires are administrated electronically, and completed by the respondents on their own (Saunders, Lewis, & Thornhill, 2009). This study made use of a demographic questionnaire to gather personalized data, and a UX questionnaire to gather

information regarding the user's experiences with mobile phones prior to the study and during the study.

5.3.6.1 Sampling

Prior to any data collection processes being conducted, the research population must be selected. Sampling is the process of selecting units, such as people or organizations from a population of interest from which data is collected (Trochim, 2006). A sample represents a subset of the population being studied. The population in sampling refers to the entire collection of people or things being studied. Sampling is extremely beneficial as it enables the researcher to collect specific data since the researcher is only working with a group or sample of participants.

The sampling techniques available can be divided into two types, namely probability or representative sampling and non-probability or judgmental sampling (Allyn & Bacon, 2008):

Probability sampling is defined as a method of sampling in which the participants are selected randomly from a population in such a way that the researcher is aware of the probability of selecting each participant. Non-probability sampling is defined as a method of sampling in which the probability of selecting a participant is unknown. This study implemented convenience sampling as it was limited to the geographical area of Port Elizabeth in the Eastern Cape. The following distinguishing characteristics were taken into consideration when choosing the sample for this study:

- Participants who are motor impaired in the upper body I.e. participants who are disabled in the hands, arms, shoulders, or neck (motor impaired);

- Participants who are accustomed to using various technologies and have valid background information of mobile technology. This is imperative, so that the participants do not have to be educated regarding what the device is, and how to make use of the device as this would defeat the goal of the experiment as the goal is not to teach participants how to make use of a mobile phone;

- Participants between the ages of 18 years to 60 years of age.

5.3.6.2 Data Analysis

Once data is collected by means of various data collection techniques, this data is in a raw state, meaning that the data has just been collected from its source and is not yet processed for use (Zins, 2007). In order for this data to be meaningful, the data needs to be analysed. Depending on the data collected, quantitative or qualitative, various methods exist for data analysis. The following approach was applied within this study:

Inductive Approach:
The inductive approach is otherwise referred to as the grounded approach because the nature of the theory or explanation emerges as a result of the research process. In other words, this approach has the following characteristics (Saunders, Lewis, & Thornhill, 2009):

- The study is not started with a clearly defined theoretical framework;
- Instead, relationships between the data is identified and questions or hypotheses are developed to test these relationships;
- Theory emerges from the process of data collection and analysis.

With regard to the analysis process, the following techniques were applied within this study (Saunders, Lewis, & Thornhill, 2009):

- **Summarizing Data**: This activity involves the researcher collecting data, and summarizing the data into a form that is briefer. With regard to this study, data was collected from the participants by means of a questionnaire and then summarized into various tables as displayed in Chapter 6;
- **Categorizing Data:** This involves the identification of categories, and placing data into these categories. For this study, various categories were identified from literature and used within questionnaires that were used by the researcher.

5.3.6.3 Validity and Reliability

Throughout the research process it is imperative to ensure that the data collected is valid and accurate, according to the study. To achieve this, the collected data has gone through a process referred to as validation. Validating the findings means that the researcher determines the accuracy and credibility of the findings by means of triangulation (Creswell, 2002). Within the validating phase, two concepts should be focused on, validity and reliability.

Reliability is the extent to which results are consistent and accurate, meaning that the data collected can be trusted in terms of its outcome (Golafshani, 2003). Validity refers to whether the data collected meets its outcome in terms of what is was gathered for. In other words, does the data provide the expected outcome successfully? (Golafshani, 2003).

5.3.6.4 Triangulation

When collecting data, various sources exist, each source providing data of a certain quality. In order to collect data of a high quality, data should be collected by means of various sources. Triangulation refers to the usage of various sources of information in order to increase the validity of the information. This information can be collected from sources such as participants or literature (Guion, Diehl, & McDonald, 2013). One of the advantages of triangulation is that it provides increasing confidence in the data, whilst creating innovative ways of understanding a phenomenon (Guion, Diehl, & McDonald, 2013). Various approaches of triangulation exist,

namely data triangulation, investigator triangulation, theory triangulation, methodological triangulation, and environmental investigation (Shamuganathan, 2013). To obtain triangulation in this study, three main methods of collection were used. This included questionnaires, an interview, case study, and literature reviews. Table 5.3 displays how triangulation was achieved in this study. It lists the 4 research methods and their purpose.

Source No	**1**	**2**	**3**	**4**
Method	Literature review/survey	Case study	Interviews	Questionnaire
Objective	Gather required information from literature to gain understanding of various fields such as mobile technology, HCI, people with disabilities, UX, and research design.	Determine mobile phone usage by motor impaired users.	To interact face to face with motor impaired users.	Gather information concerning the UX of mobile phones for impaired users and to determine to what extent accessibility features improves accessibility.
interpretation	• Understand the term NUI and what it entails; (1) • Understand what motor impairments are, including the various challenges they face when interacting with mobile phones; (1) • Understand the term UX, what it entails, and how it is concerned with regards to people with motor impairments; (1) • Gather information on research methods in order to determine the best approach for this study. (1) • Determine how motor impaired users interact with mobile phones; (2) • Determine the challenges motor impaired users face with mobile phones; (2) • Create a comfortable environment for the participants and interact with them in order to complete the prepared questionnaires; (3) • Determine the UX of motor impaired users when interacting with mobiles phones; (4) • Determine the UX of motor impaired users when using accessibility features of mobile phones; (4) • Determine the challenges motor impaired users face when using mobile phones. (4)			

Table 5.3 Data triangulation chart for this study

It was important that these methods were implemented appropriately and correctly as each method provided a platform for the next research method. The literature reviews created the base for the study as the researcher was able to collect data from current knowledge and use this to source a problem and determine why it is a problem; determine methods to address the problem; and determine methodical approach to address the identified problem, see chapters 2,3, 4, and 5. Once the literature reviews were conducted and analysed a platform was created for the case study which was used to determine how motor impaired users currently interact with mobile phones, see chapter 5 section 5.4.1 The case study then provided the platform for the participant interviews which then created a platform for the various questionnaires used within the study, see chapter 5 section 5.4.1.3 Take not that these methods were used throughout the case study. Once the various research methods were implemented and the necessary outcomes were achieved the final output for the study could be determined, which was to determine the extent to which accessibility features assist motor impaired users. Figure 5.3 is a graphical representation of how this study reached triangulation.

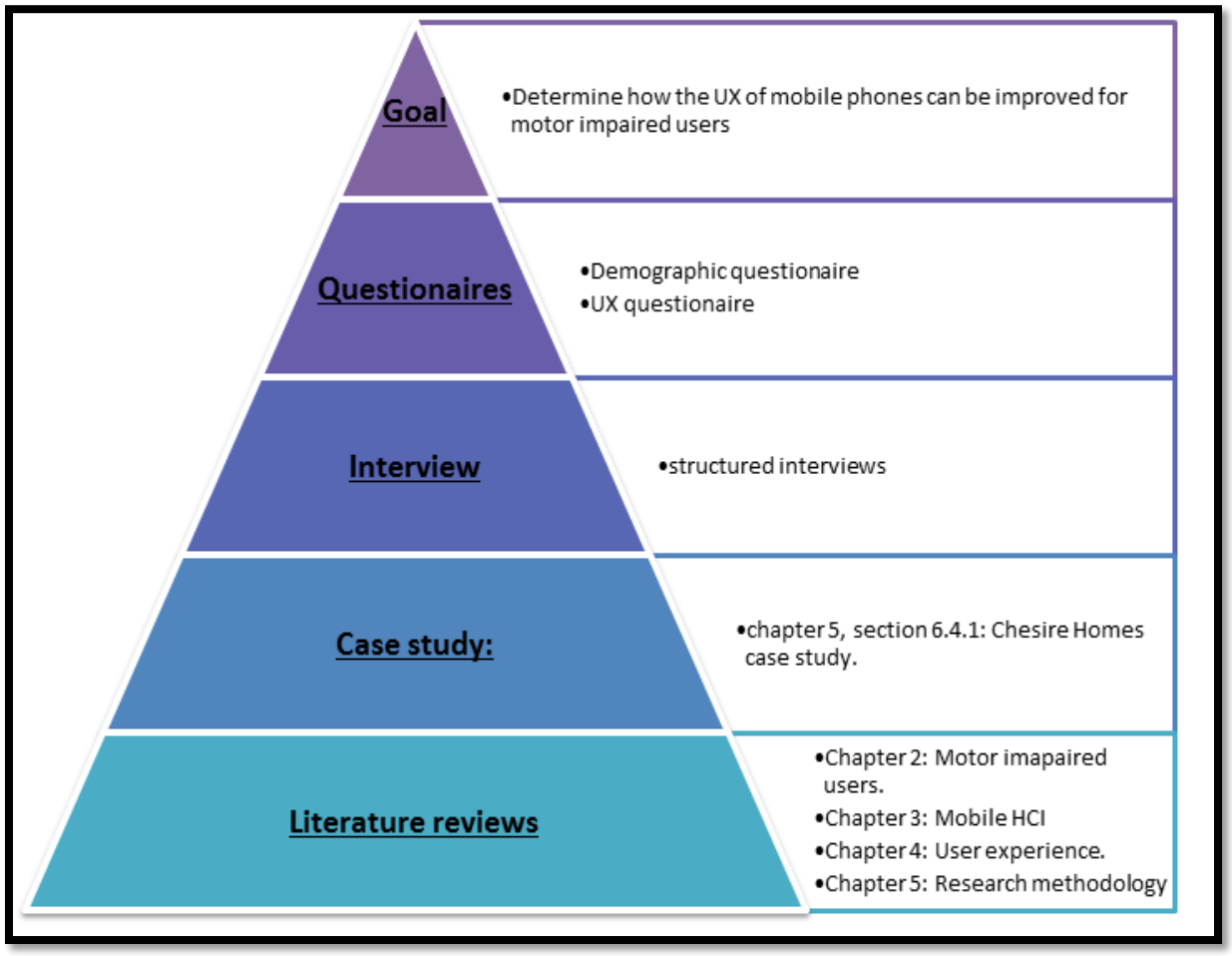


Figure 5.3 Triangulation pyramid for this study depicting the various research methods of this study

5.4 The Research Process for This Study

This research seeks to address the following research questions:

Main Research Question

- How can the user experience of motor impaired people be improved when interacting with mobile phones?

Sub-Research Questions

- How can the unique challenges motor impaired users face when using mobile phones be addressed?
- To what extent do the accessibility features of mobile phones assist users with motor impairments?
- What are the existing user experience guidelines for motor impaired users interacting with mobile phones?
- To create new guidelines specific to motor impaired users using mobile phones.

In order to answer these questions, a specific research process was followed. This process is depicted in Figure 5.4 and illustrates the processes as well as the data collection methods employed to provide answers to the different questions.

The research philosophy that was adopted in this study is the phenomenological approach. Phenomenology focuses on how humans make sense of their surroundings (the environment). The population for this study was motor impaired people. This meant that this study would require the researcher to interact with human participants, therefore phenomenology was found to be more suitable.
The research approach that was applied in this study was an inductive approach, using qualitative data collection methods. This method was selected due to the flexibility it provides regarding the research focus, and it creates theory based on the research data.

A case study was adopted as the research strategy. This method was appropriate as case studies creates a platform for an in depth analysis that aims to increase knowledge about various groups and organizations. With regard to this study, applying a case study as the research strategy enabled the researcher to conduct an investigation focused on how new forms of interaction and technologies can be implemented to improve interaction with mobile phones for motor impaired users.

A cross-sectional time horizon was adopted in this study, as the research involved observing participants during a certain period in time. This study involved various participants being studied whilst using a technological device within a set period of time.

This study made use of qualitative data collection methods, this included literature reviews, interviews, and questionnaires. The data gathered from these methods were analysed and are presented in chapter 6. The section to follow discusses the data collection process for this study and provides an overview of how the data collection methods were implemented in the study.

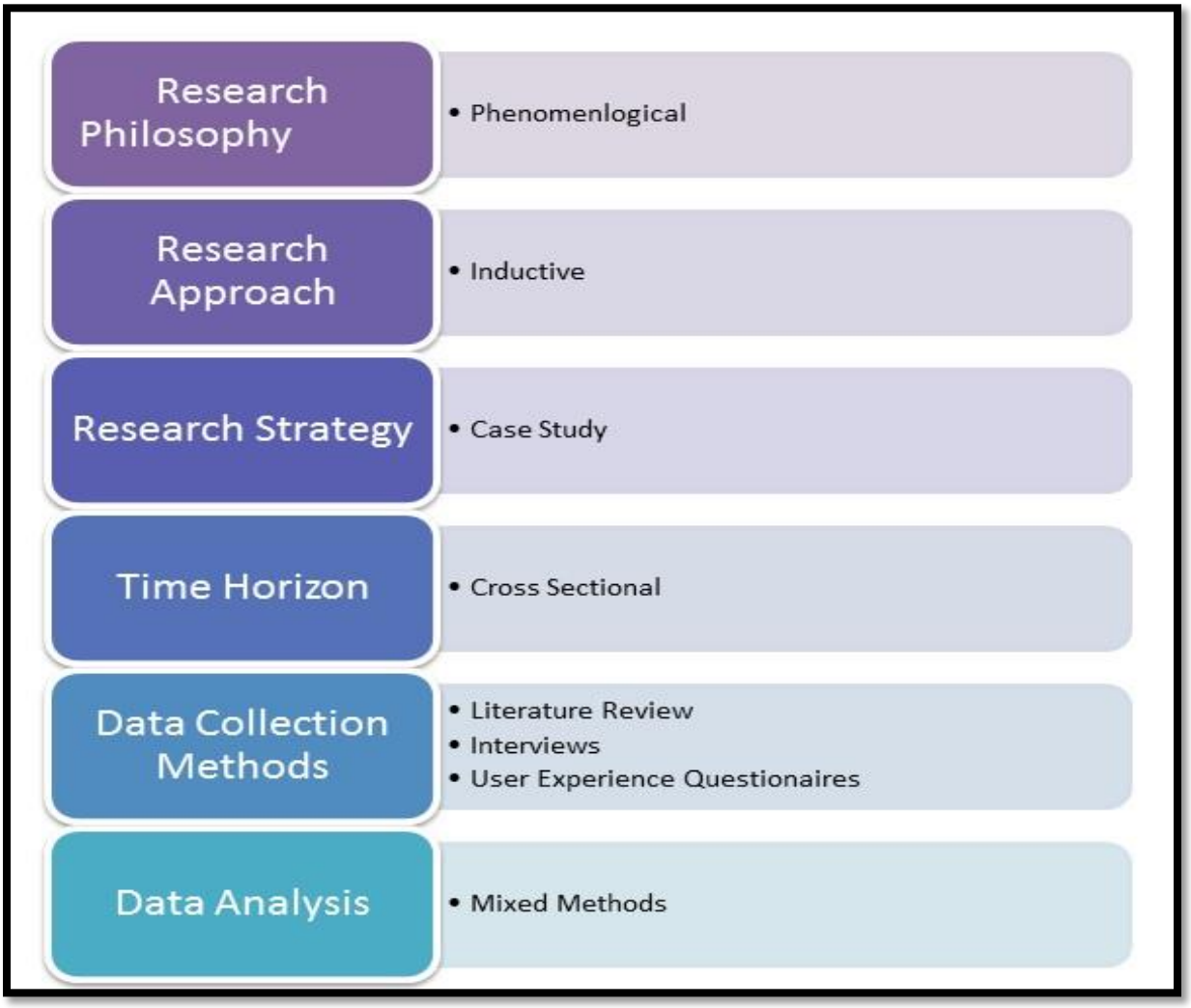


Figure 5.4 Research Design of this study

5.4.1 Data Collection Process

A case study was selected as the research strategy for this study. The case study followed a single case study approach as opposed to that of a multiple case study. The case study investigated the use of mobile phones as an interaction device for motor impaired users. The purpose of this

investigation is to promote new and improved methods of interaction for impaired users. These methods seek to improve interaction in terms of usability, accessibility, and user experience.

