ADDIS ABABA UNIVERSITY

College of Natural and Computational Sciences

Developing Design Principles for Autistic Android Application Users : The Case of English Alphabet

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This is to certify that the thesis prepared by Abreham Bekele, titled: *Developing Design Principles for Autistic Android Application Users, the Case of English Alphabet* and submitted in partial fulfillment of the requirements for the Degree of Master of Science in Computer Science complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

Autism Spectrum Disorders (ASD) are enduring neurodevelopmental and behavioral disorders found in early childhood. Children diagnosed with the disorder show communication, emotional, and social impairment varying from mild to severe. Over the last decade, an immense amount of research in computer science has been done on developing different computer-assisted solutions in improving the condition of children diagnosed with autism. The solutions comprise of computer, multi-touch table, smartphone-based application to improve or develop communication (verbal skills), emotional (non-verbal skills), and social interaction skills in these children. However, most of the android applications developed for autistic users are difficult to use, this is mainly due to the lack of standard usability guidelines and principles for developing android applications for autistic users. This research paper identifies design principles to tackle this issue of usability regarding android applications developed for autistic users with an emphasis on English alphabet teaching android application. First characteristics of autistic users that affect the usability of android applications are identified, then usability attributes that are related to autistic users' characteristics are identified, and then, finally, design principles from previous literatures are revisited and the new ones are developed based on autistic user characteristics and usability attributes**.** The design principles identified are then tested on end-users, in this case, autistic users, to determine whether they are effective or not. This is done by way of mockups; different mockups for English alphabet teaching android application are developed to test various alternate presentation for each design principles. The mockups are then tested on end-users and test results are documented. The test results show that the design principles identified in this research paper are worthy to be considered in designing English alphabet teaching android application to autistic users, but the principles can also be applied in developing other android applications too.

Keywords: Autistic Users, Design Principles, Android Applications, Autism Spectrum Disorder, Usability Attributes, Autistic User Characteristics

Dedication

To my parents

Acknowledgments

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Chapter 1 : Introduction

1.1 Background

ASD is a developmental disorder of the brain that affects the sociability, language, behavioral, flexibility, and imagination aspects of the person afflicted by it [1]. Autistic persons face a myriad of impairments in different aspects of life, such as communication and social interactions, making each case unique, requiring different types of therapy. Because of their mental imbalance autistic persons always experience difficulty in their personal and social life. With the prevalence of autism, it's important to have the right tools for the diagnosis and therapy of the different symptoms of autism. With the advent of smartphone technology such as tablets, professionals have new tools to use in therapy to improve the quality of life of autistic persons. Different studies also show that autistic persons are highly fascinated by technology for learning something rather than traditional methods of learning [2].

To help children with ASD in learning, several therapy and treatments are used; these methods might include various medications, speech or language therapy, assistive technology, sensory integration therapy, music therapy, visual schedules, gentle teaching, holding therapy, and vitamin supplements [3]. Numerous works have proven that the ability to learn and communicate can be developed in children with ASD by using 'assistive technology' [4] such as smartphone technology.

Smartphone technology provides a proper educational environment for autistic persons. Learning through the use of smartphone technology could expand the scope of learning anytime and anywhere. Smartphone assisted learning has gained attention in describing the future of education [5]. Current researches conducted on the role of smartphone applications for kids with ASD have proven that mobile information and communication technologies (MICTs) could improve participation in educational settings and social contexts; these applications include androids, iPads, Apple smartphones, and tablets [6].

Smartphone devices with educational games has also been found as good alternative in assisting autistic users in learning by making them feel relaxed and comfortable while they do their learning activities [7].

Assisting learning with educational games has been widely introduced among children with ASD [8]. Despite the great role of smartphone applications in assisting autistic users to learn better, this solution, i.e., supporting education with game, presents problems of its own. In particular, the currently available smartphone applications intended to aid learning for individuals with autism are difficult to use [9]. The challenges have something to do with the UI design process, which arises from improper design decisions, improper use of UI design elements and a lack of usability guidelines and principles [9, 10, 11].

Myers and Rosson [12] stated that the trend of software development during the period they have conducted their survey has been devoting an average of 48% of the code to the UI design. These days from the growing need for usable software applications, it would thus seem justified to allocate a reasonable proportion of the effort in software development projects to ensure the usability of UI.

To arrive at the acceptable UI, one also needs genius, a stroke of inspiration, and plain old luck [13]. Even the most gifted designers, however, would be pressing their luck too far if they were to ignore systematic usability engineering methods. Usability engineering is a set of activities that ideally take place throughout the lifecycle of the product, with significant activities happening at the early stages before the UI has even been designed to ensure the usability of the product being developed [13].

Gould and Lewis [14], states that the need to have multiple usability engineering stages, those supplements each other, was recognized early in the field; though not always followed in the development process. According to Nielson [13], following each stage in usability engineering emphasizes that one should not rush straight into the design. These usability engineering stages are also called the usability engineering life cycle.

Mayhew [15], states these stages as requirement analysis; three levels iteratively executing design, development, and testing activities at each level; and the installation and final evaluation.

Each stage by itself also contains activities to ensure the usability of the product under development. Under requirement analysis, we have a user profile, contextual task analysis, usability goal setting, platform capabilities, and constraints, and UI design principles.

The design, testing, and development stage are iteratively executed in three levels: Level 1 consists of work reengineering, conceptual model design, conceptual model mockups, and evaluation. Level 2 consists of screen design standards, prototyping, and evaluation; Level 3 consists of a detailed user interface design and evaluation. The final stage installation stage consists of deployment and user feedback. Of all these stages of usability engineering, the focus of this research paper is on UI design principles which are defined during the requirement analysis stage. UI design principles are objectively structured rules and laws that are intended to improve the quality of UI design [16].

Concerning the development of engineering products for users with disabilities (differently-abled-users), Batusek and Kopece [17], discussed how UI should be designed for visually impaired people. The authors put the following specific demands on a UI designed for visually impaired people.

- The system must enable comfortable control using a combination of speech commands and a keyboard (hot-key commands).
- Speech commands should be supported by a speech (system-driven) command dictionary that allows expressing command in several ways, making the control of the system more intuitive.
- Easy customization and configuration are very important features of the system, especially for blind users that often use the system for a long time.
- It is very important to enable the user to obtain the information quickly and to allow to get an information overview.
- The orientation of the user should be supported by the information about the position that is always accessible in speech form as well as in the form of audio glances, earcons, and environmental sounds.

Morris [18], organizes and presents characteristics of older adult learners, along with recommendation based on those characteristics, with the hope that their accessibility will enhance designer intuition and provide suitable information to guide user testing. The following are some of the recommendations the author suggests based on the visual characteristics of older adult learners that should be considered in UI design:-

- Font size:- Provide multiple font sizes, and allow the user to select the best size for the task.
- Text characteristics:- Consider using high-quality, anti-aliased character fonts on displays with relatively high resolution. Also consider using negative contrast displays (dark characters on a light background).
- Resolution:- Maximize the displayed resolution of screen objects.
- Display terminals:- Use display terminals that tilt and swivel, so that users with bifocals can adjust displayed information to suit their needs. Also consider using larger displays than usual.
- Lighting:- Ensure that the work area is brightly lit.
- Colour:- Use colour combinations that are effective and do not burden the perceptual system. For example, avoid blue for thin lines and small shapes. Avoid colour combinations that ask the viewer to distinguish between colours of shorter wavelengths, e.g., blues and greens.
- Colour for text:- Choose the colour for text and background carefully. Consider using white text on a blue background as a suitable colour combination for the display of text.
- Brightness:- Older viewers need higher brightness levels to distinguish colours.
- Object speed:-Avoid fast-moving objects on the screen.

A lot of researches have also been done on the area of autism, but most of them focus on developing applications for autistic users, for instance, applications to improve autistic users verbal communication and behavior, and a little has been done regarding how to design a usable UI, on techniques and tools needs to be applied to design usable UI for them.

UI design principles are one of the techniques that can help in designing usable UI by paving the way on how usable UI should be designed. But first autistic user characteristics will be identified, based on those characteristics usability attributes that need to be considered will be identified, then previous design principles will be revisited and the new ones will be developed based on the identified autistic user characteristics and usability attributes and then finally the effectiveness of the identified design principles will be tested on autistic users via the use of different English alphabet teaching android application mockups.

1.2 Motivation

The motivation for this research paper is initiated from an encounter with an autistic child in our neighborhood. The child has been observed wanting to play games on smartphone devices as other children do, but he encounters difficulties with those games. So, this triggers the need to improve the usability of android applications so that they can also be used by autistic users easily. As we read through other researches, we found that there is a challenge in developing usable android applications for autistic users because of the very nature of the disease. Even android applications specifically designed for them are difficult to use because of their UI design process which arises from improper design decisions, improper use of UI design elements and lack of usability guidelines and principles [9, 10, 11]. We believe that improper design decisions, improper use of UI elements and lack of usability guidelines and principles can be allievated through the use of UI design principles specifically crafted for designing a UI for autistic users.

1.3 Statement of the Problem

Designing software to meet users' needs demands to consider the capabilities and constraints of the user. Conventionally, a persona is defined and, often, during design, existing UI design principles are applied for the respective persona. However, the existing UI design principles for users with ASD are insufficient and some of them lack autistic users consideration.

Hence the process of developing a UI for users with special needs, such as autistic users, can have its challenges. Furthermore, in the case of autistic users, as the characteristics may vary depending on the level of the severity of autism, a thorough study is needed to develop UI design principles.

On the other hand, a study shows that autistic users are more fascinated by technology for learning than traditional methods of learning [2]. And, this could be an opportunity to develop a usable application.

Researches have been done in the area of autism which focuses on improving the behavior and intellect of autistic persons. Many software applications have been developed to help people with ASD, and most of them run with the android platform.

Android applications with educational games are found to be alternative aid for autistic children to deliver effective teaching [19]. This approach, combining games with learning, has been widely introduced among children with ASD [20]. However, this solution presents problems of its own. In particular, currently available android applications intended to aid learning for individuals with autism are difficult to use while they also demand more learning and operation efforts [9]. Basically, the challenge is related to the UI design process, which arises from improper UI design decisions,e.g.,displaying too much information per screen, improper use of UI elements,e.g., inappropriate color usage, which arises from lack of usability guidelines and principles [9, 10, 11].

UI design process needs to be revised if it is to offer optimal opportunities for understanding and learning for special needs users [21]. The software design process for users with autism must adapt specifically to the needs of its target audience [21].