To obtain the best results as possible, the case study followed an approach prescribed by Yin (2008). Yin suggests that a case study should consist of various phases, each one being applied throughout the process of the case study. The phases include the plan for the case study, the design, the preparation of the case study, the collection of data, the analysis of the data, and the sharing of the data once it is processed into an understandable form. To follow, each phase of the case for this study will be discussed:

5.4.1.1 Plan

The research was commenced by conducting a set of literature reviews. These literature reviews considered the critical points of current knowledge to provide an overview of the following:

- An initial literature review was conducted to gather information regarding the various research designs and methodologies;
- A second literature review was conducted to provide an overview of natural user interfaces and natural interaction on mobile phones;
- A third literature review was conducted to provide an overview of the disabled community;
- The final literature review was conducted to provide an understanding about the field of user experience.

Once the findings from the literature reviews had been studied, the findings assisted the researcher in identifying a problem description and research questions. The literature reviews also provided a platform for the participant interviews as it provided the researcher with a understanding regarding what is lacking in the area of focus.

5.4.1.2 Design

The case study took on the form of a single case study. The case study made use of various methodologies, this included interviews, questionnaires, and literature reviews. The case study involved the use of NUI device which was the Samsung Galaxy s5 (note this study started in the year 2013, this was the latest device at this time) (see appendix H). The research environment was Cheshire Homes in Summerstrand, Port Elizabeth, from which 7 motor impaired participants were chosen in order to test the usability of the Galaxy s5. The following distinguishing characteristics were taken into consideration when choosing the sample for this study:

- Participants who are motor impaired in the upper body I.e. participants who are disabled in the hands, arms, shoulders, or neck (motor impaired);

- Participants who are accustomed to using various technologies and have valid background information of mobile technology. This is imperative, so that the participants do not have to be educated regarding what the device is, and how to make use of the device as this would defeat the goal of the experiment as the goal is not to teach participants how to make use of a mobile phone;

- Participants between the ages of 18 years to 60 years of age.

5.4.1.3 Prepare

Before any experiments could take place, the researcher determined that no ethical clearance was necessary for this study, since the study did not involve the publishing of any identifying data and it was conducted on a small group of participants from a private institution. The study made use of various data collection methods. The following methods were used in the study:

- Consent form;
- Moderator script;
- Device;
- Biographical questionnaire;
- Mobile phone usage questionnaire
- Task list;
- Wrap up questionnaire;
- User experience questionnaire.

The above methods were used to collect various forms of data pertaining to the study. Next each of the above methods will be discussed as used in the collection phase of this study.

Consent Form:

A consent form was read and signed by the director of Cheshire Homes on behalf of the participants. The consent form stated the participant's rights and what was required of them throughout the evaluation. It also provided background information pertaining to the study. See Appendix C.

Moderator script:

The moderator script was designed as a guide for the researcher to follow when conducting the interviews in the collection phase. The moderator script provided the various processes to take place throughout the interviews and how they will be implemented. See Appendix D for the moderator script used in this study.

Device:

The device that was used for this study was the Samsung Galaxy s5, (see Appendix H). In the year 2014 Samsung released the Samsung Galaxy s5 mobile phone (note that this study started in the year 2013). The Galaxy s5 was selected for the study based on the following capabilities (Beavis, 2014):

- It is a mobile device that has various NUI capabilities;
- It was seen as one of the best mobile phones in 2014 (Spoonauer, 2014);
- It was one of the most popular phones in South Africa for the year 2014 (Writer, 2014);
- The device has various features that support disabled users in terms of interaction (Writer, 2015) :
    - Blind users
    - Physically disabled users

Biographical Questionnaire:

The biographical questionnaire was designed to collect the background information of the participants taking part in the observation. The data was stored in a confidential manner. The second goal of this questionnaire was to collect the participant's knowledge of mobile devices. See Appendix B for the biographical questionnaire used in this study.

Task List:

In order to test the usability of the Galaxy s5, participants had to complete a set of tasks on the device. To achieve this, a list of tasks was determined by the researcher. The tasks were derived from simple real-life scenario tasks that basic users perform on their mobile devices on a daily basis. The goal of these tasks was to test the participants in terms of UX and usability. These tasks aimed to test the overall ability of the mobile phone to meet the needs of motor impaired users. See Appendix E for the study's task list.

Wrap Up Questions:

The participant interviews had two phases. The participants completed the tasks on the Galaxy s5 with and without the assistant features activated. Therefore, two sets of wrap up questions were derived in order to compare the participant's experiences with regards to the assistant features. See Appendix F for wrap up questions.

User Experience Questionnaire:

A user experience questionnaire enables the assessment of the user experience that a product or service delivers. The user experience questionnaire in this study supported users to express

their feelings, thoughts, and overall impression of the device in terms of an NUI device for people with disabilities. The questionnaire was composed of long questions and short questions based around a rating technique similar to the Likert scale. These questions considered various factors that were found in literature. A few of these questions are listed below, including a brief discussion on how they relate to what was found in literature:

- Do you experience any barriers (in terms of use) with your current device? If so, explain what these are?
    - This question was asked of the participants as it was found in literature that most mobile devices and their interaction methods are not suitable to be used by users who suffer from motor impairments as discussed in Chapter 2.

- Considering the tasks you have just completed, did you find it easier to complete the tasks with or without the assistant features? Why do you feel this way?
    - It was found in literature that Samsung stated that their accessibility features have proven that it will improve interaction for users who are disabled. Therefore, this question was asked to test whether this statement is true (See Appendix H).

- Is the interface of the Galaxy s5 user friendly and easy to use and understand?
    - It was found in literature that natural user interfaces stand out and get the user immersed in the tasks they perform as outlined Chapter 3.

- I found it easy to find the various icons;
- I found it easy to navigate through the device;
    - In literature it was found that, to deliver a pleasant user experience, a system has to meet various goals such as having a system that is easy to navigate and that the user is able to find the various options or features that pertain to the user's goal when using the system as discussed in Chapter 3.

The goal of this questionnaire was to determine if motor impaired users' needs are met when interacting with mobile phones, and to determine if the data found in literature is fully adhered too with regards to accessibility features.

5.4.1.4 Collect

The collection of data took place throughout the participant interviews and followed the following process:

The participants were made to feel comfortable and relaxed whilst being introduced to the Galaxy s5 (getting a feel for the device). They were then informed to make use of the device as they would use their own and to try to imagine that they are not in an evaluation environment,

but in a natural environment performing daily mobile tasks. The participants were informed that they would be observed throughout the evaluation.

The performance evaluation consisted of a set of tasks that were performed by the participants and evaluated by the moderator. Whilst the participants were attempting to complete the tasks on the Galaxy s5 they were observed by the moderator. The performance evaluation consisted of various tasks such as accessing the accessibility features, sending an email, and navigating through the app menu, etc. Whilst the participants completed the tasks on the device the following was taken into consideration (evaluation criteria):

- How long it took the participant to navigate to certain features/applications on the device;
- How long it took the participant to make use of the feature;
- How long it took the participant to realize that they made a mistake and how long it took them to recover from this error;
- How often did the participant make a mistake?

Once the participants had completed the tasks at hand (on their own abilities), they were required to take part in the second part of the usability evaluation. This part of the evaluation enabled the participants to share their thoughts and experiences, and it provided an opportunity for the participants to provide any comments regarding the device and the tasks they had just completed. This process was an imperative part of the evaluation since it enabled the collection of preference data about the tasks performed and about the Galaxy s5. Once participants had completed the tasks they were required to complete a user experience satisfaction questionnaire.

The user experience satisfaction questionnaire allowed the participants an opportunity to answer various questions relating to the device and to the tasks they had just performed. These questions will question the usability, accessibility, and UX of the device.

In addition, use was made of Brajnik's Barrier Walkthrough technique to guide the accessibility aspects of the evaluation. Brajnik (2009) designed a methodology for a heuristic evaluation which is guided by accessibility barriers (Brajnik, 2009). The purpose of this method is to assist evaluators in the identification of barriers that exist for users with disabilities. Brajnik advises the use of a table to determine the severity of each barrier. To determine the severity of a barrier, two parameters should be considered (Brajnik, 2009):

- **Impact** of the barrier on effectiveness, productivity, satisfaction and safety;
- **Persistency** with which the barrier shows up when carrying out the task.

The barriers can be categorized into 3 categories, namely minor problem which indicates that the user is not majorly affect by the barrier and is able to easily overcome, remember and learn to avoid it; significant problem indicates that the barrier heavily affects task execution which the

requires the user to perform trial and error strategies; critical problem indicates that the user is unable to complete the task at hand which leads to the user giving up on the task as the user has spent a large amount of time trying to overcome it (Brajnik, 2009). Brajnik's evaluation method is aimed at the more common tasks that are completed on the web, this again indicates that mobile phone/device use by disabled users are exclusive or not considered.

5.4.1.5 Analyze

Once the data was collected, it was studied and analysed into a form that is more understandable for the purpose of this study. See Chapter 6. Data was gathered from the various literature reviews, interviews, and questionnaires. The literature reviews provided background information on various areas of knowledge whilst the interviews and questionnaires provided qualitative data.

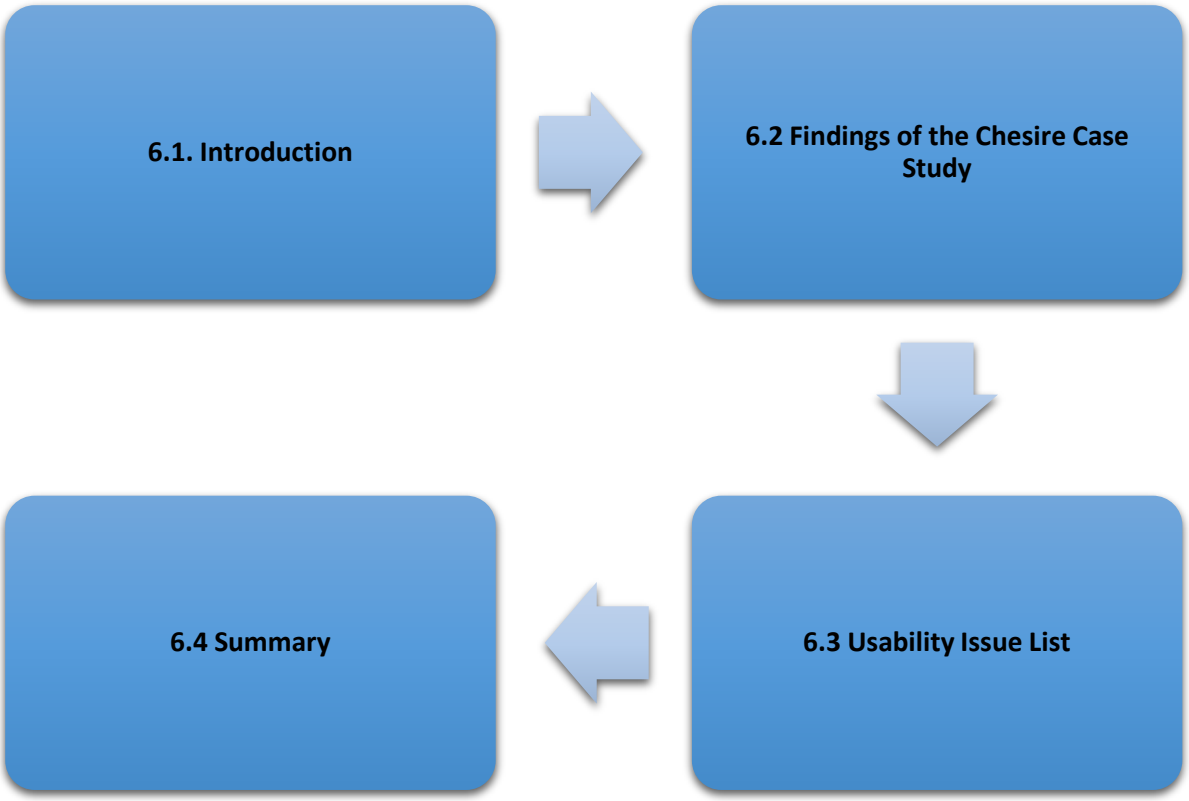
5.4.1.6 Share

This phase of the study involved identifying the final outcome of the study, which was to deliver a set of mobile user experience guidelines for the motor impaired. These guidelines are discussed in detail in Chapter 7.

5.5 Summary

This chapter defined the research methodology and research design which was implemented within this study. The chapter discussed the identified problem for this study, then went on to discuss the various research questions and objectives that are to be met in order to test the various identified areas of knowledge, in order to assist the researcher in reaching a solution to the problem. The entire research process of the study was examined. This includes the various phases of a case study and how each of the phases was implemented. Finally, the various research methods and techniques to be implemented in order to address the identified problem were considered and discussed.

6. RESULTS AND ANALYSIS



6.1 Introduction

The previous chapter discussed the various research methods that was implemented within this study, as well as the data collection process that took place.

This chapter presents the analysis of data that were collected by means of various data collection methods. These results were used to assist in answering the research questions in order to derive a set of mobile UX guidelines for users that are motor impaired.

The analysis of the collected data in order to address the main research question and the sub-research questions is presented below. Section 6.2 discusses the findings from the participant interviews; while Section 6.3 discusses the usability issue list that was derived from this study.

6.2 Findings

A participant interview was used as one of the methods to gather data from the participants. The interviews consisted of the following phases:

- Collecting biographical data;
- Collecting data regarding mobile phone usage of the participants;
- Attempting various tasks on the Galaxy s5 without the assistant features;
- Collecting data by means of wrap up questions considering the experience that the participants had on the device without the assistant features;
- Once again, attempting various tasks on the Galaxy s5, but with the assistant features;
- Once again, collecting data by means of wrap up questions considering the experience the participants had on the device, but with the assistant features;
- Collecting data from the participants by means of long and short questions in the form of a user experience questionnaire to gather the overall experience that the participants had.

The findings from each of the phases mentioned above will be displayed and discussed below.

6.2.1 Biographical findings

The following biographical data was collected from the participants:

Participant	Gender	Age				Language
		18-24	25-35	36-49	50+	
1	Male		*			IsiXhosa, English
2	Male				*	IsiXhosa, English
3	Male			*		IsiXhosa, English
4	Female				*	English, Afrikaans
5	Male		*			Afrikaans, English
6	Male		*			English, Afrikaans
7	Female		*			English, Afrikaans

Table 6.1 Biographical Data of Participants

The data presented in Table 6.1 is the biographical data collected from the participants who took part in the study. The participant sample consisted of 7 participants. Five of these participants were male participants and the other two participants were female. The age groups of the participants ranged from 18 years old to 50 years plus. Four of the participants were between 25 – 35 years of age, one participant was between the age of 36-49, and two participants were older than 50 years of age. The home languages of the participants ranged from English to Afrikaans and isiXhosa.

6.2.2 Mobile Phone Usage

Once the biographical data had been collected from the participants, data based on their knowledge of mobile phones and technology was collected from the participants. This data is presented in Table 6.2. The purpose of this questionnaire was to gather the participant's background knowledge on mobile phones to determine their experience with this sort of technology.

Participant	Do you own a mobile device?	How long have you been using mobile devices (years)			Do you have general knowledge regarding mobile devices in terms of usage	Does your mobile device have accessibility features	Does your mobile device cater for your needs when considering your disability	Rate your knowledge on mobile technology in terms of usage
		1-3	4-6	6+				
1	Yes	*			Yes	No	No	Basic
2	Yes			*	Yes	No	No	Intermediate
3	Yes	*			Yes	No	No	Basic
4	Yes	*			Yes	No	No	Intermediate
5	Yes			*	Yes	No	No	Intermediate
6	Yes			*	Yes	No	No	Expert
7	Yes			*	Yes	No	No	Intermediate
%	100%				100%	100%	100%	

Table 6.2 Mobile Phone Usage

It was found that all of the participants owned a mobile device. None of the participants owned a device that had accessibility features and none of them found that their own devices truly catered for their needs. With this being said it was found that most of participants were only able to use their devices to complete basic operations such as phone calls, and the sending of short text messages via SMS. The participants are unable to make full use of their mobile phones as a result of their impairments and their mobile devices lacking the ability to adapt to their needs. With this being said, the most common issues the participants experienced with their own devices is as follows:

- Holding the device, this was the most common issue as none of the participants was able to do so;
- Most of the participants reported that they only capable of completing basic tasks such as answering calls and the typing of short text messages;
- 2 of the 7 participants made use of pointing devices to enter information on their devices, whilst the other 5 had to place their devices on a flat surface to complete interaction.

Three of the participants had been making use of mobile devices for about 1 to 3 years, whilst four of the participants had been using mobile devices for longer than 6 years. According to the participants, all of them had knowledge of mobile devices ranging from basic to intermediate to expert knowledge.

6.2.3 Wrap up questions and Comments and Quotes

The following tables present the comments and data gathered from the participants after completing set out tasks on the Galaxy s5. The data to follow presents the participants personal views on the Galaxy s5 as an NUI device without the assistant features activated. See Table 6.3

	What do like about the Samsung Galaxy s5?	What do you dislike?	Did you have trouble using the Samsung Galaxy s5?	How would you describe your experience with the Samsung Galaxy s5?	Would you consider using the Samsung Galaxy s5 on a daily basis?
Participant 1	It is easy to use	Nothing at all	Yes, typing was hard as I do not have full control of my hand	Good, nice experience	Yes
Participant 2	Touch screen is easy to use	Nothing	Yes with typing	Good experience	yes
Participant 3	Phone in general	Can't hold the device due to disability	No	Excellent	Definitely
Participant 4	Phone in general	Nothing	Yes it is a bit too sensitive	Beautiful	Yes all the time
Participant 5	Phone in general	Nothing	Yes with the typing.	Good	Yes
Participant 6	It is very clear	It is sensitive	Yes it is big in size	Nice	Yes
Participant 7	Nice features	Need to get use to it	No	Really nice	Yes

Table 6.3 Participant findings without assistant features

The participants were required to complete a set of tasks on the Galaxy s5 without the assistant features (see Appendix E). Once this step was completed, they were required to complete a set of wrap up questions (Table 6.3) from Appendix F, Section 1.

Once participants had completed the first set of wrap up questions, they were then required to complete a set of tasks while using the assistant features of the Galaxy s5. Once this was completed, they completed another set of wrap up questions to gather their thoughts on the device with the assistant features activated, see table 6.4. (See Appendix F, Section 2).

	What do like about the Samsung Galaxy s5?	What do you dislike?	Did you have trouble using the Samsung Galaxy s5?	How would you describe your experience with the Samsung Galaxy s5?	Would you consider using the Samsung Galaxy s5 on a daily basis?
Participant 1	Not much	Not easy to control the mouse	Yes was harder to use	Good	Yes
Participant 2	Using the voice features	Nothing	No trouble	Pleasant	yes
Participant 3	Like the cursor and voice features	Nothing	No just need to get use to it	Nice, good experience	Yes
Participant 4	The cursor	Bit too sensitive, as I don't have full control of my hands	Yes using the small space of the cursor	Was ok	Yes
Participant 5	Phone in general	Complicated using the assistant feature	Yes with navigating	Was good	Yes
Participant 6	Everything is in close range with the feature	Nothing	Yes, switching on the assistive features	Good	Yes
Participant 7	Not much with the assistant feature	More complicated	Yes cant hold it in my hands	Not good as before	Yes

Table 6.4 Participant findings with assistant features

The purpose of the two sets of wrap up questions is to provide the researcher with a basic comparison of the participant's experiences. These experiences were based around the participants using the Galaxy s5 without and with the assistant features.

When using the device without the accessibility features it was found that 5 of the participants didn't find anything major that they disliked about the device, apart from the remaining 2 users who found that the device was too sensitive and holding the device was seen as an issue. 5 of the 7 participants had major issues with the device as they reported that the device is too sensitive and typing was a task they could not complete, these issues affected usability as assistance was required from the researcher.

When using the device with the assistive features activated 4 of the 7 participants reported aspects of the device they did not like. The participants found that the device was more complicated, certain features were too sensitive and difficult to understand. It was found that 5 of the 7 participants reported major issues with the device, participants reported that the device was harder to use, using the cursor was too complicated, navigating through the device was harder, and accessing the assistant features was an issue.

Overall the participants found the device enjoyable to use only because they were not accustomed to using a device that is "high tech". When comparing the results of the usability testing it is evident that more negative feedback was reported when the participants made use of the mobile phone with the accessibility features activated. Throughout the participant interviews it was found that the participants requested more help from the researcher when using the accessibility features. Participants requested help when navigating the device via an accessibility feature (cursor), accessing accessibility features, and understanding how to operate the accessibility features. Based on these results it can be said that the participants had more difficulty when using the device with the accessibility features activated, this implies that there is still room for improvement as accessibility features are implemented with a general approach.

6.2.4 User Experience Questionnaire

Once participants had completed the second set of wrap up questions they were then required to complete a user experience question. (See Appendix G). The purpose of the UX questionnaire was to gather the participant's thoughts and feelings that they had experienced when using the device. This assisted the researcher in determining the level of user satisfaction that was experienced by each participant.

From the findings (Table 6.5) it was found that most of the users made use of mobile devices that were very simple in terms of design, features, and implementation. 3 out of the 7 participants had no usability issues with their current mobile devices, whilst the other four participants encountered minor issues in terms of usability. Note that it was reported by the participants that they use their devices to complete simple tasks only such as making a phone call. It was derived that the participants are limited or constrained to the completion simple tasks only due to the following factors:

- The participants have the need to participate only in the completion of simple tasks;
- The participants participate in tasks that they feel confident in. I.e. if a task is found to be difficult for the participant, the participant avoids participation due to lack of understanding;
- The participants participate only in tasks they are able to physically achieve. I.e. their mobile phones are unable to adapt to their needs.

Seven of seven participants found that the Galaxy s5 is an amazing device to use owing to the fact that they found the device very easy to use, attractive in terms of interface design, and they reported that they would use the device on a daily basis. Four participants found that they struggled to make use of the device with the assistant features activated owing to reasons such as complexity, sensitivity, and having to adapt to the features, whilst three of the seven participants found that the assistant features made interaction a more pleasant experience. Note that even though the participants reported that they enjoyed using the device and found it pleasant to do so, all of the participants required assistance on more than one occasion from the researcher. This ranged from completing simple tasks such as navigating between screens too more complex tasks such as operating the assistive features. With regards to errors made by the participants, the following trend appeared:

- On some cases the participants had to be guided through the entire task;
- Participants had issues performing multi touch gestures such as pinch too zoom;
- Finding the accessibility features was extremely common;
- Most of the participants found the touch screen too sensitive to touch.

It is derived that even though the participants enjoyed using the device, a considerable amount of time was spent teaching the participants how complete the various tasks. This defeats the NUI goal of learnability. It can therefore be said that the participants based their UX on what they visually experienced rather than on their competency.

Consequently, it was found that the majority of participants found the device more pleasant to use with the assistant features deactivated, whilst all participants felt that making use of NUIs to improve interaction with technology is the way forward for disabled users.

It can be derived that even though all the participants were motor impaired, the severity of the participant's impairment differed from each other. With this being said, it was found that the accessibility features of the Galaxy s5 had a "one size fits all" approach to the implementation of the accessibility features. This is where contextual UX could be beneficial as the device would be able to adapt to the needs of each specific user rather than a generalization of users.

participants	What mobile device are you currently using?	Do you experience any barriers (in terms of use) with your current device? If so, explain what these are	Considering the mobile device you are using now, how would you describe your experience with the Samsung Galaxy s5?	Once again, considering the mobile device you are using now, how easy did you find it to complete the tasks at hand?	Considering the tasks you have just completed, did you find it easier to complete the tasks with or without the assistant features? Why do you feel this way? (physically disabled participants only)	On a scale of 1 to 5, with 1 being extremely difficult and 5 being very easy, how easy was it to make use of the implemented assistive interaction features?	Owing to the accessibility features of the Samsung Galaxy s5. Would you consider this device over the mobile device you are using now? If not, why?	Do you prefer using the Samsung Galaxy s5 with or without the assistive features? If you prefer to use it without, why is this so?	Do you feel that making use of assistive technology / features like the Samsung Galaxy s5 is the way forward for users with disabilities ?
1	Nokia Asha	To complete simple tasks, no	Much better, has more features	Very easy	Without	2	Yes	Without, need to get used to it	Yes make life better
2	Nokia 6020	No issues except for holding my phone	Like the touch screen	Very easy	With	4	Yes	With the features	Yes
3	LG 105	Bit complicated	Very easy to use	Easy, simple	With	5	Yes	With the features	Yes, makes life easier
4	Nokia 2A	Bit slow and confusing	Very nice to use	No problem	Without	2	Yes	Features to sensitive	Yes, improves life
5	-	No problem	Was good	No problem	Without	2	Yes	Without	Yes
6	Nokia	Difficult to use	Nice	Easy	With	4	yes	With features	Defiantly
7	Samsung star	Its ok to use	Great	Simple and easy	Without	3	yes	Features are complicating	Yes

Table 6.5 User Experience Questionnaire

The findings of the questionnaire short questions can be categorized into the following categories:

- User interface
- Assistant features
- Navigation
- Visibility
- Handling of the device

The participants were required to rate the device according to the following criteria:

A. Strongly agree = 5
B. Agree = 4
C. Undecided = 3
D. Disagree = 2
E. Strongly disagree = 1

6.2.4.1 User Interface

This category enabled the participants to rate the Galaxy s5 with regard to the interface of the device. Criteria for this category were based on the look and feel that the interface provided to the user.

Question	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7
The interface of the Galaxy s5 is user friendly and easy to use and understand.	4	5	5	5	5	4	4

Table 6.6 User Interface Questions

It was found that all of the participants found the UI of the Galaxy s5 highly pleasant to work with as they all gave it a high score regarding ease of use and understanding of the interface. These scores were based on the look and feel of the UI.

Question	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7
I found it easy to find the various icons to complete the tasks at hand	4	5	4	5	5	4	3

Table 6.7 User Interface Questions

Navigation was given a high score based on the participant's feedback. The participants found navigation very easy owing to high quality and resolution, and the very clear interface of the Galaxy s5. A positive contribution to the high scores for navigation is the fact that swiping is used as an interaction modality for on screen navigation.

6.2.4.2 Assistant Features

This category enabled the participants to rate the Galaxy s5 with regard to the assistant features. Samsung stated that these features are beneficial for users who are disabled. This provided the opportunity to test whether this statement is true and what it means for disabled users in terms of usability.