These days, the design principles used to develop applications for autistic users are general in nature and not related sufficiently close to the needs of its target users [21].

That is why developing UI design principles for autistic android application users can be beneficial in this case. UI design principles can be helpful in developing usable software applications for special needs users, like autistic users.

1.4 Objectives

The general objective of this research paper is to develop design principles for autistic android application users, the case of English alphabet.

The following specific objectives will help to accomplish the general objective stated above.

1. Reviewing UI design principles that are available in literatures
2. Collecting the user profile of users with ASD and aligning the profile description towards usability attributes in [13] (especially learnability, effectiveness and other attributes related with autistic user characteristics)
3. Identifying design principles that can be adapted and those that should be created
4. Developing mockups to test the effectiveness of the identified design principles
5. Conducting usability test using the mockups by having autistic users as test user

1.5 Methods

1.5.1 Literature Review

Various UI design principles and guidelines are available in literatures. These literatures will be reviewed thoroughly to identify different UI design principles and guidelines which will be applicable for developing android application for autistic users.

1.5.2 Collecting Autistic User's Profile.

Knowing the user characteristic is important in software application development [22]. So, in this stage, autistic users' characteristics that will affect the usability of software applications will be identified**.** The user characterists are collected through literature.

1.5.3 Identifying Usability Attributes.

All types of usability attributes can't be applied to all kinds of users since some usability attributes are critical for some users and some are not [13]. So, in this phase, usability attributes that relate to autistic users' characteristics will be identified.

1.5.4 Developing Design Principles

Based on autistic user characteristics and usability attributes design principles that will be used to develop android applications for autistic users will be identified.

1.5.5 Design and Testing of Mockups

Different mockups for English alphabet teaching android application will be developed to test the effectiveness of the identified design principles. The mockups will be tested on autistic users to verify whether the identified design principles are effective or not.

1.6 Scope and Limitation

The UI design principles will be used for developing an English alphabet teaching android application. But we will certainly believe that the design principles identified in this research paper can also be used in developing other android applications for autistic users. Concerning the platform the UI design principles identified in this research paper are specifically applied to applications that run on an android smarthphone devices. But this doesn't mean that the design principles can't be applied to the other platforms, however we can't be sure of that unless verified by experment since user interaction styles varies between platforms.

1.7 Application of Results

This research paper will identify UI design principles that should be used in android applications development for autistic users by using an English alphabet teaching android application as an illustration. The principles will lead to a better fulfillment of the users' requirements.

The usability of existing android apps will also be improved by either adding extra features to make their use easier/more comfortable or by changing their look to be more suitable to autistic users. Also, the output of this research paper will be used as a good input for future research works which will be performed in the area of UI design for autistic users.

1.8 Organization of Thesis

The rest of this research paper is organized as follows: Chapter 2 discusses the literature review. In Chapter 3, research papers that are related to our work will be discussed. Chapter 4 will present the identified design principles. The design and development of the mockups and evaluation of the mockups will be discussed in chapter 5. Finally, Chapter 6 will discuss the conclusion and future works.

Chapter 2 : Literature Review

This chapter focuses on ASD, ASD and technology, ASD and UI design challenge, characteristics of autistic users, usability attributes that needs to be considered, and UI design principles, and how they are developed.

2.1 Autism Spectrum Disorder (ASD)

According to the latest version of the diagnostic and statistical manual of mental disorders (DSM-V) [23], ASD is defined as a developmental disorder of the brain that mainly affects communication and social skills of persons. Persons with ASD might also exhibit fixed or repetitive behaviors [23]. By fixed or repetitive behaviors, we mean that shaking head and body, repeating voices heard, clapping hands, swinging arms to the left and right, etc.

Autistic users have also a serious problem that is connected with communication skills such as unable to make a proper conversation, misinterpreting nonverbal interactions, or experiencing difficulty in building friendships appropriate to their age [23]. Besides, autistic users are highly dependent on routines, highly affected by the changes in their environment, or their focus is intensely taken by inappropriate items. Moreover, autistic users show a wide range of symptoms varying from mild to severe [23].

As a spectrum, each person with ASD displays different levels of affliction in the same core aspects. ASD affects the way that information is processed in the brain, making the person afflicted by it perceives the world differently than a typical person [1]. An example of this is, they have difficulty interpreting facial expressions and body language, giving away the idea that they lack empathy.

While every user with ASD shows unique characteristics, the characteristics are often classified into the following three categories [22]:

1. Impairment in reciprocal social interaction: users showing this behavior could have the difficulty in expressing their own emotions and fail to understand other people's emotion;

2. Impairment in communication: this characteristic of users indicates that the user has a lack of verbal and nonverbal language use; and
3. Restricted, repetitive, and stereotyped patterns of behavior, interest, and activities: refers to autistic users with the tendency of doing the same thing over and over again, such users may also show unusual interests in objects, e.g., they may play with toys in a different way than non-autistic persons will do.

Some other studies also confirmed that autistic user characteristics can be shown by its effect on five senses, social interaction, and emotional expression [24].

Each classification of autistic user characteristics has its own diagnostic criteria for what symptoms or traits to look for to reach a diagnosis of ASD, and yet they are very similar. Adding another difficulty for the proper diagnosis and treatment of the symptoms of ASD is that it is common for a person with ASD to also have some other disorders which could be masked by sharing similar symptomology thus causing erroneous diagnosis and treatment [1]. With all the series of impairments inflicted on a person with ASD, it is of extreme importance to provide proper therapy. Advances in technology make possible the development of tools for therapy and also everyday life, making life easier for people with ASD and their families. Many tools are developed for autistic users to make their life better; this includes different software systems especially those which run on the android platform.

There are several things to consider when we develop any software system, not only specific to autistic users, knowing the characteristics of the end-users is one of them. Consideration of user characteristics is an important step in the software development process for the design of any software system since the way the user interacts with the system directly affects the usability and overall performance of the system [22].

Its consideration is of vital importance especially, when designing software for special needs users, such as autistic users. Autistic users face a myriad of impairments in different aspects of life [22]. So, in this case, identifying their characteristics before trying to develop any system for them has to be given great emphasis, though one cannot directly go into developing the real product after identifying their characteristics.

2.2 ASD and Technology

Technology can provide a great deal of support for individuals with ASD [25]. In the broadest sense, technology, mostly electromechanical tools, can help an individual accomplish work, enjoy leisure pursuits, and get assistance. Technology can be a great aid for persons with ASD because it is customizable. It can be configured in a variety of different ways and used to solve a variety of problems. Besides, its portability is invaluable for persons with ASD [25].

As new and more sophisticated consumer electronics are available to the public, they also bring new opportunities for improving the quality of life and therapy of persons afflicted by some disability or impairment, including persons with ASD [22]. People with ASD, especially children, seem to have a high proficiency for computers and other devices, making smartphones' the device of choice for most autistic children.

The use of smartphones among users with ASD is increasing dramatically due to the new and cool gadgets these devices are providing [26]. These devices are primarily used as communication devices, but they can also be used as a learning device. Moreover, these devices are known for their flexible multimedia content and storage, portability, mobility, and affordability. The UI of these devices is flexible and easy to use, particularly for those who have weak fine motor skills [26], such as people with ASD. The flexibility, functionality, and advanced capabilities of these devices are opening new opportunities for further research in the area of computer-based intervention for children with ASD [26].

2.3 ASD and User Interface Design Challenge

Though smartphone devices are found to be a good tool to assist autistic users in many ways, many smartphone applications that are currently being developed for autistic users are difficult to use, so it is important to study autistic users' characteristics carefully to design usable smartphone applications for them.

There is a lack of study on autistic users' characteristics and on usability issues of smartphone applications designed for them, many research works conducted on autistic user's area focuses on what to develop rather than on how to develop.

Due to the great advancement of smartphone devices these days, more in-depth research is needed to make them better used by autistic users [26].

The difficulty of smartphone applications currently developed for autistic users is particularly related to UI design [19]. The challenges have something to do with the UI design process and the existing usability guidelines which are insufficient and unproven [11, 18].

UI plays a vital role in terms of visibility, design, and precision for depicting the exact amount of information for the intended users [11]. It is important to have a usable UI to help autistic users in the learning process [11]. It is also important to have smartphone applications that are designed based on usability attributes that can cater to autistic users' need, especially in enhancing their learning, communication, social and cognitive skills [11].

Recent studies conducted on the existing design principles showed the design principles are insufficient and unproven to develop usable smartphone applications for autistic users [11]. Thus, it is a need to have proven design principles to develop a usable smartphone application for autistic users. Even minor decisions that have been made in UI design will be able to negatively or positively contribute to the application. Thus, it is a need to study the elements of a good UI design and to have proven design principles to design usable UI for smartphone applications, which in this context is for autistic users.

By having good elements of the UI design process for smartphone applications, autistic users can enhance their disabilities in learning, communication, social, and cognitive skills through smartphone technology.

2.4 Characteristics of Autistic Users

User characteristics are needed to establish the general requirements of the product and useful to identify the category of users to define overall UI style and approach [15]. Hence, consideration of the user’s characteristics is an important aspect of the design and specification process for the development of any software system.

This is because the way the user interacts with the system directly affects the usability of the product (application) and the overall performance of the user [22].

When designing software for users with special needs (e.g., autistic users), the consideration of user characteristics is even more important [22].

In this section, characteristics of autistic users that affect the usability of the android applications are discussed. For the case of this research paper, the psychological/cognitive and physiological/physical traits of autistic users are considered.

In Table 2.1, we presented autistic users characteristics identified as to potentially will affect the usability of a given software product [21, 23, 26].

Table 2.1: Autistic user characteristics

Autistic user characteristics	**Description**
Finds failure very debilitating	Telling them they are doing wrong is often offensive to autistic users
The tendency to seek local cohesive, looking for meaning in matters of detail	tend to focus on particular details rather than looking for general meaning
The tendency to spend too much time on the same task	May engage themselves in doing the same thing over and over again or talk constantly about specific things that interest them.
Prone to sensitivities	maybe highly sensitive to noise, finding intolerable noise which is barely perceptible or unremarkable to others
Visual Learners and thinkers	Better understands when ideas, words, and concepts are associated with images
May not understand remote object references and/or some forms of abstraction	Failure to understand complex interlinked features
Repulsive to some colors like black	Autistic users often feel intolerable with black color
Limited motor skills	having difficulty grasping or manipulating objects, such as a mouse

2.5 Usability Attributes Needs to be Considered

Usability is a measurable characteristic of a product's (e.g., software) UI. As a result, a usable software system can be considered as a system that supports the effective and efficient completion of tasks in a given work context [13]. Also, since usability is often measured by assessing the performance of users while they interact with the product, the usability of a product is often related to its interface.

There are some factors that make the given software product usable or not. These factors are called usability attributes. It is important to note that not all usability attributes are necessarily applied to all types of users. Rather, it is a need to study the user characteristics first to identify which usability attributes are applied to them and which are not [13], these are the usability attributes that should be considered in UI design for autistic users according to [11]:

1. Ease of use

   This element refers to the simplicity in performing the given task. The amount of effort required to use a given software application, to accomplish a certain task using that software application should be given consideration when designing software applications for autistic users. The software application does not need to require much effort from autistic users to use it. It has to avoid complex features for autistic users to use it simply.

2. Understandability

   This element refers to the clarity and learnability of the user interface elements used to interact with the product. Considering understandability as one usability attribute in designing applications for autistic users is very important. Understanding something for autistic users often takes more time and patience when it's compared with non-autistic users.

3. Appearance

   This element refers to the look and feel of the UI, it also includes the ability of the software application to give cues to the user on how it behaves and how it interacts. No one can turn back from using a beautifully designed interface and this includes autistic users as long as the interface is designed considering their context. A user interface should attract its users to stick and engage with it.

4. Efficiency

   This element refers to the resources that will be used to increase the accuracy and completeness of the task. The interface must be able to improve the speed and accuracy to complete the task.

5. Satisfaction

   This element refers to the users' comfortable feeling towards the application.

2.6 Design Principles and how they are Developed

UI design principles are objectively structured rules and laws that are intended to improve the quality of UI design [16]. For instance, Constantine and Lockwood [28], devised the following principles in their book called Software for Use:

- *The structure principle*: Design should organize the user interface purposefully, in meaningful and useful ways based on clear, consistent models that are apparent and recognizable to users.
- *The simplicity principle*: The design should make simple, common tasks easy, communicating clearly and simply in the user's language, and providing good shortcuts that are meaningfully related to longer procedures.

- *The visibility principle*: The design should make all needed options and materials for a given task visible without distracting the user with extraneous or redundant information. Good designs don't overwhelm users with alternatives or confuse them with unneeded information.

- *The feedback principle*: The design should keep users informed of actions or interpretations, changes of state or condition, and errors or exceptions that are relevant and of interest to the user through clear, concise, and unambiguous language familiar to users.

- *The tolerance principle*: The design should be flexible and tolerant, reducing the cost of mistakes and misuse by allowing undoing and redoing, while also preventing errors wherever possible by tolerating varied inputs and sequences and by interpreting all reasonable actions.

- *The reuse principle*: The design should reuse internal and external components and behaviors, maintaining consistency with purpose rather than merely arbitrary consistency, thus reducing the need for users to rethink and remember.

Raskin [29], also devised two laws of UI design in his book the Human Interface;

- *First Law*: A computer shall not harm your work or, through inactivity, allow your work to come to harm.
- *Second Law*: A computer shall not waste your time or require you to do more work than is strictly necessary.

He also mentions that "users should set the pace of interaction," meaning that a user should not be kept waiting unnecessarily.

Nielsen and Molich's [30], also devised 10 general UI guidelines. They are also called 'heuristics' because they are more like rules of thumb than specific usability guidelines. The guidelines are consistency and standards, visibility of system status, system match to the real world, user control and freedom, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetic and minimalist design, help users recognize**,** diagnose, and recover from errors and help and documentation.

UI design principles describe how one wants the end product to be perceived by the users and how you want users to feel about the experience [31]. Creating these principles, before starting a design is a brilliant kick-off for a project and a great way to get to know the project's scope. Always being able to refer to and fall back on these principles, will help a designer to efficiently move through the complete development process of a product.

According to Oskam [31], one needs to follow the following steps to craft a design principle for the development of any software product.

- **Research**

This focuses on getting to know the end-user. The user's characteristics must be known first hand, before crafting design principles for them. This can be done through a workshop, an interview, or through analyzing existing user surveys and analytics. The end-users need, concerns, functional and technical demands should be known.

- **Brainstorm**

Based on the characteristics of the users identified, the researcher should brainstorm on the design principles that would fit the user characteristics.

- **Make them almost perfect**

The researchers should tweak and refine the design principles until they are short, specific, easy to understand, and easy to memorize. The researcher should also carefully check whether different principles do not conflict with one another and see to it that they can be upheld for the product or service as a whole, cross-feature.

- **Check with stakeholders**

The researcher should check the principles with end-users, this can be done by way of a prototype, a prototype can be developed based on the design principles crafted, every design decision should be based on the design principles.

- **Let them grow and mature over time**

The design principles should be revisited especially with long-term projects, new insights might lead to different or new design principles.

Chapter 3 : Related Work

This Chapter presents researches that have made effort so far concerning UI design principles for autistic users. The following researches consider a specific kind of environment as their problem area and this research paper will focus on the gaps based on the general context.

Hussain et al. [32], analyzed the existing smartphone applications developed for autistic users and proposed application design principles based on interaction design (IxD), that would fulfill the user's requirements in a better manner. According to the authors, five smartphone applications were involved in the analysis and as a result, the authors identified fifteen suggestions for the design principles. The design principles recommended are targeted towards apps developed to improve the communications skills of children with ASD. The design principles proposed by the authors are based on IxD. IxD is the discipline of designing interactive products to support people in their everyday lives. It defines the behavior of systems and is concerned with form and content, as related to system behavior and user input. IxD embodies three dimensions-form, content, and behavior. The design principles proposed by the authors are summarized in Table 3.1.

Table 3.1: Design principles for users with communication difficulties

Dimension	Design Principle	Suitable design
form	User interface	Simple design without much visual stimuli
	Number of pictures	Limited number of pictures
	Screen size	Large UI elements
	Icon	Easily distinguishable icons
	Color	Alternate color other than black

Dimension	Design Principle	Suitable design
content	Guide the user through the app	Guiding the user through the usage of the app
	Admin section	Password protected admin section
	Picture-exchange communication system	Picture-based communication
	Audio	Audio-aspects corresponding to images
	Language	Language consideration
	Upload photo	An option for uploading photographs
	pronunciation	Pronunciation-of completely-formulated sentence
behavior	Evaluating parameter	Evaluating child's growth
	Image life	Having images identical to real-life objects
	navigation	Simple navigation buttons

The design principles proposed by the authors in Table 3.1 [32] are targeted towards developing apps for autistic users with communication difficulties. Moreover, the design principles are merely theoretical and they are not proven by experiment. Regarding the approach, the authors evaluated the current smartphone applications to reach at the design principles.

Sofian et al. [11], conducted survey on existing usability attributes used to design smartphone application for autistic users. The authors identified commonly used usability attributes in studies to develop smartphone applications for autistic users. The authors analyzed 23 research papers to come-up with usability attributes that should be considered in the design of smartphone applications for autistic users.

The authors also proposed design principles respective to the usability attributes they identified. The usability attributes and the respective design principles are summarized in Table 3.2.

Table 3.2: Usability attributes with the respective design principles

Usability attributes	Design principles
Effectiveness	Large UI elements Limited number of words & features Allowing the repetitive to take place
Efficiency	Reduced time in performing the task Updates to the latest version
Satisfaction	Provide feedback for the development team Easy on the eye of users
Ease of use	Easy and quick access to information Single clickable button Clear icons
Understandability	Easily understandable icons Easily recognizable icons Catchy pictures and button
Appearance	Appropriate color of the font Suitable size of UI elements Suitable background-color

The design principles proposed by the authors are merely theoretical as the authors themselves said [11]. The authors didn't conduct any evaluation to say whether the proposed design principles are effective or not. Besides, some of the design principles identified are also vague, e.g., allowing the repetitive to take place, single clickable button.

Al-Wakeel et al. [9], conducted a usability evaluation on two Arabic mobile applications designed for users with ASD and then come up with design principles. The applications were "Touch to Speak" and "Tap to talk". The authors analyzed the usability of these two applications using techniques such as eye-tracking and Morae. The authors also used measurement tools to collect qualitative and quantitative data and determine the participants' satisfaction with products.

From their study, the authors proposed a recommendation for the optimal design of the ideal AAC (Alternative and Augmentative Communication) application. The design combined advantages from both applications and avoid the issues that appeared in them. The authors also suggested some new features from their experience that they thought is helpful to include in the recommended application. The recommendation includes the number of pictures, the home page, the next page icon, a tutorial to guide users, the ability to hide or unhide text, and the ability to pronounce the completely formulated sentence.

The recommendations given by [9] were targeted towards autistic users with communication difficulties. The author's study focuses on evaluating already existing two applications and developing a modified app by combining good features from both apps and avoiding their bad features.

In other related work, Khan et al. [10], also conducted a comparative analysis of android and iPhone applications designed for peoples with ASD. The authors analyzed the usability of the selected applications based on the survey conducted on Autistic users.

Based on the results of their survey the authors stated that currently available smartphone applications for autistic users have usability issues, the authors also proposed an abstract app design by combining the good features from the two apps they have conducted usability tests on.

The two smartphone applications selected for usability tests were an iPhone application named CommApp and an android application named AAC Speech Communicator. The authors conducted the test on 50 autistic users. They requested autistic users to use each application for 15-20 minutes and then fill the questionnaire they prepared. Among the 50 participants, 6 were in the range of 0-3 years, the questionnaires of these children were filled by their parents or guardians. 9 children fall in the range of 4-8 years, 17 were between the ages of 9-15 years, 7 were in the range of 15-18 years and the remaining 11 were above 18 years old.

The study conducted by Khan et al. [10] comes app with an ideal app design for autistic children with communication difficulties which shall comprise recommendation such as, there should be the main menu screen containing the buttons for admin section, help, about settings and categories, the admin section should be password protected, admin section should contain an option to add customized pictures and voices, the interface should contain bright soft color which gives positive vibes to the autistic users, the icon for categories should be recognizable so that the children do not need to memorize too much, there should be an option both for proper grammatically correct sentence and just words and object names and there should be a tutorial to guide users about the functionality of the app.

Again, the recommendations given by Khan et al. [10] are only recommendations to design the apps they already tested with autistic users in a better way. If we carefully examined the given recommendations, we realize that the recommendations are given specifically for the apps the authors tested with the autistic users, e.g., one of the recommendations says, there should be an option both for proper grammatically correct sentence and just words and object names, this is given to improve improper grammatical construction in the sentences produced by the AAC speech communicator. So, this recommendation is specific to the apps aimed to improve the communication skills of children.