Question	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7
The assistant features are easy to access and switch on/off.	2	4	2	4	4	2	2

Table 6.8 Assistant features Questions

Questions	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7
I find that the assistant features do benefit me in terms of interaction.	2	5	5	1	2	2	2

Table 6.9 Assistant features Questions

Questions	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7
Using the accessibility features made it easier to use the device	2	5	5	2	2	2	2

Table 6.10 Assistant features Questions

With regard to the accessibility features, it was found that, at first, the participants had trouble making use of the accessibility features. Once the participants had more practice with the accessibility features, and more guidance was provided, it was found that some of the participants found it more pleasant to use the Galaxy s5. Complexity was once of the main issues when using the accessibility features as most of the participants required persistent assistance when using the accessibility features.

6.2.4.3 Navigation

This category enabled the participants to rate the Galaxy s5 with regard to navigation. This enabled the researcher to gather information based on how the participants made their way around the device and how easy it was.

Questions	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7
I found it easy to find the various icons to complete the tasks at hand	4	5	4	5	5	5	4

Table 6.11 Navigation Question

Questions	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7
Navigating through the device was easy	5	4	5	5	5	5	4

Table 6.12 Navigation Question

As mentioned, navigation was found to be a pleasant experience for the participants.

6.2.4.4 Visibility

This category enabled the participants to rate the Galaxy s5 with regard to visibility. This category took various aspects into consideration such as visibility and understanding of the text on screen.

Question	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7
The icons on screen are visible and easy to understand	5	4	5	5	5	5	5

Table 6.13 Visibility Question

Question	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7
The text on screen is easy to read and understand	5	5	5	5	4	5	5

Table 6.14 Visibility Question

Owing to the high resolution, and clear display of the Galaxy s5, the participants had no trouble reading and understanding the visuals on screen.

6.2.4.5 Handling the device

This category enabled the participants to rate the Galaxy s5 with regard to handling the device in terms of weight and size.

Question	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7
The size of the device made it easy to handle	3	4	1	5	3	2	5

Table 6.15 Handling of Device Question

The participants had issues handling the device, as most of them placed the device on their laps and made use of assistive devices such as pointing devices to complete interaction. On some cases the participants required assistance from the evaluator to place the Galaxy s5 on the laps and to hold it to make use of the camera.

6.3 Usability Issue List

In this section the issue list is presented in Table 6.16. The list contains the various issues that the participants encountered in terms of usability when using the Galaxy s5. The identified issues were categorized into the following categories:

- Typing
- Navigation
- Learning
- Visibility
- Device look and feel
- Understanding

Category	Usability issue	Participant	Recommendation
Typing	Participants had difficulties typing owing to their disability, the keyboard size and sensitivity	1, 2, 3, 4, 7	When the assistant features are activated typing can be made easier by enabling users to make use of the cursor for typing as well.
Learning	Participants had difficulty learning how to make use of the device, especially when using the assistant feature	1,2,3,4,5,6, 7	Using the assistant feature should be implemented in an easier manner that is common in terms of interaction.
Visibility	Some participants found that the icons on screen are a bit small. To counter this was the magnifying option, but an issue was raised in terms of accessing and using the feature.	3, 6	Depending on the accessibility feature, when accessed the resolution of the screen can be changed to enable larger on-screen text and icons.
Device look and feel and handling	Most of the participants had issues handling the device owing to their disabilities. Therefore, some participants used the device on their laps or wheelchair arms.	1, 2, 3, 4,5, 6	The device can be mounted on the participant's wheel chair to make access easier.
Understanding	Some of the participants had trouble fully understanding how the assistant menu works, including various features of the device.	1,4,5	Provide access to help features when using the accessibility features.

Table 6.16 Issue list for the Samsung Galaxy s5

6.3.1 Brajnik's Barrier walkthrough

Table 6.17 implements Brajnik's (2009) evaluation method with regards to the usability study conducted in this research. As mentioned in Chapter 5, Brajnik's methodology is aimed at disabled users using the web. For this study Brajnik's methodology was adapted to motor impaired users interacting with mobile phones. The barriers for Table 6.17 were derived from the usability issue list for this study as presented in table 6.1.6. Each of the barriers were categorized according to the impact, persistence and severity. Note that Tables 6.17 results were determined as a result of grouping all the participants' issues.

Barrier type	Impact	Persistence	Severity	Details
Typing	3	2	Critical	Most of the participants had difficulty with typing mainly as a result of the sensitivity on the on screen keyboard.
Learning	2	3	Critical	Throughout the usability study the participant's required persistent assistance from the evaluator with regards to how to interact with the device.
Visibility	3	2	Critical	Some participants found that the icons on screen are a bit small. To counter this was the magnifying option, but an issue was raised in terms of accessing and using the feature.
Device look and feel and handling	2	3	Critical	Most of the participants had issues handling the device owing to their disabilities. Therefore, some participants used the device on their laps or wheelchair arms.
Understandable	3	2	Critical	Some of the participants had trouble fully understanding how the assistant menu works, including various features of the device.

Table 6.17 Barrier walkthrough evaluation

Brajnik states that a barrier can be categorized as minor (score: 1), significant (score: 2) or critical (score: 3). Once the various scores have been determined for impact and persistence then only can the overall categorization score be determined as the severity of the barrier. According to Brajnik table 6.18 should be used to determine severity scores.

Impact	Persistence	Severity
1	1	minor
1	2	minor
1	3	significant
2	1	significant
2	2	significant
2	3	critical
3	1	critical
3	2	critical
3	3	critical

Table 6.18 Branik's table for computing the severity score of user problems

Tables 6.6 to 6.15 contain the evaluation results from the participant's point of view. Note that these results were gathered directly from the participants after they completed the predefined tasks on the Galaxy s5. Throughout the evaluation the following trends were recognized amongst the participants:

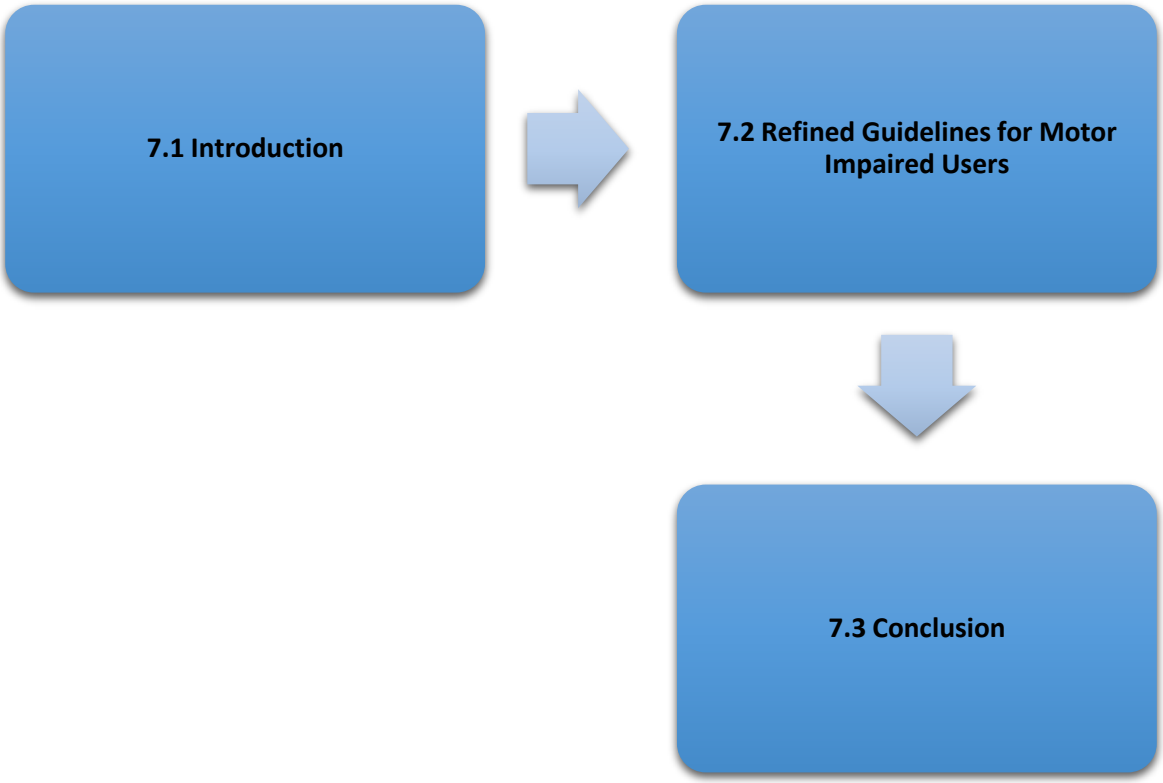
- The participants required assistant from the evaluator, on some occasions constant assistance was required;
- Evan though the participants had difficulty completing tasks, positive results were still provided by the participants. With this said it should be noted that the participants scored their experiences with the device whilst being assisted by the evaluator. In other words the participant's scores were based on the assistance from the evaluator.

To provide honest results for the sake of the study tables 6.16 and 6.17 results are based on the evaluator's evaluation of the participants. This was necessary since the participants scored themselves whilst being assisted by the evaluator and not their own experiences. As the evaluator it was noted that the participants faced an array of issues, see section 6.2.4.

6.4 Summary

This chapter displayed the various results that were gathered from the case study. In this chapter various tables were used to display the data, followed by a narrative discussing and analysing the data in the table. Based on the findings, it was found that the NUI features of the Samsung Galaxy s5 contributed negatively to the UX of the tasks at hand in terms of accessibility and usability, as complexity was seen as a major issue. The findings presented a list of barriers for the participants which presented the opportunity for the delivery of adapted guidelines for motor impaired users in the chapter to follow.

7. GUIDELINES FOR THE USER EXPERIENCE OF MOBILE PHONES FOR MOTOR IMPAIRED USERS



7.1 Introduction

This chapter will present a refined version of the guidelines based on the findings from the empirical data collection. The chapter also reflects the triangulation that was undertaken in this study.

7.2 Refined guidelines

Chapter 4 presented an outline of a variety of guidelines and principles that must be considered when motor impaired user interact with mobile phones and their respective interfaces and the variety of interaction style.

After the guidelines were tested through end users completing tasks on a mobile phone followed by a Barrier walkthrough, the findings were triangulated and the refined guidelines are presented in Figure 7.1.

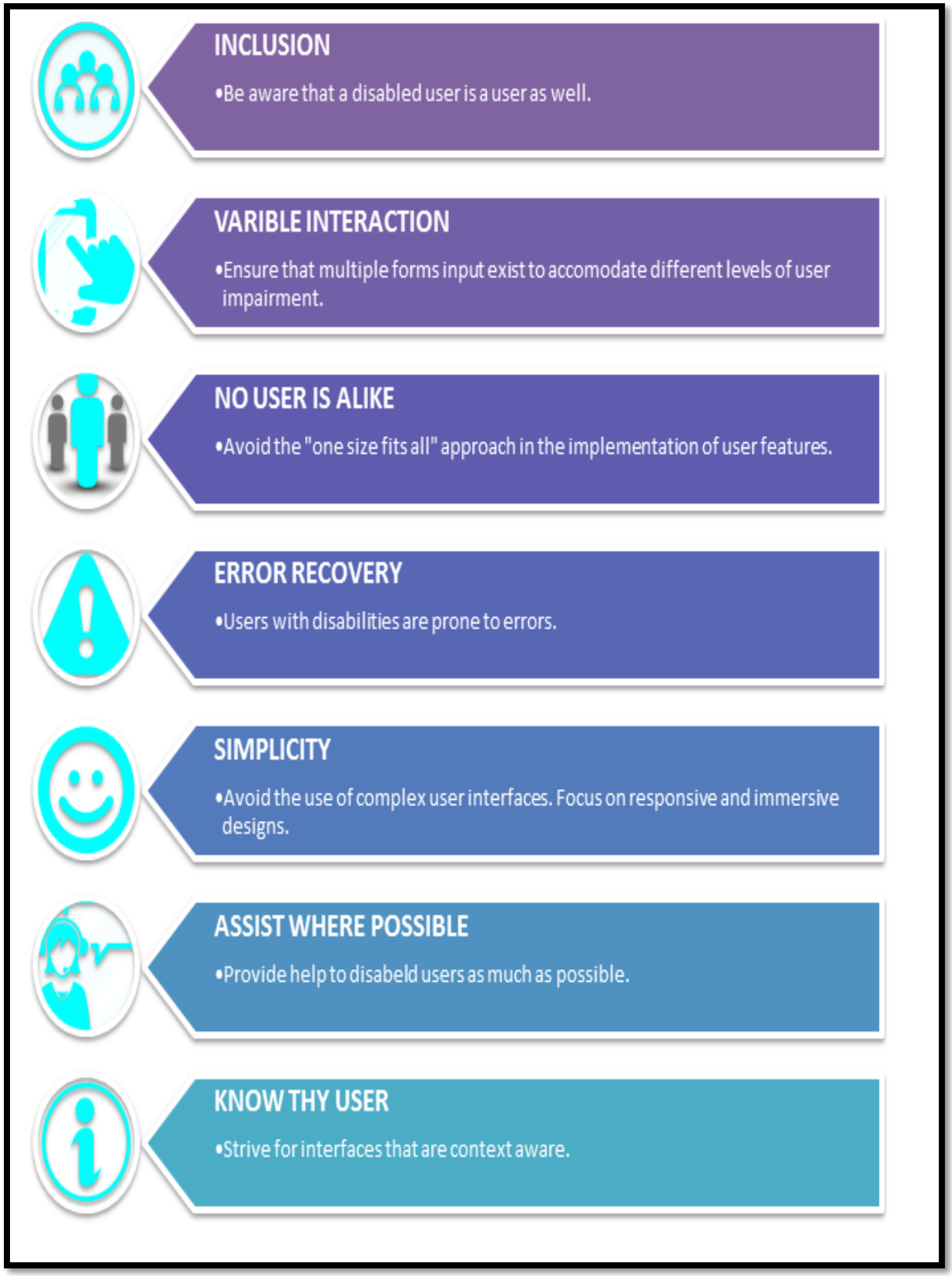


Figure 7.1 Proposed guidelines for the study

7.2.1 Guideline 1: Inclusion

As a result of a literature review (chapter 2), it is derived that disabled users are excluded when considering the design and implementation of mobile phones and applications. This exclusion creates a platform for a list of issues as disabled users are in most cases not considered in mobile phone and application design. Based on this factor the following guideline was derived:

Be aware of the fact that a disabled user is a user as well

Implementing inclusive designs will be beneficial to the wellbeing of the system and its users as the result in systems that promote:

- **Flexibility**: as it can be used by a wider range of users;

- **Equality**: as various users' needs are considered in the design of the system. i.e. the should aim to create different user experiences depending on the user's needs;

To achieve this it is important that there is an understanding of who the users are, and what their context of use is. With regards to mobile phones, focus needs to be placed on how users with motor impairments use these devices. This can be achieved by the involvement of motor impaired users throughout the design lifecycle of the system. Throughout this lifecycle the following steps are advised:

- Evaluation studies that include motor impaired users interacting with prototype designs, this will provide developers with the opportunity to determine various aspects of the system that need to be improved or altered in terms of functionality and UI design;

- As discussed in chapter 2, users with motor impairments make use of assistive technologies to assist them in interacting with various objects and devices. It is imperative that developers are aware of this and understand how these devices are used so that user tests and system designs can be based around this;

- The discussion of accessibility issues with motor impaired users. This provides an opportunity to determine the issues motor impaired users face when interacting with mobile phones. Once these issues have been identified, prototypes considering these issues can be used to determine alternative methods.