Pavlov [33], proposed the requirements for building an accessible UI for users with ASD and presents the UI of Open Book, a reading assistive tool for people with ASD. The author extracted the requirements from existing researches on improving reading comprehension for people with ASD and from the feedback of users and clinical professionals. The author then applied the requirements to create the interface of the Open Book tool**.**

The author's objective was to develop an Open Book software to assist autistic users with reading difficulties. An Open Book software system is a distributed software system for assisting people with ASD in reading documents. The software system employs various natural language processing techniques to simplify documents and provides aids while reading. The author built the tool using a distributed architecture that consolidates various NLP components and language resources.

The author used guidelines from two sources to develop the Open Book Software system and he further proposed requirements for the design of UI for people with ASD. The first set of guidelines used by the author are guidelines proposed by the UK Department of Health for the preparation of documents for people with learning disabilities [34] and the second set of guidelines used by the author are guidelines proposed by Freyhoff et al. [35], to create easy-to-read information for People with learning disabilities.

Based on the two sets of guidelines, the author proposed another set of requirements for designing UI for users with ASD. The author also designed an Open Book software system based on the requirements he proposed.

The author proposed the requirements based on the dos and don'ts in the following three categories: Presentation, navigation, and page loading, and interaction. E.g., the dos under the presentation categories include: - use contrast between font and background, use soft mild colors, make sure text box is separated from the rest, present text in a single column, use simple graphics, and use clear, sans-serif fonts.

The requirements proposed by Pavlov [33] seems to be applied for software systems that run on PC, though they are not explicitly stated. The requirements are also set for designing reading and comprehension tools as they are crafted based on guidelines developed for assisting users with reading disabilities.

The other thing is the requirements proposed by Pavlov [33] lack autistic users characteristics consideration in some aspects, e.g., under navigation and page layout categories, the authors stated that the designer should support navigation with mouse or keyboard, this comes from lack of proper study on autistic user characteristics since it is thoroughly confirmed by other sources that most autistic users experience difficulties with the use of mouse and keyboard because of their motor problem [27].

The other limitation of this paper is that the author said the requirements he proposed can be applied to design any UI for people with ASD, which is not proven by experiment, and also as we can see from the requirements themselves, the requirements cannot be applied to design UI of android applications to autistic users.

In another related work Darejeh and Singh [36], presented a review of different literature works on how usability could be increased for users with less computer literacy. The authors reviewed different literatures to extract UI design principles by identifying the similar problems of this group of users. Though there are different groups of users with less computer literacy, the authors selected three groups of users based on the literature that need special attention from software designers. The first group is elderly users, as users with a lack of computer background. The second group is children, as novice users and the third group are users with mental or physical disorders.

The author's study focuses on the mentioned groups, followed by a comparison between previous researches in the field which reveals that some commonalities exist between the needs of these users, but here we only tend to present the design principles the authors proposed regarding the third group of users, i.e., users with mental disorders.

Regarding users with a mental and cognitive disability, the authors presented two design principles by referring to previous research works.

The first design principle is the principle proposed by Fryia et al. [37], which suggests that software designers should eliminate features that cause unnecessary stress and frustration that can create a negative effect on system usability.

According to Fryia et al. [37], software designers can reduce complexity by decreasing the number of features available at any given time and by rearranging them to accommodate full functionality.

The authors adopted the second principle from Grynszpan et al. [38]. In research he conducted on designing a multimedia interface for users with autism, Grynszpan et al. [38], suggested that the user interface should be designed simple and do not need investigation for finding elements if it is to help users with ASD.

From the analysis of literature, Darejeh and Singh [36], came up with two principles that targeted users with ASD. The first one was reduced software complexity and the second one was simplicity.

Though they seem general, the two principles proposed by Darejeh and Singh [36] are acceptable since they considered some aspects of autistic user characteristics, but they are not enough. As a matter of fact, the research work showed the need for an in-depth study on usability issues for autistic users.

Summary

The related works addressed in this Chapter are different from this research paper in terms of the approach they followed. All of them started from studying and evaluating existing software applications developed for autistic users to propose design principles rather than from studying autistic user characteristics. This is the reason we found some incompatible design principles in some of them [11, 32]. In terms of experimentation, the design principles proposed (recommended) by all of them are merely theoretical except for the design principles proposed by Pavlov [33]. In terms of the platform, some of the design principles are developed for desktop platforms [33].

The other way the research papers are different is in terms of the target groups they addressed in their study. Three of the research papers are targeted towards autistic users with communication difficulties [9, 10, 31].

Two of them are more of general design principles to be considered for the development of any smartphone application for autistic users [11, 35] and one research paper focuses on developing design principles for the design of e-book to improve autistic users reading difficulties [33]. As a weakness, there are inconsistencies and vagueness in some of the design principles [11, 32]. Table 3.3, summarizes this research paper and the related works addressed in this Chapter.

Table 3.3: Summary of related works

Research titles	Authors	Approach	Test	platform	Focus areas	Weakness
Interaction design principles	Hussain et al.	Apps	No	Smartphone	Communication	Generality
A review on usability guidlines	Sofian et al.	literature	No	Smartphone	General	Vagueness and Generality
A usability evaluation of Arabic mobile applications	Al-Wakeel et al.	Apps	No	Smartphone	Communication	Didn't consider other alternatives
Usability issues for smarthphone users	Khan et al.	Apps	No	Smartphone	Communication	incompleteness
UI for people with ASD	Pavlov	literature	Yes	PC	Reading	Inconsistency
A review on UI design principles	Darejeh and Singh	literature	No	Smartphone and PC	General	Incompleteness and Generality
Developing design principles for autistic android application users	**This work**	**Users**	**Yes**	**Smartphone**	**Alphabet learning**	

Despite some of the differences outlined above, we will modify and adapt some of the design principles proposed in the previous research papers to incorporate them in our study.

So, this research paper will focus on the gap identified from previous research works and identify design principles for autistic users based on their characteristics and usability attribute.

Chapter 4 : User Interface Design Principles for Autistic Android Applications Users

This Chapter presents the identified design principles to be considered while designing a UI of android applications, the case of English Alphabet. Autistic users' characteristics and usability attributes that lay a foundation for the design principles are discussed first, then design principles from previous literatures are discussed and revisited and, additional ones are developed. Then after, the modified and new design principles that are used to achieve the identified usability attributes are summarized. Finally, the correlation between autistic users' characteristics, usability attributes, and identified design principles are discussed. Figure 4.1, describes the process we followed to come up with the design principles identified in this research paper.

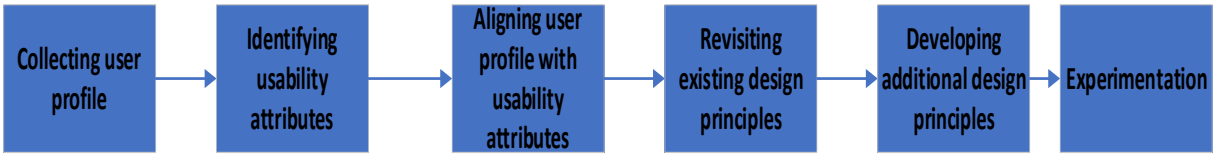

Figure 4.1: High-level process for identifying design principles

4.1 Summary of Autistic User Characteristics and Usability Attributes

Autistic users' characteristics and usability attributes are discussed in Chapter Two. Here, the correlation between those characteristics and usability attributes are discussed. It is important to note that not all usability attributes are necessarily applied to all types of users. Rather, it is a need to study the user characteristics first to relate the proper usability attributes [13]. Different usability models are considered in selecting the appropriate usability attributes for autistic users since the usability attributes vary between models. Usability models are collectively discussed in [39]. By considering this, the usability attributes listed in Table 4.1 are selected for autistic users and mapped to the respective characteristics.

The debilitating characteristic of autistic users in the event of failure, looking for matters of detail, visual learning, failure to understand complex features and prone to sensitiveness are mainly cognitive and perceptual characteristics. According to [40], learnability and understandability are the two usability attributes mostly affected by user's perceptual and cognitive characteristics, yet understandability is often included under learnability. So, in this case the characteristics can be mapped to learnability usability attribute.

Spending too much time doing the same task can be mapped to efficiency usability attributes. ISO 9241-11 [39] defines efficiency as the time users take to accomplish a given task completely and accurately.

Repulsiveness to black color is mapped to attractiveness usability attributes. We took attractiveness from ISO 9126 [41]. Repulsiveness to color is mainly a psychological trait and attractiveness is one of the usability attribute affected by such trait [40]. Attractiveness is often related to the product's look and feel, which usually includes the appropriate usage of color.

Lastly, a limited motor capability is mapped to the effectiveness usability attribute. Limited motor capability can have a tremendous effect on users' successful accomplishment of a given task, which is often related to effectiveness usability attribute [40].

Table 4.1: Correlation between autistic user characteristics and usability attributes

Autistic user characteristics	Description	Usability attribute
Finds failure very debilitating	Telling them they are doing wrong is often offensive to autistic users	Learnability
The tendency to seek local cohesive, looking for meaning in matters of detail	tend to focus on particular details rather than looking for general meaning	Learnability

Autistic user characteristics	Description	Usability attribute
The tendency to spend much time on the same task	They may engage themselves in doing the same thing over and over again or talk constantly about specific things that interest them	Efficiency
Prone to sensitivities	finding intolerable noise which is barely perceptible or unremarkable to others	Learnability
Visual Learners and thinkers	Better understands when ideas, words, and concepts are associated with images	Learnability
Repulsive to some colors like black	Autistic users often feel intolerable with black color	Attractiveness
May not understand complex linked objects or some forms of abstraction	Failure to understand complex interlinked features	Learnability
Limited motor skills	having difficulty grasping or manipulating objects, such as a mouse	Effectiveness

4.2 Ammended and Suggested Design Principles

Some previous design principles are discussed and summarized in Table 4.2. These design principles are crafted as a result of a test conducted on smartphone applications developed for autistic users. These design principles are thoroughly discussed in Chapter Three. The design principles are summarized and brought here for easy reference for subsequent sections

Table 4.2: Design principles from previous literatures

Design principles	Description
Large image size	The screen size of the images should be made very large to make it easier for the users to see the items and to enable them to correctly press/tap each item on the screen without accidentally hitting another icon/button
Reduced number of pictures on each page	In each page, the number of pictures should be within the acceptable limit
Alternate color usage other than black	An alternative color should be used since, often, the color black is found to be repulsive
Simple Navigation	There should be simple navigation buttons

We recommend amendment of the design principles in Table 4.2 since those design principles are more of general in nature. For instance,

- the first design principle suggests the use of " Large image size", we will modify this design principle to consider touch target size instead of the UI element size, because here we are considering that autistic users might miss the UI element when they tap on it, in this case to help them not to miss the UI element, it is more reasonable to increase the touch target size than the size of the target it self.
- The second design principle says "reducing the number of pictures on each page", here again we will modify this design principle to "reducing the number of touch targets per screen".
- The third design principle suggests an "alternate color usage other than black"; but it can't suggest other colors preferable by autistic users.
- The fourth design principle suggests the use of "simple navigation", but it can't answer questions such as, which navigations to use: buttons, or gesture navigation.