Once the factor of exclusion is void, and disabled users are considered more in the implementation of mobile phones and applications, then only can other factors be addressed as an attempt is being made to address the base factor. In other words, the root cause has to be addressed first.

7.2.2 Guideline 2: Variable Interaction

From literature it was derived that most mobile phones with NUI functionality implement touch as a form of interaction. Some mobile phones are capable of extending this by allowing users to use gestural and voice interaction to a small extent. Derived from the findings of the case study, it was found that a common issue reported by the users was the fact that the touch screen of the device was to sensitive which meant the participants were extremely prone to errors. Based on this factor the following guideline was derived:

Ensure that multiple forms of interaction exist to accommodate different levels of user impairment

This factor can be mitigated by implementing methods that are natural and effortless for the user. These methods are referred to hands free interaction. When implementing various interaction methods to the benefit of motor impaired users, ensure that these methods are:

- Are direct and allow user freedom;
- Make use of the systems capabilities to its advantage;
- Allows the user to feel in control, rather than the system being in control;
- Interaction methods for the system should promote user exploration;

Implementing this sort of flexibility into your system will benefit both abled and disabled users since users now have the ability to choose a method of interaction that meets their preference. This is extremely beneficial to motor impaired users as it was determined that most forms of common interaction are not suitable to their needs.

Enabling multiple methods of interaction motor impaired users can make use of methods that meet their expertise which will result in users experiencing higher levels of satisfaction. Throughout the usability study conducted within this research study, it was found that the touch screen of the prescribed mobile phone could not detect the users input when interacting with an assistive device such as a pointing stick. Interaction methods should thus consider the use of assistive technologies.

7.2.3 Guideline 3: No User is Alike

From literature (chapter 2) it was determined that a list of motor impairments exist, each one different to the other. It was found that no disability is alike as various levels of impairment exist. From the case study it was derived that the accessibility features had a "one size fits all" implementation as most of the methods could not be altered according to participant's impairment severity. Based on this factor the following guideline was derived:

Avoid the "one size fits all" approach in the implementation of user features

This issue can be mitigated by enabling users the ability to alter features to their needs. For example a user can reduce the sensitivity of the touch screen. The goal here is to aim for personalization. Firstly it is imperative that there is an understanding of who the users are. It was found that motor impaired users have various characteristics pertaining to them, chapter 2, section 2.2.1 lists the various characteristics pertaining to motor impaired users. It was found that these characteristics can be categorized into physical, social and emotional characteristics.

As different users have different needs, it is not always possible to meet all user needs but a balance needs to exist between what is needed and what is wanted in terms of system design and functionality. In other words, designers need to design for diversity, this means that:

- Designers have to know their audience;
- Once the audience is identified, usability tests have to be carried out to determine how the various user characteristics impact on the design of the system in terms of functionality an UI;
- Avoid the universal design. Aim for designs that focus on diversity rather than a generalized approach.
- Focus needs to be placed on adaption. This means that designers need consider the needs of all users and their intent for interacting with the system. The system needs to adapt to the user's needs, instead of the user adapting to the system.

7.2.4 Guideline 4: Error Recovery

From literature (chapter 2) it was derived that disabled users are prone to a list of barriers that negatively influences their experiences when interacting with mobile phones. These barriers list from minor issues such as touch screen sensitivity, to major issues such as the inability to enter commands on the device. This study found that the participants made a number of errors as a result of the various barriers the participants faced with the mobile phone. Based on this factor the following guideline was derived:

Users with disabilities are prone to errors, therefore they should be assisted where possible

When interacting with mobile phones, especially mobile phones that consists of touch screens, motor impaired users are more than likely going perform an error when interacting with the device. This is due to the fact that touch screens are extremely sensitive, for users with dexterity this creates a challenging situation as the user does not have full control of their hands, resulting in the user inputting unwanted demands.

When a user is in a situation where an error has occurred it is advised that the following steps be implemented:

- Firstly the user should be aware that an error has occurred. The user should be notified in a manner that is appropriate and easily interpreted by the user.

- Once the user is aware of the error, it is important that the user understands why the error has occurred. This should be conveyed to the user in a language that is understood by the user and not presented to the user in error codes.

- Now that the user understands that an error has occurred, provide the user with the opportunity to either go back the previous screen or allow the user to complete the step again.

Ultimately the goal is to design a system that provides no room for error, in other words users should not fall into the situation where an error has occurred. Designs should be simple in terms of design, clear, consistent and understandable. This guideline should be implemented hand in hand with guideline 6.

7.2.5 Guideline 5: Simplicity

To make use of a system successfully, it is important that the user has an understanding of how to interact with the system and an understanding of how the system works. For physically disabled users understanding how the system works, plays a major role, especially for users who are not accustomed to interacting with technology. From this study it was found that the participants reported the accessibility features complicating. Throughout the study the participants requested assistance from the researcher on more than one occasion. See chapter 6, section 6.2.4. Based on this factor the following guideline was derived:

Avoid the use of complex user interfaces. Focus on responsive and immersive designs

Implementing designs that are easy to use and understand will more than likely result in users wanting to make use of the product or service. Designing for simplicity means that users are free from designs that are complex as the focus here is a design that is easy to use and understand. Following this approach benefits both abled and disabled users as the users find the system more usable.

Simplicity promotes accessibility as users are able to achieve their goals in an efficient, affective and faster manner. Aiming for simplicity goes hand in hand with guideline 4 and 6 as a simple design means that the UI is designed in an understandable manner this results in users creating less errors and requiring less help. To design for simplicity aim for/to:

- Remove unnecessary features and functions;
- Avoid the use of complex interactions such as hovering over content , for users with motor impairments this can be seen as a difficult task to achieve;
- Accessibility should be the base for the design of the system, enabling ease of access for all users;
- Controls on screen, including text should be visible at all times especially for users with poor vision;
- Let important content on screen find the user. For example tasks should be implemented in easy to understand methods that speaks to the user and leads the user to achieving their goal;

7.2.6 Guideline 6: Assist Where Possible

It was found that the motor impaired participants made many mistakes throughout their participation in the case study. As a result it was derived that when the participants made a mistake, the ability to seek help from the device/application was lacking. To assist the participants, the researcher had to be involved in completing the participant's task. Based on this factor the following guideline was derived:

Provide help to disabled users as much as possible

Since disabled users are prone to making more errors, more user help should be implemented to accommodate user errors. The goal here is to provide user help from the system itself rather than an external party. To determine user needs in this regard, evaluation studies should take place to determine the various aspects of the system where users with motor impairments might require assistance. Once an understanding is gained of when users will require assistance, appropriate methods can be put into place to provide user assistance. With regards to providing user assistance consider the following for motor impaired users:

- Help should be provided at the right time in an understandable manner;
- Help should be provided from within the system in a clear and concise way;
- Instructions should be provided in a manner that is understandable and easy to perform;
- When providing user help, do so in as little words as possible. Follow the approach of a wizard which will allow users to gain help step by step.

7.2.7 Guideline 7: Know Thy User

From literature (chapter 4) it was found that mobile phones lack the ability to adapt the unique needs of motor impaired users. It was found that the mobile experience is majorly influenced by the context surrounding the user. With this said, the context of motor impaired users differs to those non-disabled users. For example, a motor impaired user might be constrained to a wheelchair. Based on this factor the following guideline was derived:

Strive for interfaces that are context aware

This issue can be mitigated by implementing contextual UX that will enable mobile phones to adapt to the user's needs depending on the users context. An approach for this is enabling users the ability to efficiently provide information of their context. To design for contextual UX the following approach is suggested:

- Know and understand your users deeply and across all touchpoints. User segments should be based on the users wants and needs;
- Collect real time data from users. Make use of GPS, browsing history and social graphs;
- Optimize the individual experience of the user. Aim for predictability by determining user intentions.

Following an approach that is for contextual UX will allow developers to truly understand who their users are and gaining an understanding of what the users are doing or trying to achieve. The goal here is to design for individual experiences by focusing on user personalization. For users with motor impairments this can be achieved by:

- Allowing users to provide demographic data which can be used by the system to its benefit, for example if the user has poor vision the system can adjust itself accordingly by increasing content size;
- Allow users to change interface functionality manually according to their preference;
- When users suffer from dexterity, sensitivity of user controls should adjust accordingly especially when using assistive devices to interact with content on a touch screen;
- Adaption to the users' needs should take place immediately when needed.

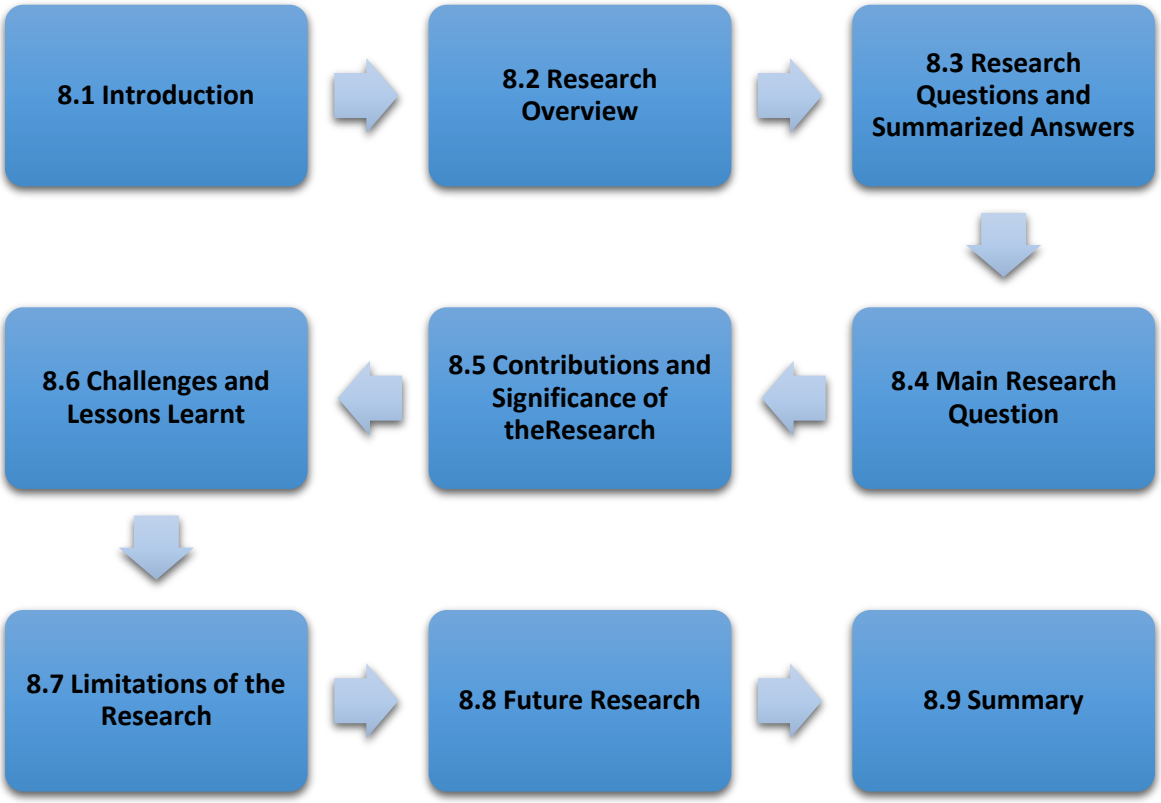
7.3 Conclusion

This chapter discussed a set of guidelines that focuses on the design of mobile phones and UIs for the use by users impacted by motor impairments. These guidelines were derived as a result of the applicability of guidelines from literature to motor impaired users. This chapter concluded with the main output of the study, which is a set of UX guidelines for the design mobile phones/applications for motor impaired users.

These guidelines were determined after data was gathered by means of triangulation. This involved the process of conducting various literature reviews, including the collection of various guidelines pertaining to interaction, navigation, accessibility, UX, usability and mobile phones. A summarised version of these guidelines were then applied to a usability study which involved 7 participants who are impaired by a motor disability to determine the applicability of the selected guidelines. These participants/disability were selected as a result of availability of participants and due to the high numbers of people living with physical disabilities such as motor impairments in the Eastern Cape, South Africa. Each of the participants were in a wheelchair with limited dexterity.

It was found that there is lack with regards to guidelines focusing on mobile phone interaction for motor impaired users as most of the guidelines are generalized and speak to overall usage/interaction for a generalized population. This is where a list of barriers are presented as disabled people should not be generalized in population due to their unique requirements. In the usability study it was found with the application of the derived guidelines from literature various factors were presented for impaired users when interacting with mobile phones. To counter these factors specific guidelines were derived and presented in this chapter. For motor impaired people the benefit of these guidelines are that they speak directly to motor impaired users and addresses areas that provide various barriers for motor impaired users in terms of interaction and navigation on mobile phones. Implementation of these guidelines will benefit motor impaired users as well people suffering from other disabilities and non-disabled people.