So, in this section, we are going to clarify existing design principles and develop additional ones based on some common autistic user characteristics that are not considered in the previous design principles. Those characteristics are listed and described in Table 4.1.

Design principle one: Appropriate touch target size

Touch targets include the area that responds to user input. Touch targets extend beyond the visual bounds of a UI element. The default minimum touch target size for a UI element should be 48*48dp (dp stands for a device-independent pixel: it is a unit of length that allow mobile device software to scale the display of information and user interaction to different screen sizes) according to [42] and if there are more than one touch targets per screen, they should be separated by a minimum 8dp space [42]. So here, we will identify the minimum touch target size for a UI element in the case of autistic users and we will also identify the appropriate minimum space that should be used if there are more than one touch targets per screen. We will use the default minimum size for touch targets that is identified by [42] as a bench mark and we will increase it by 1dp until we reach the minimum touch target size that should be used in the case of autistic users.

We will also increase the default mimimum space that should be used if there are more than one touch targets, i.e., 8dp, by 1dp to identify the minimum space that should be used if there are more than one touch targets per screen in the case of autistic users. Here we only consider the touch target size surrounding the UI element, not necessarily the target size.

Design principle two: Reduced number of touch targets in each page

Once we identify the appropriate minimum size for touch targets and determine the minimum space that should be used for multiple touch targets, the next thing will be to identify the number of touch targets that should be used per screen. Touch targets with a minimum size for autistic users will be displayed per screen to identify the maximum number of touch targets that a single screen could accommodate. The minimum spacing between touch targets will also be used in determining the maximum number of touch targets that should be used per screen in the case of autistic users. Android screen with a size of 5.0 inch will be used for the test so that it will be used as a benchmark for other screen sizes.

Design principle three: Limiting the UI content to most important elements

This design principle deals with avoiding unnecessary UI elements to make autistic users focus on the most important content since autistic users concentration and focus was taken by small matters as discussed in Section 4.1.

Design principle four: Alternate color usage other than black

It has been already known that autistic users are repulsive to black color from previous research works. But previous research works didn't specify the appropriate color to use in UI design for autistic users. It is known that there are millions of colors out there and there aren't any verified techniques on how to select and test certain colors, which represents the other all colors, with specific user groups. UI designers simply took the colors which they think is appropriate for target user groups and taste those colors with them through the use of mockups. Once the appropriate color for target user group is identified, the rest is upto the UI designer.

UI designers use what we call color theory to design aesthithically pleasing UIs. Color theory is the basis for the primary rules and guidelines that surround color and its use in creating aesthetically pleasing visuals [43]. Color theory doesn't suggest which colors to use in UI design with respect to certain user groups. Testing and identifying the appropriate colors to be used for UI design concerning certain user groups is a work left for UI designers and other professionals.

But once the appropriate colors for target user groups are identified, one can use the color theory basics to design a pleasing UI by creating the desired harmony between those colors. To do so color theory presents a color wheel which suggests different types of color schemes [43].

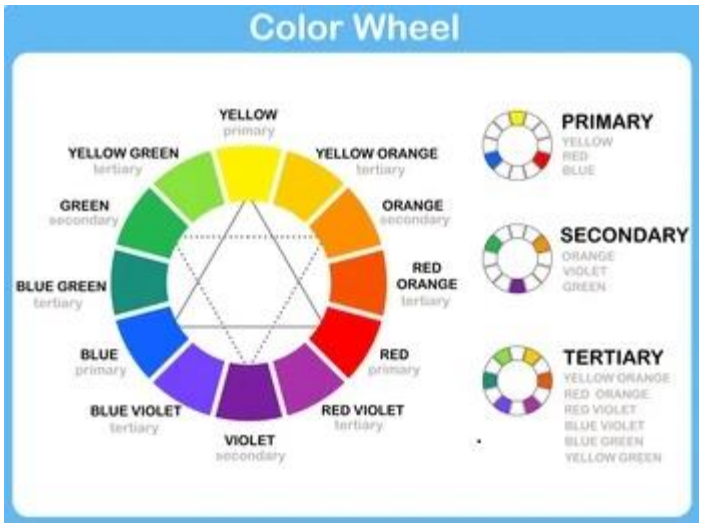

Figure 4.2: Color wheel

For the case of this research paper , we are going to identify the appropriate colors that should be used in UI design for autistic users from primary, secondary and tertiary colors which revolves around the color wheel as depicted in Figure 4.2 (adapted from [44]) and we will also use white color as background color for this matter, since white color goes with every other color according to [45]. We will conduct the experiment with the purest form (hue), tint, tone and shades of each colors as depicted in Figure 4.3 (adapted from [43]).

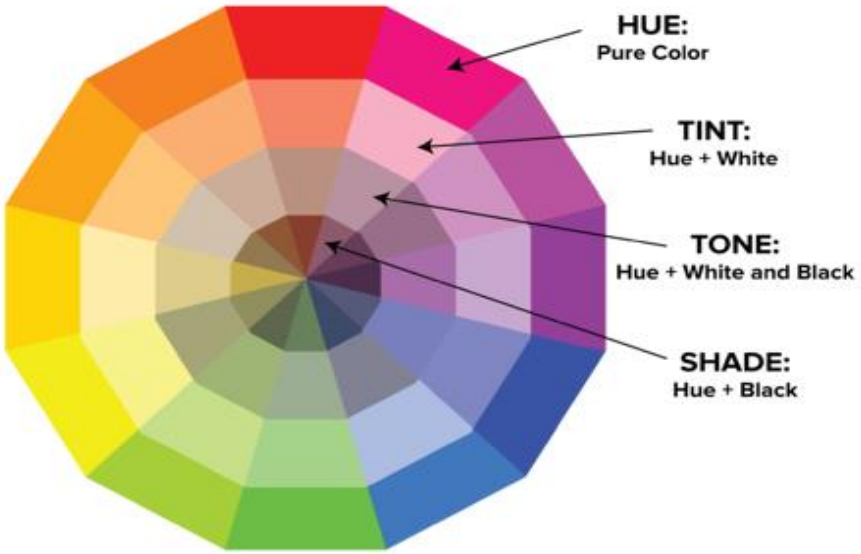

Figure 4.3: Hierarchies of colors

We might come up with many different variants of a single color when we add different percentages of white, gray and black color to it. Testing with all those variants of a single color is beyond the scope of this research paper. So, for the case of this research paper we are going to stick to the tint (lightest), tone (moderate) and shade (darkest) variants of a single color.

Design principle five: Easy navigation style

The two most common navigation styles to get around any android application are gesture navigation and button navigation [46]**.** In this research paper, we are going to identify the appropriate navigation style to be used in android application development for autistic users.

Now, let's come to the additional design principles we developed for autistic users. The first autistic user's characteristic that was not considered in the previous design principles was that autistic users often found failure debilitating, telling them they are doing wrong is offensive to them. Considering such characteristic is useful in designing usable applications to maintain the learnability of the UI. So, we think that it is important to devise a design principle considering this autistic user characteristic.

Therefore:

Design principle six (New): Appropriate failure reporting mechanism

Choosing the right failure reporting mechanism is essential in developing android applications that involve tasks that measure the user performance level. Here we don't focus on reporting errors happened as a result of failure in android application, but we tend to focus on identifying the appropriate failure mechanism to use in response to failures happens when autistic users make mistakes.

Though reporting failure in the form of message is the most common way of failure reporting mechanism in many android applications [45, 46, 47], for the case of this research paper, we are only going to use other two failure reporting mechanism, failure reporting with metaphor "X" and failure reporting with "sound", to identify the appropriate failure reporting mechanism that should be used in UI design for autistic users. The reason we will not use failure reporting with message is because of our test users reading inability.

The other characteristic that was not considered in the previous design principles is autistic users' tendency to spend much time on a given task, considering this autistic users' characteristic is useful in developing usable applications with improved efficiency.

Therefore:

Design principle seven (New): Longest time possible for time-sensitive tasks depending on the nature of the task

Autistic users' tendency to spend too much time on a given task lays a foundation for the development of this new design principle.

Autistic users might take a few exra time to learn a given system when it is compared with non-autistic users. So a UI designer should need to consider this in android application development for autistic users, especially in developing applications with time-sensitive tasks. How much time to spend on a given task depends on the nature of the task.

In this research paper, we are going to measure and quantify the time autistic users will need for tasks like tapping to identify an object from the list of two, three, four and five objects in comparison with non-autistic users as an illustration.

The other characteristic that was not considered in the previous design principles is autistic users' tendency to sensitivities. E.g., autistic users might be disturbed by the sound of a voice which is normal or barely perceptible to non-autistic users. So, it's important to measure and quantify the loudness of sound appropriate for autistic users.

Therefore:

Design principle eight (New): Safe and appropriate loudness of sound

According to CDC (Center for disease Control and Prevention) a loudness of sound with 60DB is appropriate for non-autistic users (DB stands for decibel, a unit of measurement for the loudness of sound) [50]. But the loudness of sound appropriate for autistic users was not measured and quantified. So in this research paper, we are going to identify the loudness of sound that is appropriate for autistic users through experiment and evaluation.

Although not explicitly stated, we think that, the limited motor capability and visual learning ability of autistic users are considered in the previous design principles. When the authors propose the “usage of pictures” and “large image size” design principles in Table 4.2, it is certain that they proposed so considering autistic users visual learning ability and limited motor capability. The test and experimental procedure for the identified design principles will be thoroughly discussed in the next Chapter.