8. CONCLUSION



8.1 Introduction

This research study focused on the development of mobile human computer interaction for motor impaired users. It involved the study of natural user interfaces on a specific mobile phone as a form of interaction with content for motor impaired users. In literature it was found that a list of barriers arise for motor impaired users when interacting with mobile phones. The reason for this is that most disabled users do not have the necessary interaction skills to make use of common interaction methods on mobile phones. This provided the researcher with the opportunity to promote new methods of interaction by means of this study. Therefore, this study promoted the use of natural user interfaces on mobile phones as an interaction method or device for disabled users. Natural user interface was selected based on its ability to enable users to interact by means of natural interaction. This means that users are able to interact with content by means of inherent interactions such as touch or voice.

This final chapter summarizes the entire study in Section 8.2. The chapter then goes on to restate the research questions and objectives whilst referring back to the answers as found in literature. (See Section 8.3). The chapter then presents the lessons that were learnt by the researcher, as well as the various challenges faced and future research that may be conducted in Sections 8.4 to 8.6.

8.2 Research Overview

This study began by investigating the existing body of knowledge to gain an understanding of what is currently in place in the field of interest.

In Chapter 2, the disabled community was discussed. This discussion started off by defining the term disability, hereafter the focus was scoped down to users with motor impairments. Various motor impairments were presented along with a discussion based on how they affect the lives of the affected person. The chapter went on to discuss the various barriers that disabled people face when accessing information and when using mobile phones.

Chapter 3 discussed human computer interaction. The chapter investigated the field of human computer interaction and determined how the various HCI components play a role in this study. Hereafter the investigation focused on NUIs, where various forms of NUI interaction was discussed along with implementation methods which seek to benefit motor impaired users. Hereafter UX and mobile phones was investigated, where the focus was to determine the role UX plays when considering mobile phones and how users with motor impairments are influenced by this field. The chapter concluded with techniques for evaluating UX.

Chapter 4 was a discussion based around sets of guidelines that had been found in literature. This discussion focused on various guidelines considering the various aspects of focus for this study that included mobile phones and mobile applications implementation, UX, usability, and NUIs.

Chapter 5 discussed the research design and methodology that was used within this study. The research onion model was used to explain the methodology of the study. The chapter continued by discussing the technological device that was used in the case study to gather results for the study.

The results and analysis of the case study are discussed in Chapter 6. This chapter concluded with the findings of the study by means of narratives and analysis.

The chapter then concluded by answering the main research question for this study which was to deliver a set of mobile UX guidelines that focuses on the needs of motor impaired users in Chapter 7.

8.3 Research Questions and Objectives

This study employed a case study approach during which seven participants who reside at a private facility that cares for persons with a different range of disabilities, participated in an evaluation of a mobile phone that uses natural user interaction techniques. The step-by-step approach to the research study allowed for the answering of the sub-research questions that resulted in an answer to the primary research question. The overall objective of the study was also achieved.

8.3.1 Sub-Research Question One

How can the unique challenges motor impaired users face when using mobile phones be addressed?

Information regarding this research question was gathered by means of a literature review and usability study. According to literature it was found that the current capabilities of mobile phones do not meet the needs of motor impaired users as it was found that a list of barriers presents itself to the user. Some of these barriers include:

- Motor impaired users may find it hard to interact with mobile phones owing to the device size and the size of buttons used for input;
- In some cases, interaction with mobile phones is impossible owing to the user's impairment. For example; a user who suffers from Cerebral palsy has very little ability to move may not be able to input commands into the device by means of touch;
- Holding the device can be challenging for users who do not have full control of their hands;
- Input on mobile phones making use of buttons may require the user to use more strength to complete an input request;

- Situationally induced impairments (chapter 2, section 2.4.4).

Currently to address these issues, mobile phone accessibility features are made available to users. These features were tested in a usability study and it was found that these features still present barriers similar to those found in Chapter 2. With this in mind, this study investigated the use of NUIs to extend the capabilities of mobile phones through hands free interaction methods. This is discussed in detail in Chapter 2 and 3.

8.3.2 Sub-Research Question Two

To what extent do the accessibility features of mobile phones assist users with motor impairments?

In the case study conducted for this study, the usability of mobile phone accessibility features was evaluated for use by motor impaired users. It was found that the participants reported difficulty as opposed to ease of use when using the accessibility features. Chapter 6 reports on these findings. Some of the issues reported by the participants, include:

- Some participants had to be guided through the entire task;
- Participants struggling to perform multi touch gestures such as pinch too zoom;
- Difficulty in finding the accessibility features was extremely common;
- Most of the participants found the touch screen too sensitive to touch.

In literature it was found that mobile phones along with accessibility features lack the ability to adapt to the user's needs. It was found that depending on the user's context, the device should adapt accordingly to provide a pleasant UX to the user. It was derived that this can be achieved through the implementation of contextual UX as described in Chapter 2 and 3.

8.3.3 Sub Research Question Three

What are the existing user experience guidelines for motor impaired users interacting with mobile phones?

In literature it was found that a vast list of guidelines exist for the implementation of mobile phone applications i.e. user interfaces and interaction design. It was found that no guidelines are specific to motor impaired users. The guidelines derived from literature were used as a guide for the proposed guidelines of this study. The comprehensive set of guidelines are discussed in Chapter 4. These guidelines include:

- Elements of mobile user experience;
- NUI principles;
- UI design guidelines;

- HCI principles;
- Interaction design guidelines;
- Navigation guidelines;
- Accessibility guidelines;
- User experience elements;
- Factors for the evaluation of user experience;

8.4 Main Research Question

The main research question is answered after the creation of the foundation through the findings of the sub research questions. The findings from the sub research questions were triangulated and resulted in answering the primary research question, namely:

How can the user experience of motor impaired people be improved when interacting with mobile phones?

Figure 8.1 depicts the refined set of guidelines resulting from this study. These guidelines are to be considered when designing mobile phones and applications for motor impaired users as per the findings of this study.

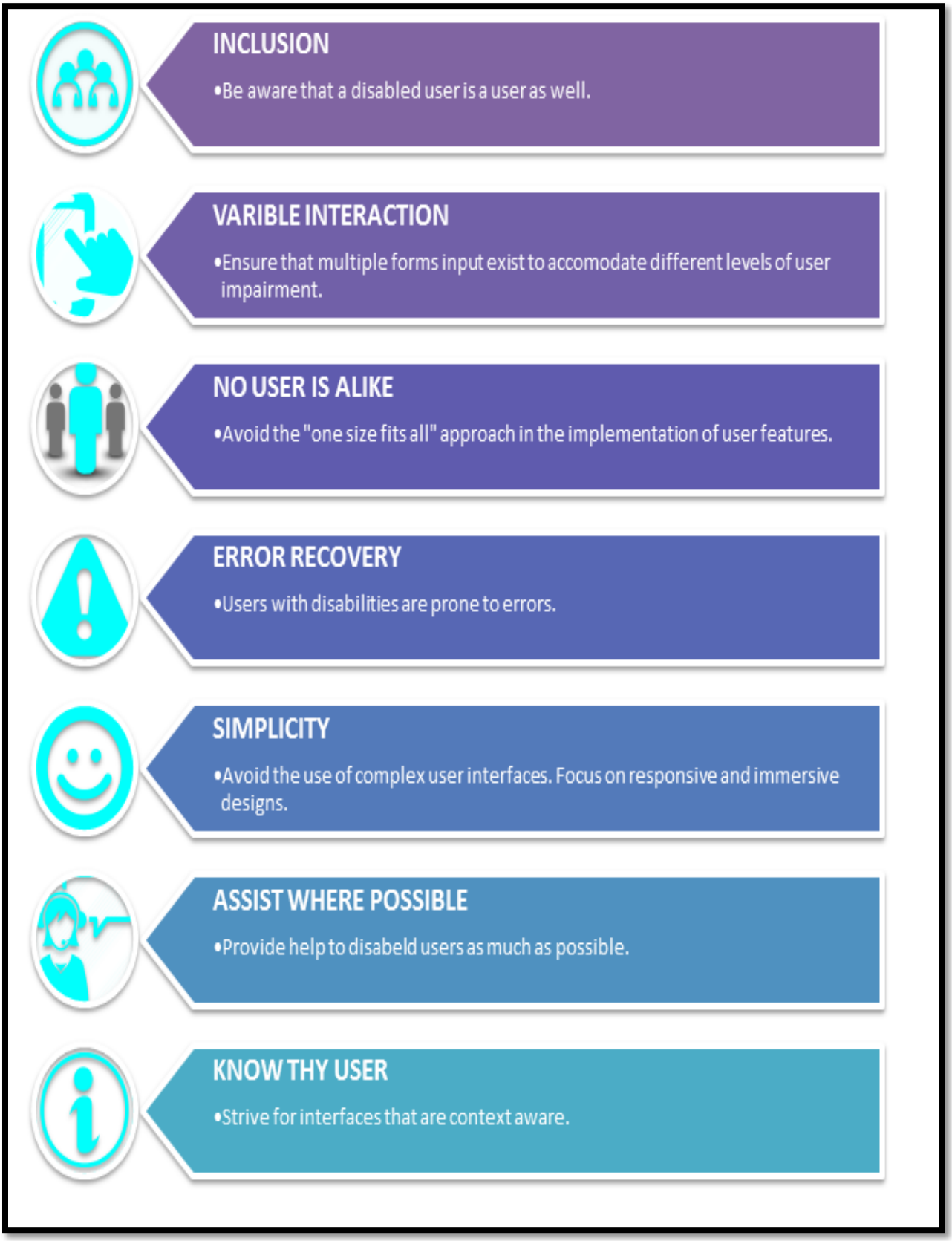


Figure 8.1 Proposed guidelines for this study

8.5 Contributions and Significance of the Research

This study contributes to the existing body of knowledge on accessibility and then more specifically to that of human computer interaction and user experience in the following manner:

- Insights into the characteristics and limitations with regards to interaction with technology for people with motor impairments;
- Insights into the current use of mobile devices by persons with motor impairments;
- An outline of how natural user interfaces can be used to the benefit of persons with motor impairments;
- An outline of guidelines that should be considered when designing for a positive user experience for motor impairments persons interacting with mobile phones.

8.6 Challenges and lessons learnt

The research study was conducted over a period of three years. Many challenges were faced but also many lessons were learnt in the process. The first lesson was that of how to successfully use a research process to conduct a formal research study. As the researcher hails from a software development background, it took some time to gain insights into the research processes. With regards to the actual study it became apparent that there is still a huge gap that exists in terms of interaction design for disabled persons. The knowledge of how disabled persons live their daily lives and interact with technology, was an eye-opener as it displayed the various challenges that the disabled face on a daily basis. A further lesson was the fact that each case of disability is unique and therefore it will be very difficult to derive a concise set of guidelines to support motor impaired persons in general. All guidelines will need to contain some form of flexibility to allow for the differences in the end users.

8.7 Limitations of Research

The study is limited in the sense that it made use of a small sample size based on convenience sampling and the availability of suitable participants. It was also limited to one geographical area and can therefore not claim to be representative of all motor impaired users. The aim of the study was limited to understanding the context of motor impaired users interacting with natural user interfaces and the specific issues that should be considered when designing NUI interactions for motor impaired persons.

8.8 Future Research

This study was limited in its scope and can benefit from being expanded to include the following:

- A bigger target population that is more representative of the different disabilities;
- A comprehensive set of steps and guidelines on how to implement natural user interfaces as an interaction style for use by physically disabled users;
- The development of applications using the natural user interface guidelines to accommodate physically disabled end users;
- Implementation of contextual user experience to enable mobile phones the ability to adapt to user needs;
- Dissemination of information to create an awareness of the research opportunities in terms of interactions styles that can be used by physically disabled users when interacting with mobile technologies.

8.9 Summary

This chapter concluded the research study. The chapter outlined the aims and objectives of the study and how these were achieved. It also provided an overview of the limitations of the study that introduces opportunities for further research.

Finally, this chapter and the dissertation serves as evidence that a research process suited to the problem statement was followed to answer the primary research question of the study

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User Experience Guidelines for Mobile Natural User Interfaces: A case study of physically disabled users

Appendix A: Test Plan

Prepared by: Gershwin Jacobs

A. Appendix: Test Plan

1. Introduction

This document describes the usability evaluation plan of a usability study on natural user interfaces (NUI). The usability evaluation is part of a Masters dissertation entitled

"User Experience Guidelines for Mobile Human Computer Interaction: A case study of motor impaired users".

The plan includes the sections:

- Purpose of the usability evaluation and device selection
- Target audience
- Design of usability evaluation
- Data collection methodology
- Deliverables
- Resources
- Schedule

2. Purpose of evaluation and device selection

The evaluation will evaluate the usage of the Samsung Galaxy s5 as a mobile phone in terms of usability, accessibility, and user experience as a interaction device for disabled people. The s5 was chosen due to the following reasons:

- It is a mobile device that has various NUI capabilities;
- It is seen as one of the best mobile phones in 2014 (Spoonauer, 2014);
- It is one of the most popular phone in South Africa for the year 2014 (Writer, 2014);
- The device has various features that support disabled users in terms of interaction (Writer, 2014) :
    - Blind users
    - Physically disabled users

As mentioned the purpose of this study is to evaluate the usage of the Samsung Galaxy s5 in terms of usability, accessibility, and user experience as a interaction device for disabled people. This study is necessary due to the fact that most interaction devices or methods are not suited

to be used by users that are disabled. Therefore this study promotes the usage of NUIs as interaction devices for disabled and tests whether the Galaxy s5 is worthy of usage as a NUI mobile device for the disabled.

Throughout the evaluation various areas of the device will be tested:

- Usability
- Accessibility
- User experience
    - Navigation
    - Ease of use
    - Understandability etc.

To achieve the objectives of the evaluation, various disabled participants will be tested by means of questionnaires and interviews.

3. Evaluation goals

Various users' goals were determined according to the user tasks that were set. A user goal is seen as the final state that the user wishes to achieve whilst performing a task. These goals are necessary to determine if the tasks set are valid in terms of the evaluation.

4. Target audience

Throughout the evaluation, various participants will be tested on in order to retrieve results for the purpose of the overall study. Valid results will only be obtained if the selected participants are typical users of the device, or if the participants have valid background knowledge of the device being tested on. Therefore it is imperative that the selection criteria is decided on carefully and closely matched.

5. Background and subject selection criteria

The selection of participants is an imperative process throughout an evaluation. It is imperative that the participant's background and abilities are representative of the device being tested on, in order to achieve valid results throughout the usability study.