4.3 Summary of the Identified Design Principles

The design principles discussed in Section 4.3 are summarized in Table 4.3

Table 4.3: Summary of the identified design principles

Identified design principles	Specification
Appropriate touch target size	The size of touch targets appropriate in UI design for autistic users will be determined
Reduced number of touch targets per screen	The number of touch targets that should be available per screen for autistic users will be determined
Limiting the UI content to the most important elements	The UI content will be limited to the most important elements only
an alternate color usage other than black	Other alternate colors that should be used in UI design for autistic users will be identified
easy navigation style	The appropriate navigation style for autistic users will be identified
appropriate failure reporting mechanism	The appropriate failure reporting mechanism will be identified
longest time possible for time sensitive tasks depending on the nature of the task	The time autistic users will need for sample tasks will be measured and quantified
safe and appropriate loudness of sound	The loudness of voice appropriate for autistic users will be measured and quantified in DB

4.4 Correlation between Autistic User Characteristics, Identified Design Principles, and Usability Attributes.

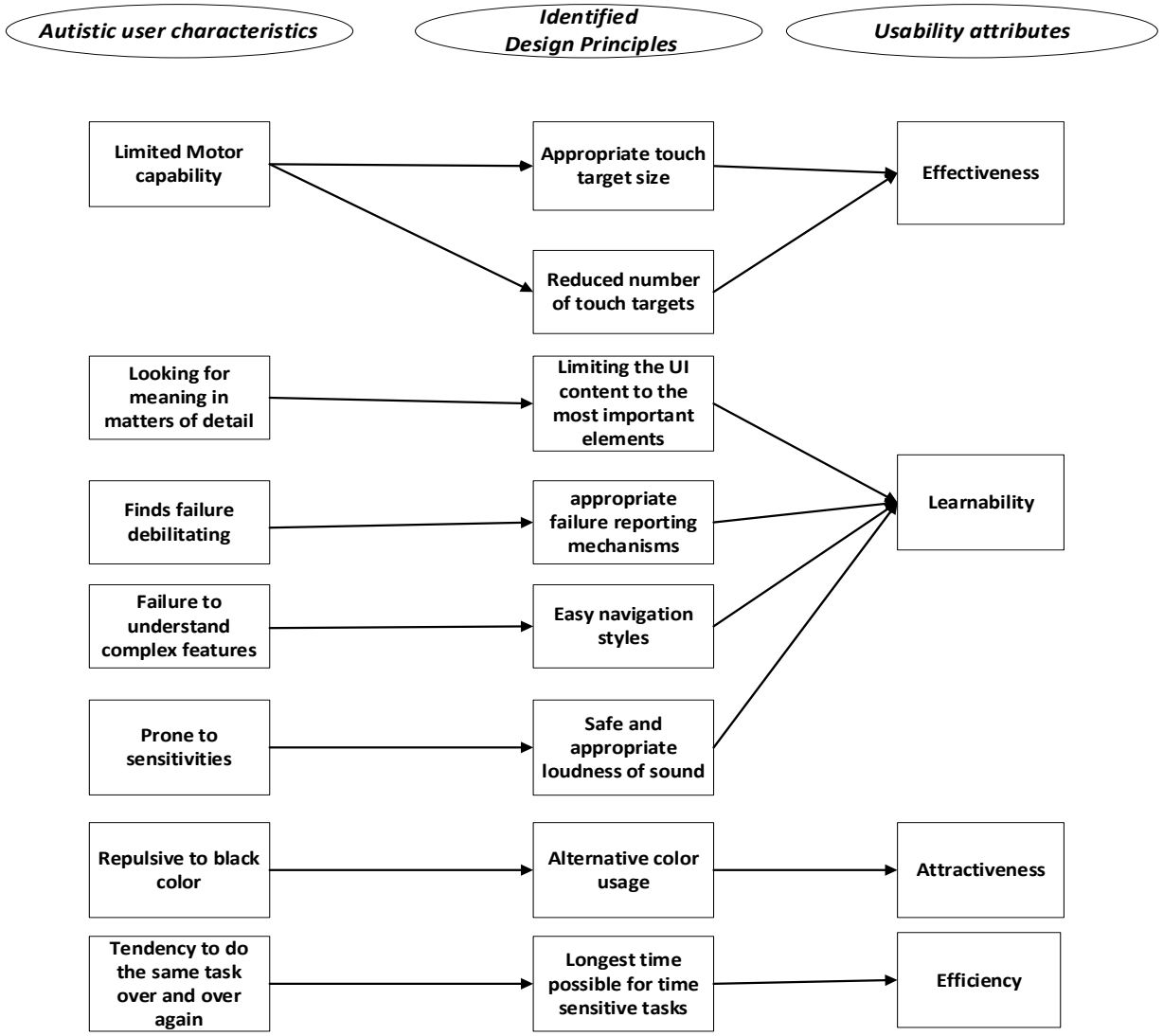

Figure 4.4: A high-level framework to relate autistic user characteristics, usability attributes and design principles

The framework in Figure 4.4 shows which autistic user characteristics laid the foundation for the respective design principles and which usability attributes are affected by the design principles. E.g., we identified, appropriate failure reporting mechanism, design principle based on autistic users reaction to failure and this design principle will inturn helps to improve the learnability of the UI.

Likewise, we can easily trace the other design principles back to autistic user characteristics. E.g., as autistic users focus on matters of detail, they might miss the important content, to avoid these in UI design, the UI designer should avoid using unnecessary UI elements which distract the user from focusing on the important content, this practice promotes better learnability.

Similarly, by using easy navigation styles we can minimize the complexity of our system which in turn improves the learnability, using the longest time possible in developing a time-sensitive apps will improve their efficiency, safe and appropriate loudness of sound again contribute to the learnability of the UI, proper color usage attracts the users to the product and the usage of large touch targets in UI design help the users to use the product.

Chapter 5 : Prototype and Evaluation

This Chapter discusses the experiment and evaluation conducted on the mockups developed based on the design principles identified in Chapter Four. First mockups development process will be discussed and then a brief discussion about the experimental procedure and the results obtained will be made.

5.1 Mockup Development

Different mockups for English alphabet teaching android application are developed to test the effectiveness of the identified design principles. The mockups are developed using XML and Java programming language in the eclipse platform.

5.2 Experimental Procedure

Twenty autistic users are selected for mockup testing from Nehemiah autism center which was found around Gotera condominium in Addis Ababa. The reason 20 users are selected for this test is according to [51], when collecting usability metrics , testing with 20 users typically offers a reasonably tight confidence interval. The users age ranges from 6 to 10 years and all of them are familiar with smartphones. The test is conducted through usability metrics, questionnaire and observation. Usability metrics were collected for “large touch target, reduced number of touch targets, limiting the UI content to the most important elements, and longest time possible for time-sensitive tasks depending on the nature of the task” design principles. The remaining design principles “ an alternate color usage , easy navigation style, appropriate failure reporting mechanism and safe and appropriate loudness of sound” were tested via the the use of questionnaires. The questionnaire was filled by autistic users’ guardians after the test users used the mockups.

The questionnaires, Annex H and Annex I, was prepared in multiple-choice format since this was best suited to our participants than Likert Scale. The participants were allowed to choose multiple answers from the given choices.

5.3 Test Results

The tests for each design principles listed in Chapter Four and the results from the test are documented as follows.

Design Principle One: Appropriate touch target size

This design principle arises from autistic user's limited motor capability as discussed in Chapter Four. Autistic users might miss the UI element while tapping on the screen if the touch target surrounding the UI element is not large enough, which inturn affects the effectiveness of the users. Here, first we set the touch target size to the default minimum, i.e., 48*48dp as described by [42] to identify the appropriate minimum touch target size that has to be used for autistic users in UI design. Then we increment the touch target size we set by 1 to arrive at the minimum touch target size that has to be used for autistic users in UI design. Here we measure the effectiveness of the user with what we call a success rate or completion rate metric [52].

The success rate metric can be measured by assigning a binary value of 0 and 1 to the users; where 1 is assigned to those who successfully complete the task and 0 to the ones who fail to do so according to [52].

Once the test is over and all the data that will be needed to calculate users success rate has been collected, the next step would be to divide the total number of correctly completed attempts by the total number of attempts multiplied by 100 [52].

$$Effectiveness=\frac{Number\ of\ tasks\ completed\ successfully}{Total\ number\ of\ tasks\ undertaken}\times 100\% \quad (5.1)$$

The task here is, autistic users will be prompoted to tap on the touch target, if they successfully tap on the touch target the application will say the name of the alphabet, if they miss the touch target the X mark will be displayed to notify the users that they miss the target. The users are presented with different touch targets sizes starting from the default minimum touch target size , i.e., 48*48dp, set by [42] depicted in Figure 5.1 and as the users try to tap on the touch target, the application will display the next touch target incremented by 1dp from the previous one.

The process will go on until the minimum touch target size appropriate for autistic users will be reached. Table 5.1 shows the test data that will be used to calculate the success rate for touch target size.

Table 5.1: Test data to identify touch target size

Tasks	Touch target size	Success (1)	Fail (0)
Task 1	48*48dp	0	All users
Task 2	49*49dp	0	All users
Task 3	50*50dp	0	All users
Task 4	51*51dp	0	All users
Task 5	52*52dp	0	All users
Task 6	53*53dp	0	All users
Task 7	54*54dp	0	All users
Task 8	55*55dp	0	All users
Task 9	56*56dp	0	All users

Tasks	Touch target sizes	Success (1)	Fail (0)
Task 10	57*57dp	0	All users
Task 11	58*58dp	0	All users
Task 12	59*59dp	0	All users
Task 13	60*60dp	0	All users
Task 14	61*61dp	0	All users
Task 15	62*62dp	0	All users
Task 16	63*63dp	0	All users
Task 17	64*64dp	0	All users
Task 18	65*65dp	0	All users
Task 19	66*66dp	0	All users
Task 20	67*67dp	0	All users
Task 21	68*68dp	0	All users
Task 22	69*69dp	5 users	15 users
Task 23	70*70dp	All users	0

So based on the test data in Table 5.1, the success rate for task 1- task 21 is 0%, the success rate for task 22 is 25% and the success rate for the last task, i.e., task 23 is 100%. So, the result showed that all autistic users have a problem tapping on a touch target with a size from 48*48dp-68*68dp. 25% of the users have successfully tapped on the touch target with 69*69dp, but the result increased dramatically with touch target size 70*70dp, where 100% of the users have successfully tap on the touch target. Based on the test result we can conclude that the default minimum size for touch targets should be 70*70dp as depicted in Figure 5.2, in the case of autistic users.

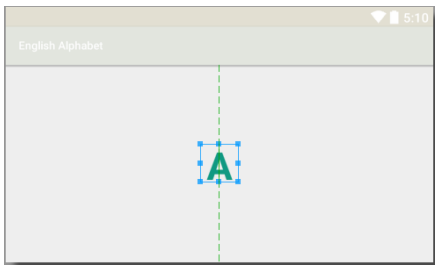

*Figure 5.1: Touch target size with 48*48dp*

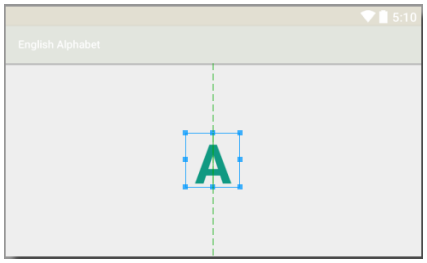

*Figure 5.2: Touch target size with 70*70dp*

For more than one touch targets per screen, the spacing between them should also need to be considered in addition to the minimum touch target size. As described by [42], more than one touch targets with a size of 48*48dp should be separated by a minimum of 8dp space. So if the mimimum space between touch targets with 48*48dp size is 8dp, what should be the minimum space between touch targets with 70*70dp size?, that is the question we are going to answer here.

So here, Figure 5.3 - Figure 5.5 shows three touch targets each with 70*70dp size separated with 8dp, 9dp and 10dp space respectively. The reason we didn't test with 0.1 increment to the default minimum space, such as 8.1dp is because, there is a very small difference between 8dp and 8.1dp and it is even hard to tell the difference between them by actually looking at touch targets separated 8dp and 8.1dp spaces.

That is why we inceremented the default minimum space by 1 to identify the appropriate mimimum space between touch targets for autistic users.

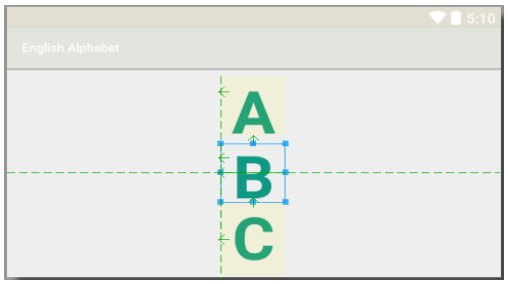

Figure 5.3: Three touch targets with 8dp space

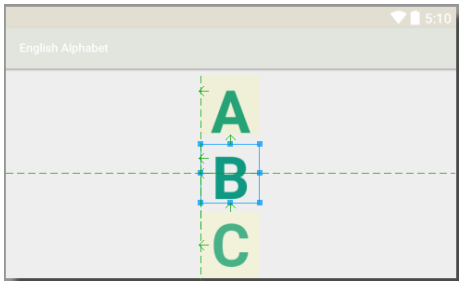

Figure 5.4: Three touch targets with 9dp space

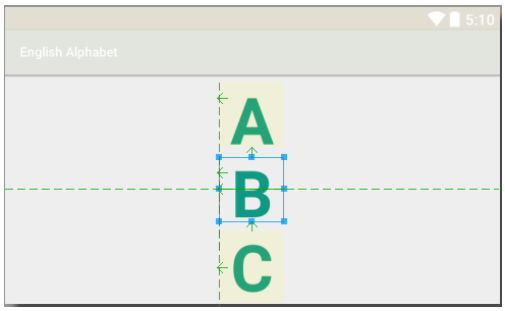

Figure 5.5: Three touch targets with 10dp space

Table 5.3, shows the test data that will be used to calculate the success rate that will be used to identify the minimum space that should be used between touch targets.

Table 5.2: Test data to identify minimum space

Tasks	Minimum space	Success (1)	Fail (0)
Task 1	8dp	0	All users
Task 2	9dp	15 users	5 users
Task 3	10dp	All users	0

Note that to get a success, the test users should correctly tap on all the touch targets otherwise the result will be a failure [52]. Based on the test data in Table 5.2, the success rate for task 1 is 0%, the success rate for task 2 is 75% and the success rate for the last task, i.e., task 3 is 100%.

The test result showed that autistic users struggle with the first task depicting three touch targets separated with 8dp space, while all users successfully accomplished the third task containing three touch targets separated with 10dp spaces.

From the test result we can conclude that the minimum space between touch targets should be 10*10dp in the case of autistic users.

Design Principle Two: Reduced number of touch targets per screen

To test this design principle the mockups from Figure 5.6 - Figure 5.27 are developed. This design principle has to do with increasing autistic users' concentration and focus. Once we set the minimum touch target size and the minimum space that should be used for autistic users in UI design, the next thing will be specifiying the maximum number of such touch targets a single screen can accommodate.

Here, mockups having different number of touch targets are presented from the first Mockup (Figure 5.6) containing one touch target to the last mockup (Figure 5.23) containing 22 touch targets. The main thing here is to identify the appropriate limit for the number of touch targets that should be presented per screen for autistic users so that to improve the effectiveness of the user. Each touch targets are designed with 70*70dp size and 10dp space between them as described in the first design principle except for the mockup in Figure 5.27 which is designed with 60*60dp touch target size and 10dp space between touch targets. Note that the number of touch targets that should be used in UI design for autistic users may vary with respect to different screen sizes and orientations. Here the mockups are tested on android screen with with 5.0 inches and therefore should be applied to that screen size only. To set the number of touch targets for other screen sizes, the mockups need to be tested on other screen sizes. We only present this, so that it will be used as a benchmark to set the number of touch targets for other screen sizes.