The following distinguishing characteristics were taken into consideration when choosing participants for the usability evaluation:

- Participants who are motor impaired in the upper body I.e. participants who are disabled in the hands, arms, shoulders, or neck (motor impaired);

- Participants who are accustomed to using various technologies and have valid background information of mobile technology. This is imperative, so that the participants do not have to be educated regarding what the device is, and how to make use of the device as this would defeat the goal of the experiment as the goal is not to teach participants how to make use of a mobile phone;

- Participants between the ages of 18 years to 60 years of age.

6. Design of usability evaluation

The usability evaluation will consist of a single session. Each session will be conducted on a single participant. Each session will consist of a set of tasks and a user experience satisfaction questionnaire for the participants to complete.

Each evaluation session will consist of the following process:

- A performance evaluation which will be conducted on the Galaxy s5 by the participant. The participant will be required to complete a number of real life scenario tasks
- A user experience questionnaire to gather the participants thoughts and experiences about the tasks they have completed on the Galaxy s5

7. Evaluation process

The usability evaluation will consist of the following:

8. Participant greeting and background questionnaire

At the beginning of each evaluation session the participant will be greeted by the evaluation moderator and made to feel comfortable and relaxed. The participants will then be slightly introduced to the topic and goals of the study. The issue of confidentiality will be explained to the participants, and they will be required to sign the consent form.

9. Orientation

Participants will receive a short introduction and orientation to the usability evaluation. Participants will receive material that will explain the purpose and objectives of the evaluation, as well as what is expected of the participants throughout the evaluation. The participants will be made to feel comfortable and relaxed whilst being introduced to the Galaxy s5 (getting a feel for the device). They will be informed to make use of the device as they would use their own and try to imagine that they are not in an evaluation environment, but in a natural environment performing daily mobile tasks. The participants will be informed that they will be observed throughout the evaluation.

10. Performance evaluation

The performance evaluation consists of a set of tasks that will be performed by the participant and evaluated by the moderator. Whilst the participants are attempting to complete the tasks on the Galaxy s5 they will be observed by the moderator. The performance evaluation will consist of various tasks such as:

- Accessing the accessibility features
- Sending an email
- Navigating through the app menu etc.

Once the participants have completed the tasks at hand (on their own abilities), they will be required to take part in the second part of the usability evaluation. This part of the evaluation will enable the participants to share their thoughts, experiences, and provide an opportunity for the participants to provide any comments regarding the device and the tasks they have just completed. This process is an imperative part of the evaluation since it enables the collection of preference data about the tasks performed and the Galaxy s5. Once participants have completed the tasks they will be required to complete a user experience satisfaction questionnaire.

The user experience satisfaction questionnaire will enable the participants with an opportunity to answer various questions relating to the device and the tasks they have just performed. These questions will question the usability and accessibility of the device.

Once a participant has completed their session, they will be thanked for their time, and the data will then be evaluated and stored.

11. Logistics

The evaluation will take place at Chesire Homes in Summerstrand, Port Elizabeth. Chesire Homes is addressed as follows:

- 7 Gomery Avenue, Port Elizabeth, 6001

Chesire Homes is located near to Nelson Mandela Metropolitan University in Summerstrand, the evaluation will take place at Chesire. Within Chesire Homes a room will be used as the main venue for the evaluation. The room will consist of an environment that will ease and relax the participants, and it will be located in an easy to access location for participants that have mobility challenges due to their disability.

12. Evaluation requirements

The following will be required for the evaluation

- The Samsung Galaxy s5. This device will be used as a natural user interface by the disabled participants

- A Wi-Fi connection to be accessed by the Galaxy s5
- A moderator to start the evaluation session, observe the participants whilst performing the performance evaluation, gather the necessary data, and to close the session at hand

13. Materials design

The following materials will be designed and implemented for the usability evaluation (in each session, the participant will be required to complete or read each one of the materials handed to the participant):

- Background questionnaire
- Task scenario
- Moderators script
- Information sheet

User Experience Guidelines for Mobile Natural User Interfaces: A case study of physically disabled users

Appendix B: Background/Screening Questionnaire

Prepared by: Gershwin Jacobs

B. Appendix: Background/Screening Questionnaire

1. Biographical information

(This information will be kept confidential)

Gender (tick the appropriate box)

Male	
Female	

Age group (tick the appropriate box)

18 – 24	
25 – 35	
36 – 49	
50+	

Home language (s)

1st language	
2nd language	

2. Mobile phone usage

1. Do you own a mobile device?
   Yes No
2. How long have you been using mobile devices?
   1 to 3 years 4 to 6 years 6 years plus
3. Do you have general knowledge regarding mobile devices in terms of usage?
   Yes No
4. Does your mobile device have any accessibility features?
   Yes No
5. Does your mobile device cater for your needs when considering your disability?
   Yes No
6. Rate your knowledge on mobile technology in terms of usage
   Beginner Intermediate Expert

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User Experience Guidelines for Mobile Natural User Interfaces: A case study of physically disabled users

Appendix C: Information leaflet and Informed consent

Prepared by: Gershwin Jacobs

C. Appendix: Information Leaflet and Informed Consent

Project title:

User Experience Guidelines for Mobile Natural User Interfaces: A case study of physically disabled users

Primary investigator: Gershwin Jacobs
Nelson Mandela Metropolitan University
School of ICT
Port Elizabeth

Supervisor: Prof Darelle van Greunen
Nelson Mandela Metropolitan University
School of ICT
Port Elizabeth

1. Dear research participant

You are invited to take part in a usability study that forms part of my formal MTech**:**

User Experience Guidelines for Mobile Natural User Interfaces: A case study of physically disabled users

The information to follow will assist you in deciding if you would like to participate in the study. It is imperative that you have full understanding about what the study consists of and what is required of you. Before you agree to take part in the study you should feel satisfied with all aspects of the study.

2. What is the study about?

Human computer interaction (HCI) is the study of interaction between humans and technology. My research focuses on the development of HCI in terms of user experience (UX), usability, and accessibility.

Currently various interaction devices and methods are focused on the interaction skills of fully abled people. Therefor disabled people face various challenges in terms of interaction. To improve interaction for the disabled, new methods of interaction need to be implemented. My research therefore promotes the usage of natural user interfaces (NUI) as interaction methods to counter the challenges disabled people face in terms of interaction on mobile phones. A NUI is an interaction device which enables interaction by means of natural interaction such as voice, gestures, or touch. This form of interaction enables users to become more immersed in the tasks they perform along with various other benefits.

It is with this motivation that this study focuses on the usability and user experience of mobile phones. Usability focuses on the performance of the device in terms of usage whilst user experience focuses on the experience and feelings the user experiences when using the device.

In order for the study to be successful, it is imperative that a valuable contribution comes from the participants in order to evaluate the usability of the Galaxy s5 as a NUI for improved interaction for disabled users.

3. What will you be required to do in the study?

The main goal is to test usability of the accessibility features of the Galaxy s5 as a NUI for improved interaction for disabled users. To achieve this goal, you as the participant will be required to complete a set of common tasks on the Galaxy s5. Once you have completed the tasks, you will then be required to complete a user experience satisfaction questionnaire.

Please note that we will be evaluating the Galaxy s5 as a NUI for disabled people, we will not evaluate you in any way. The evaluation will not require more than two hours of your time.

Note that your identity and biographical information will be kept confidential, and any information collected from the study will be used purely for research and not for public promotion.

If you decide to take part in the study, you will be required to do the following:

- Travel to the location
- Dedicate at least two hours of your time
- Sign the informed consent form
- Fill in a user experience satisfaction questionnaire to record your comments and answers

4. What are the potential benefits that may come from the study?

The benefits of the study are:

- Your participation will contribute to understanding the needs of disabled users in terms of human computer interaction
- The research is based around a new form of interaction that is growing in terms of its capabilities and popularity
- As a result of the this, new forms of interaction will be promoted for improved interaction for disabled users

5. What are your rights as a participant in this study?

As a participant in the study, you are not bound to any contract stating any protocol that you have to agree to. Your participation in the study is voluntary, it is up to you to decide whether you would like to take part in the study. Throughout the study, if you feel the need to pull out of the evaluation, you are welcome to do so without any penalties or future disadvantage.

6. How will confidentiality and anonymity be ensured in the study?

Any information obtained throughout the evaluation will be kept confidential at all times, and the information you provide will be handled confidentially. Access to your data will be strictly limited to the researcher, the supervisor of the study, and the designated examiners appointed by Nelson Mandela Metropolitan University (NMMU). All data sheets containing any personal information will be kept in a secure location and destroyed when it is no longer needed.

7. Is the researcher qualified to carry out the study?

The researcher is an MTech: Information Technology (IT) student in the department of engineering, the built environment, and Information Technology. The researcher comes from the same geographical region as you, meaning that he deeply understands your cultural context.

8. Who can you contact for additional information regarding the study?

The following contacts can be contacted during office hours:

Primary investigator: Gershwin Jacobs

Cell:

Email: Gershwin.jacobs@nmmu.ac.za

Supervisor: Prof Darelle van Greunen

Cell:

Email: Darelle.vanGreunen@nmmu.ac.za

9. Declaration: Conflict of interest

There is no conflict of interest

10. A final word

Your participation in the evaluation is highly appreciated. Please sign the consent form if you agree to take part in the study.

11. Informed consent

I hereby confirm that I have been informed by the researcher about the content of the study. This includes the nature, conduct, benefits, and risks of the study. I have also received, read, and understood the above written information. I am aware that the results of the study, and my personal details will be anonymously processed into a research report. I understand that my participation is voluntary and that I may at any stage withdraw my consent and participation in the study. I had sufficient opportunity to ask questions, and out of my own free will declare my participation in the study.

Research participant name: _____

Research participant signature: _____

Date: _____

Researcher's name: _____

Researcher's signature: _____

Date: _____

12. Verbal informed consent

(Applicable for participants that cannot read or write)

I hereby declare that I have read and explained the contents of the information sheet to the research participant. This includes the nature, conduct, benefits, and risks of the study. I have also received, read, and understood the above written information. The research participant is aware that the results of the study, and my personal details will be anonymously processed into a research report. The research participant understands that their participation is voluntary and that they may at any stage withdraw their consent and participation in the study.

I hereby certify that the research participant has verbally agreed to participate in this study.

Research participant name: _____

Date: _____

Researcher's name: _____

Researcher's signature: _____

Date: _____

User Experience Guidelines for Mobile Natural User Interfaces: A case study of physically disabled users

Appendix D: Moderators Script

Prepared by: Gershwin Jacobs

D. Appendix: Moderators Script

13. Introduction

Thank you for agreeing to participate in this study. Your assistance is required to evaluate and provide feedback on how easy it is to make use of the accessibility features of the Samsung Galaxy s5. The evaluation should not take longer than an hour. Throughout the evaluation you will observed and notes will be taken.

During the evaluation you will be required to complete a set of tasks to the best of your ability. If you need help, ask for it. You are required to complete each task on your own, one at a time using the accessibility features. When you have completed a task notify the moderator, do the same when you start a new task.

Take note that the Galaxy s5 is being evaluated, and not your ability to complete the tasks. If you cannot complete a task, notify the moderator for assistance or move on to the next task. Please provide honest feedback when completing the user experience questionnaire, and if you feel the need to take a break or step out for a moment, you may do so.

Any questions before we begin?

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User Experience Guidelines for Mobile Natural User Interfaces: A case study of physically disabled users

Appendix E: Test scenario

Prepared by: Gershwin Jacobs

E. Appendix: Test Scenario

You are an average user of a mobile device, and like every other user you use your mobile device to perform common tasks such as sending a text message etc. Due to your disability, performing these common tasks can become challenging. To test whether NUIs are the way forward for disabled users, you will be required to perform two sets of tasks.

1. User Tasks

For the 1st set of tasks you will be required to perform various common tasks at your own ability. These tasks are as follows:

1. Goal: phone a contact
   1.1. Task: add your contact to the Galaxy s5, and then phone the contact

2. Goal: send a text message
   2.1. Task: send a greeting message to the contact you have added in task 1. For example, Hi my name is Gershwin, I am a student at NMMU.

3. Goal: Navigating through application list and taking a photo
   3.1. Task: find the camera icon in the application list, and take a photo of any random object.

4. Goal: edit a photo
   4.1. Task: find the picture you have just taken and crop the image to any smaller size.

5. Goal: send an email
   5.1. Task: send a greeting email to the following address –s209077423@nmmu.ac.za, for example, Hi my name is Gershwin, I am a student at NMMU.

6. Goal: Book a movie online
   6.1. Task: Use Google.com to search for Ster-Kinekor
   6.2. Task: Scroll to the bottom of the list containing the web search results, then scroll back to the top again.
   6.3. Task: use www.sterkinekor.com to find a movie you'd be interested in seeing on Saturday evening.

Once you have completed the 1st set of tasks you will be required to answer the short questions in appendix F. After you have completed the questions you will then be required to complete the tasks again, but this time using the accessibility features. The Samsung Galaxy s5 has a range of accessibility features, each one to support a different disability. The accessibility features

improves accessibility for users who have impaired vision, hearing, or reduced dexterity which is the ability to perform tasks with the hands.

To access the accessibility features with ease, press the home key button 3 times to make use of direct access (see figure E1), then select the function you want to open.

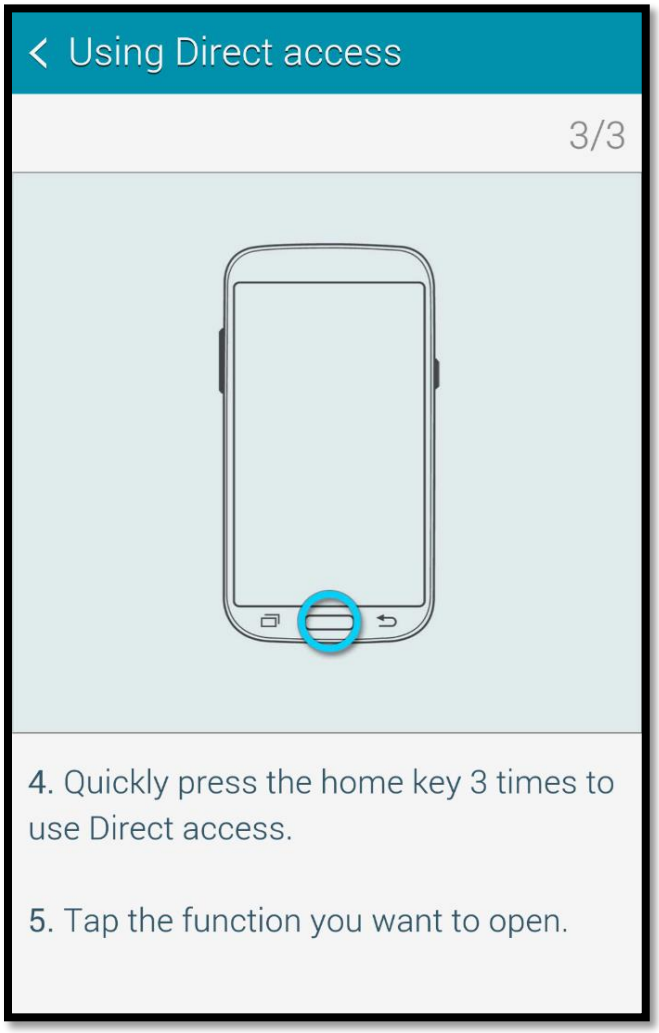

Figure E.1 Direct access on Samsung Galaxy s5

Participants must complete the following tasks by means of the Assistant menu only (note that all interaction should be completed by means of the Assistant menu)

Assistant menu provides a virtual mouse pad which enables users to access their favourite menus more conveniently.

1. Goal: phone a contact
   1.1. Task: add your contact to the Galaxy s5, and then phone the contact

2. Goal: send a text message
   2.1. Task: send a greeting message to the contact you have added in task 1. For example, Hi my name is Gershwin, I am a student at NMMU.

3. Goal: Navigating through application list and taking a photo
   3.1. Task: find the camera icon in the application list, and take a photo of any random object by saying the word “shoot”, “smile”, or “cheese” whilst the camera app is open.

4. Goal: edit a photo
   4.1. Task: find the picture you have just taken and crop the image to any smaller size.

5. Goal: send an email
   5.1. Task: send a greeting email to the following address – s209077423@nmmu.ac.za, for example, Hi my name is Gershwin, I am a student at NMMU.

6. Goal: Book a movie online
   6.1. Task: Use Google.com to search for Ster-Kinekor
   6.2. Task: Scroll to the bottom of the list containing the web search results, then scroll back to the top again. Scrolling will be done using the smart scroll features.
   6.3. Task: use www.sterkinekor.com to find a movie you’d be interested in seeing on Saturday evening.

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Appendix F: Wrap Up Questions

Prepared by: Gershwin Jacobs

F. Appendix: Wrap Up Questions

1. Without assistant features:

1. What do like about the Samsung Galaxy s5?
2. What do you dislike?
3. Did you have trouble using the Samsung Galaxy s5?
4. How would you describe your experience with the Samsung Galaxy s5?
5. Would you consider using the Samsung Galaxy s5 on a daily basis?

2. With the assistant features

(Answer the following questions whilst considering your experience with the Samsung Galaxy s5 and the assistant features)

1. What do like about the Samsung Galaxy s5?
2. What do you dislike?
3. Did you have trouble using the Samsung Galaxy s5?
4. How would you describe your experience with the Samsung Galaxy s5?
5. Would you consider using the Samsung Galaxy s5 on a daily basis?

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User Experience Guidelines for Mobile Natural User Interfaces: A case study of physically disabled users

Appendix G: User experience satisfaction questionnaire

Prepared by: Gershwin Jacobs

G. Appendix: User Experience Satisfaction Questionnaire

1. **Long questions:**

1.1. What mobile device are you currently using?
•
1.2. Do you experience any barriers (in terms of use) with your current device? If so, explain what these are?
•
1.3. Considering the mobile device you are using now. How would you describe your experience with the Samsung Galaxy s5?
•
1.4. Once again considering the mobile device you are using now. How easy did you find it to complete the tasks at hand?
•
1.5. Considering the tasks you have just completed. Did you find it easier to complete the tasks with or without the assistant features? And why do you feel this way? (physically disabled participants only)
•
1.6. On a scale of 1 to 5, with 1 being extremely difficult and 5 being very easy. How easy was it to make use of the implemented assistive interaction features?
•

1.7. Due to the accessibility features of the Samsung Galaxy s5. Would you consider this device over the mobile device you are using now? If not, why?
•
1.8. Do you prefer using the Samsung Galaxy s5 with or without the assistive features, if you prefer to use it without, why is this so?
•
1.9. Do you feel that making use of assistive technology/ features like the Samsung Galaxy s5 is the way forward for users with disabilities?
•

2. Short questions:

2.1. The interface of the Galaxy s5 is user friendly and easy to use and understand.

A. Strongly agree
B. Agree
C. Undecided
D. Disagree
E. Strongly disagree

2.2. The assistant features are easy to access and switch on/off.

A. Strongly agree
B. Agree
C. Undecided
D. Disagree
E. Strongly disagree

2.3. I find that the assistant features do benefit me in terms of interaction.

A. Strongly agree
B. Agree
C. Undecided
D. Disagree
E. Strongly disagree

2.4. I found it easy to find the various icons to complete the tasks at hand

A. Strongly agree
B. Agree
C. Undecided
D. Disagree
E. Strongly disagree

2.5. Navigating through the device was easy

A. Strongly agree
B. Agree
C. Undecided
D. Disagree
E. Strongly disagree

2.6. The icons on screen are visible and easy to understand

A. Strongly agree
B. Agree
C. Undecided
D. Disagree
E. Strongly disagree

2.7. The text on screen is easy to read and understand

A. Strongly agree
B. Agree
C. Undecided
D. Disagree
E. Strongly disagree

2.8. The size of the device made it easy to handle

A. Strongly agree
B. Agree
C. Undecided
D. Disagree
E. Strongly disagree

2.9. Using the accessibility features made it easier to use the device

A. Strongly agree
B. Agree
C. Undecided
D. Disagree
E. Strongly disagree

3. Comments:

_____

_____

_____

_____

_____

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User Experience Guidelines for Human Computer Interaction: A case study of motor impaired users

Appendix H: Samsung Galaxy s5

Prepared by: Gershwin Jacobs

H.Appendix: Samsung Galaxy s5

What is the Samsung Galaxy S5?

In the year 2014 Samsung released the Samsung Galaxy s5 mobile phone.

Figure H.1 Samsung Galaxy s5 (IBNLIVE, 2014)

The Galaxy s5 is a much more powerful and capable version of Samsung's Galaxy mobile phone range. It contains great apps to be used on the go for productivity and creativity. The Galaxy s5 is powered by the latest Android OS KitKat 4.4.2 and has the following specifications as listed in table H.1 (Beavis, 2015):

Samsung Galaxy s5	
Processor	Quad core application processor, 2.5 GHz
Memory	2 GB
Size	142.0 x 72.5 x 8.1 mm
Weight	145 g
Pointing device	Touchscreen
Storage	16/32 GB
Resolution	5.1” FHD Super AMOLED (1920 x 1080), 432 ppi

Table H.1 Samsung Galaxy s5 specifications

To increase the usability of the Galaxy s5, the device has a wide range of built in and downloadable apps that can be used in various situations (see figure H.2).

Figure H.2 Galaxy s5 built in apps

Advantages of the Samsung Galaxy s5

Due to the various abilities of the Galaxy s5 it is noticeable that it is capable of providing numerous benefits in various situations. A few of these benefits are touched on below

- The Galaxy s5 is extremely portable due to size and weight
- The Galaxy s5 has a built in fingerprint scanner
- The Galaxy s5 has a built in heart rate monitor
- The Galaxy s5 is water and dust proof
- Wide range of great applications available for download
- The Galaxy s5 is great for entertainment use in terms of gaming, movies, and music
- The Galaxy s5 has extreme ease of use due to the Galaxy s5 intuitive interface
- The Galaxy s5 is reasonably priced
- The Galaxy s5 can be used by various users due to its accessibility features

Based on the mentioned benefits, it is evident that the Galaxy s5 is an amazing device. With various add-ons the Galaxy s5 can broaden the experience even further, for example, various accessibility features are available to users that are physically disabled which takes the abilities of the Galaxy s5 to a whole new level and brings with it opportunities for new beginnings with regards to user experience.

How will the Samsung Galaxy s5 be used in this study?

Computers or interactive handheld devices are used on a daily basis by millions of users around the world. Each user is unique in his or her own way, and each user uses interactive systems to perform various activities/actions. Since each user is so unique these interactive systems are designed and implemented in a manner that seeks to provide satisfactory results with regards to usability and user experience.

In terms of interacting with interactive systems, the methods used for interaction are focused on the interaction skill of people that are fully abled. People with motor impairments, like the rest of the population, are increasingly using computers/interactive devices. Due to the current interaction devices used for interaction, however, various challenges for users with motor disabilities arise when interacting with interaction devices such as mobile phones.

The Galaxy s5 device comes standard with innovative accessibility features that suit the needs of various users, especially users that are motor impaired. The s5 is equipped and is packed with tools and various features that are capable of improving interaction for disabled users. These

tools assist users with special needs by providing better accessibility for the disabled, some of these tools include the following (Beavis, 2015):

- Visibility
  - TalkBack (see figure H.3) is an accessibility feature which assists visually impaired users in interacting with the Samsung Galaxy s5. TalkBack improves interaction by reading out the content on screen. When TalkBack is activated, special interaction gestures are implemented which are aimed at improving the overall experience for blind users.
  - Seven different font sizes are available, as well as a feature that is capable of reversing colors on the screen for users with poor vision

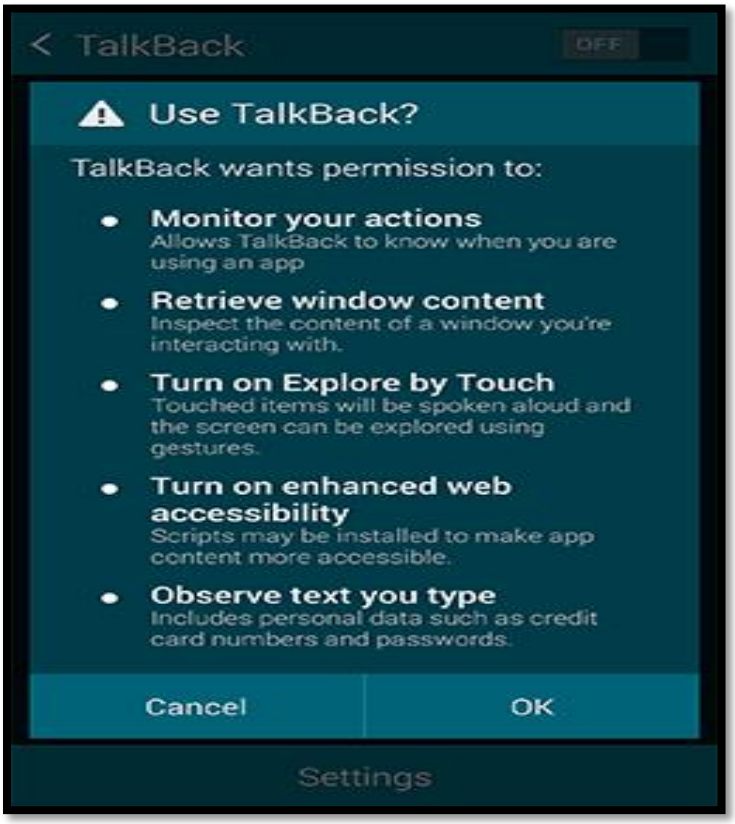

Figure H.3 TalkBack feature on the Galaxy s5

- Hearing
  - The s5 has a built in baby crying detector which notifies the user through a series of vibrations
  - Auto haptic feedback enables users to feel the phones sounds through vibrations
  - Various voice to text applications exist to ease communication for deaf users

- Physically challenged
  - Assistant menu (see figure H.4) is virtual mouse pad designed for users with limited hand movement. Assistant menu provides a virtual mouse pad which enables users to access their favourite menus more conveniently.
  - Air gestures are available for interaction Various customizable interactions are available to suit the user's needs

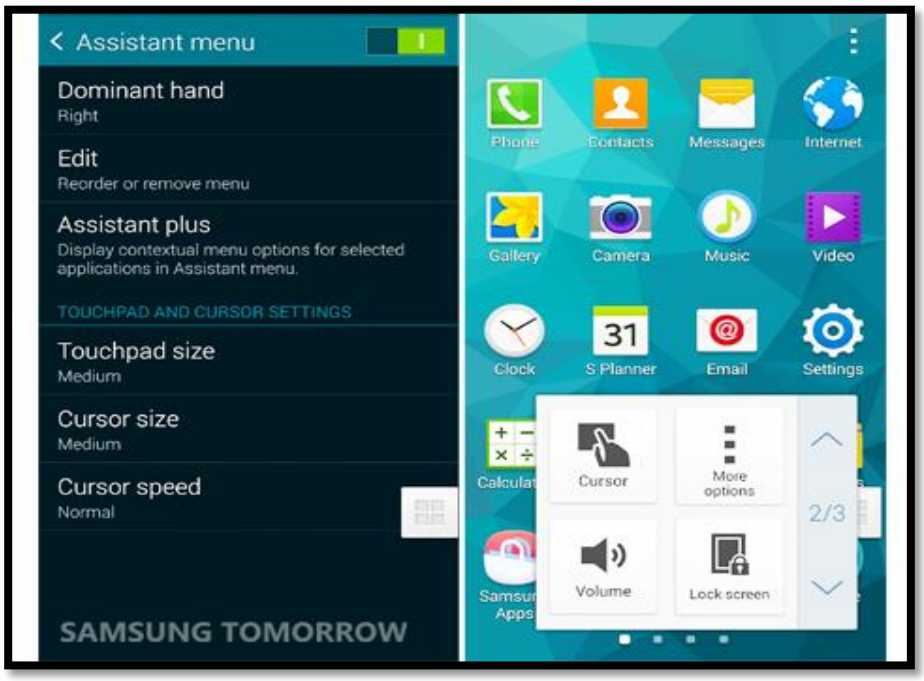

Figure H.4 Assistant menu feature on the Galaxy s5

To determine the usability of the Galaxy s5 as a NUI interaction device, the Galaxy s5 will be used in a case study to determine its worth as a device capable of assisting the physically disabled. The goal of the case study is to determine how the Galaxy s5 has a better influence on user experience in terms of usability, accuracy, and accessibility.