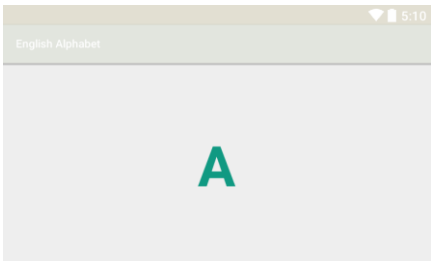

Figure 5.6: One touch target

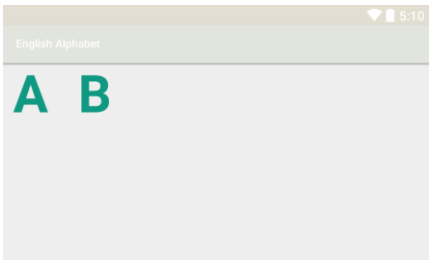

Figure 5.7: Two touch targets

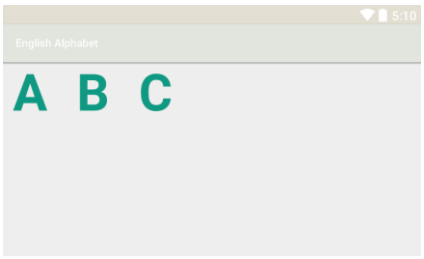

Figure 5.8: Three touch targets

Figure 5.9: Four touch targets

Figure 5.10: Five touch targets

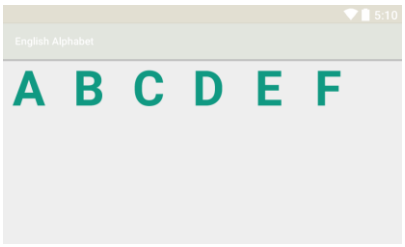

Figure 5.11: Six touch targets

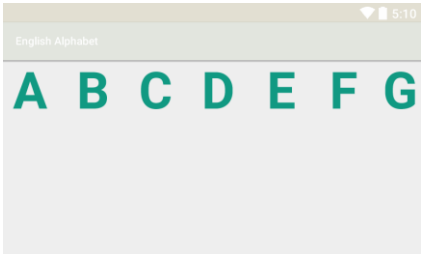

Figure 5.12: Seven touch targets

Figure 5.13: Eight touch targets

Figure 5.14: Nine touch targets

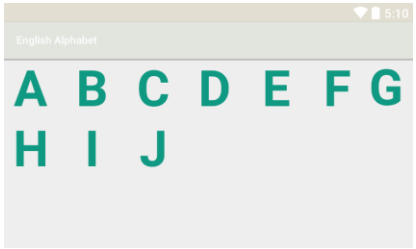

Figure 5.15: Ten touch targets

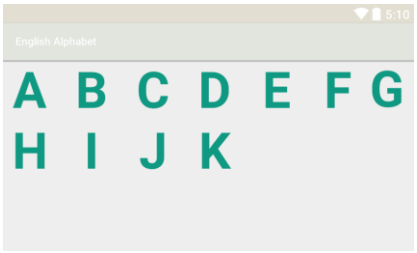

Figure 5.16: Eleven touch targets

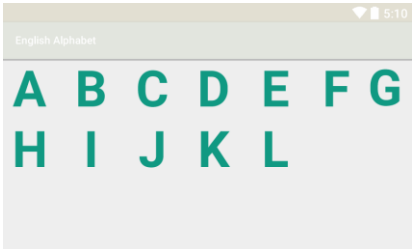

Figure 5.17: Twelve touch targets

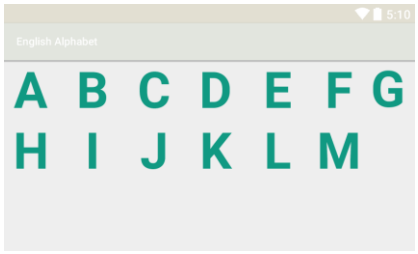

Figure 5.18: Thirteen touch targets

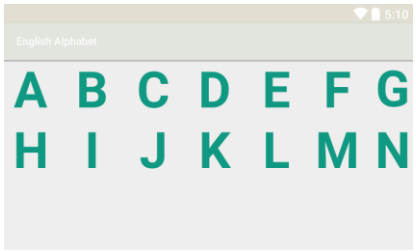

Figure 5.19: Fourteen touch targets

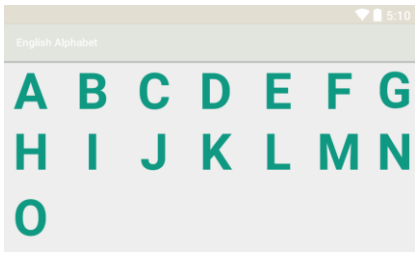

Figure 5.20: Fifteen touch targets

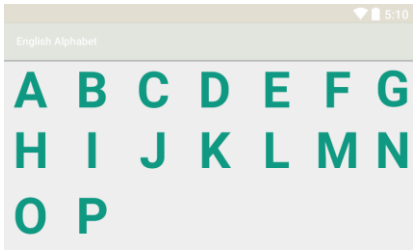

Figure 5.21: Sixteen touch targets

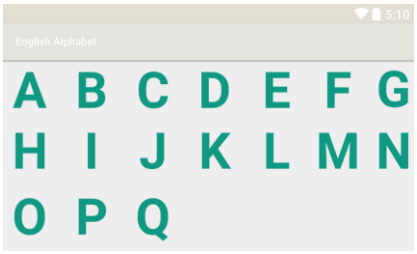

Figure 5.22: Seventeen touch targets

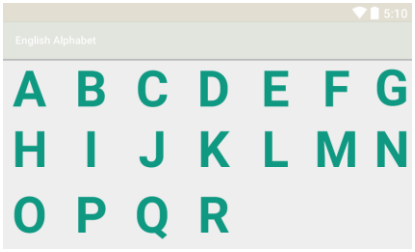

Figure 5.23: Eighteen touch targets

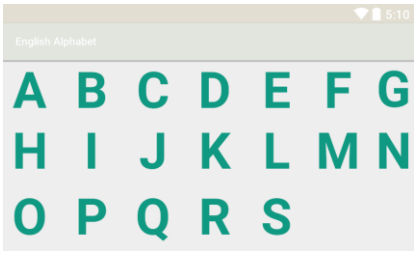

Figure 5.24: Nineteen touch targets

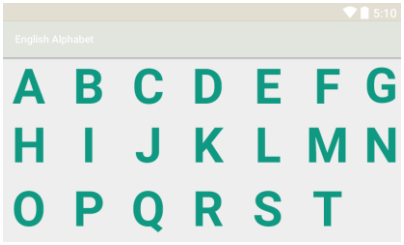

Figure 5.25:Twenty touch targets

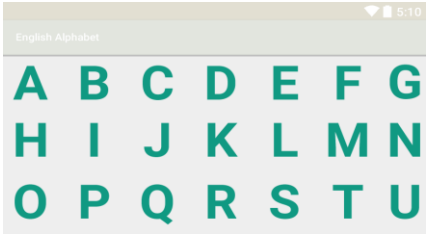

Figure 5.26: Twenty one touch targets

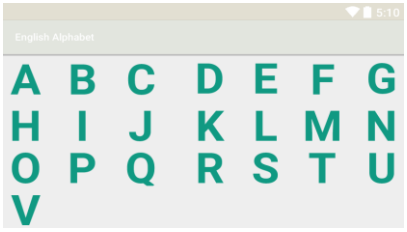

Figure 5.27:Twenty two touch targets

Table 5.3, shows test data that will be used to calculate success rate for the number of touch targets that should be used per screen for autistic users. Note that to get a success, the test users should correctly tap on all the touch targets, otherwise the result will be a failure [52].

Table 5.3: Test data for the Number of touch targets per screen

Tasks	Number of touch targets	Success (1)	Failure (0)
Task 1	One	All users	0
Task 2	Two	All users	0
Task 3	Three	All users	0

Tasks	Number of touch targets	Success (1)	Failure (0)
Task 4	Four	All users	0
Task 5	Five	All users	0
Task 6	Six	All users	0
Task 7	Seven	All users	0
Task 8	Eight	All users	0
Task 9	Nine	All users	0
Task 10	Ten	All users	0
Task 11	Eleven	All users	0
Task 12	Twelve	All users	0
Task 13	Thirteen	All users	0
Task 14	Fourteen	All users	0
Task 15	Fifteen	All users	0
Task 16	Sixteen	All users	0
Task 17	Seventeen	All users	0
Task 18	Eighteen	All users	0
Task 19	Nineteen	All users	0
Task 20	Twenty	All users	0
Task 21	Twenty one	All users	0
Task 22	Twenty two	3 users	17 users

Based on the test data in Table 5.3, the success rate for the Task 1- Task 21 is 100%. All of the test users effectively accomplishes those tasks and the success rate for the last task, i.e., task 22 is 15%.

The minimum touch target size we set will decrease if the number of touch targets per screen extend beyond twenty one for android screen with 5.0 inches, which inturn affects the effectiveness of autistic users.

E.g., Figure 5.27 shows twenty two touch targets each with 60*60dp which is less than the minimum touch target size we identified for autistic users in the first design principle. So based on the test result, it is better if the number of touch targets per screen does not exceed twenty one for android screen with 5.0 inches which complies with the touch target size and minimum space between touch targets we set in the first design principle.

Design Principle Three: Limiting the UI content to the most important elements

In addition to reducing the number of touch targets per screen, it is also better to avoid unnecessary UI elements to make autistic users focus on the most important content since autistic users concentration and focus was taken by small matters as discussed in Chapter Four. Bear in mind that the size of touch targets and the space between them depicted in Figure 5.28 and Figure 5.29 comply with the size we set in the first design principle.

So here autistic users have been observed as their concentration is taken by the arrow depicted in Figure 5.29, which was inserted there to relate the other contents and which inturn affects the learnability of the UI.

To evaluate the learnability of the UI, we measure the time autistic users spend on both tasks and compares them. The reader should understand that here, we are not measuring the educational learnability of the UI, i.e., autistic users might learn better if the alphabets are associated with images and texts, but that's educational learnability and it is not the objective of this research paper. We are here evaluating the learnability of the UI from the usability engineering perspective, i.e., we are evaluating how easy it is for users to accomplish a task the first time they encounter the UI and how many repetitions it takes for them to become efficient at the task [53].

Figure 5.28: Three UI elements

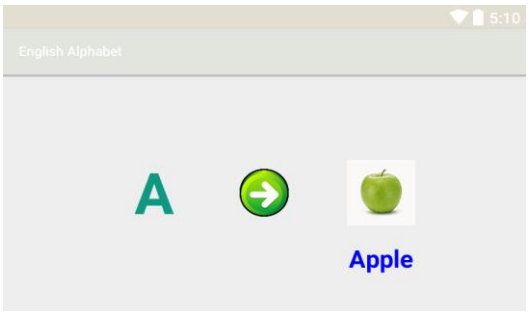

Figure 5.29: Four UI elements with an arrow button

The task here is, to identify the alphabet and the picture associated with the alphabet. We ask autistic users to identify the alphabet and the picture from both mockups in Figure 5.28 and in Figure 5.29 and measure how long they take to do so for the first time. Next, we ask them to comeback and do the task for a second time-again, measuring their task completion time. This process repeats for several more times. Table 5.4 presents the time autistic users take for each trial for the first task in Figure 5.28.

Table 5.4: Time autistic users take for the first task

Trial / Users	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
User 1	5 min	4 min	4 min	3 min	3 min	3 min
User 2	6 min	5 min	4 min	3 min	3 min	3 min
User 3	7 min	5 min	5 min	3 min	3 min	3 min
User 4	6 min	5 min	4 min	3 min	3 min	3 min
User 5	5 min	4 min	4 min	3 min	3 min	3 min
User 6	6 min	5 min	4 min	3 min	3 min	3 min
User 7	5 min	4 min	4 min	3 min	3 min	3 min
User 8	5 min	5 min	4 min	3 min	3 min	3 min
User 9	5 min	4 min	4 min	3 min	3 min	3 min
User 10	6 min	5 min	4 min	3 min	3 min	3 min

Trial / Users	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
User 11	5 min	4 min	4 min	3 min	3 min	3 min
User 12	7 min	5 min	4 min	3 min	3 min	3 min
User 13	5 min	4 min	4 min	3 min	3 min	3 min
User 14	6 min	5 min	4 min	3 min	3 min	3 min
User 15	5 min	4 min	4 min	3 min	3 min	3 min
User 16	6 min	5 min	4 min	3 min	3 min	3 min
User 17	5 min	4 min	4 min	3 min	3 min	3 min
User 18	6 min	5 min	4 min	3 min	3 min	3 min
User 19	5 min	4 min	4 min	3 min	3 min	3 min
User 20	6 min	5 min	4 min	3 min	3 min	3 min
Total time	112 min	91 min	81 min	60 min	60 min	60 min
Average time	5.6 min	4.5 min	4.05 min	3 min	3 min	3 min

The result from Table 5.4 shows that, the average completion time for the first trial is 5.6 min and then the completion time decreases-by trial 4, i.e., 3 min, it levels off, reaching the saturation plateau.

Table 5.5: Time autistic users take for the second task

Trial / Users	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
User 1	7 min	6 min	5 min	4 min	4 min	4 min
User 2	7 min	5 min	5 min	4 min	4 min	4 min
User 3	7 min	6 min	5 min	4 min	4 min	4 min
User 4	8 min	6 min	5 min	4 min	4 min	4 min
User 5	7 min	5 min	6 min	4 min	4 min	4 min
User 6	6 min	6 min	5 min	4 min	4 min	4 min
User 7	7 min	5 min	6 min	4 min	4 min	4 min
User 8	7 min	6 min	6 min	4 min	4 min	4 min
User 9	6 min	5 min	5 min	4 min	4 min	4 min
User 10	7 min	6 min	6 min	4 min	4 min	4 min
User 11	7 min	5 min	5 min	4 min	4 min	4 min
User 12	7 min	6 min	6 min	4 min	4 min	4 min
User 13	6 min	5 min	5 min	4 min	4 min	4 min
User 14	7 min	6 min	6 min	4 min	4 min	4 min
User 15	7 min	5 min	5 min	4 min	4 min	4 min
User 16	7 min	6 min	5 min	4 min	4 min	4 min
User 17	7 min	5 min	5 min	4 min	4 min	4 min
User 18	7 min	6 min	5 min	4 min	4 min	4 min
User 19	7 min	5 min	5 min	4 min	4 min	4 min
User 20	6 min	5 min	5 min	4 min	4 min	4 min
Total time	151 min	108 min	106 min	80 min	80 min	80 min
Average time	7.55 min	5.4 min	5.3 min	4 min	4 min	4 min

The result from Table 5.5 shows that, the average completion time for the first trial is 7.5 min and then the completion time decreases-by trial 4, i.e., 4 min, it levels off, reaching the saturation plateau.

When we compare the time autistic users took on the two tasks, autistic users take a slight long time on the second task depicted in Figure 5.29, e.g., comparing the time between the two tasks on trial 4 shows that autistic users are 1 minutes late doing the second task in Figure 5.29. The reason is, their concentration and focus was taken by an arrow depicted in Figure 5.29, which was inserted there to relate the other contents. From this we can conclude that, it is a good practice if the contents of UI are limited to the most important ones only to improve the learnability of the UI for autistic users..

Design Principle Four: an alternate color usage other than black

It has already been discussed in Chapter Four that autistic users are repulsive to some colors e.g., black color. Knowing which colors are repulsive to autistic users is one thing and identifying colors that are appropriate for autistic users and therefore, should be used in UI design for them is another thing.

So, here, other alternative colors are tested to identify the proper color to be used in UI design for autistic users. Different primary, secondary and tertiary colors are selected for the test as discussed in Chapter Four. The various colors are depicted in status bar, title bar, background and content of the UI. According to [54], using the same color with slight variation for status bar, title bar and background blends them together, which inturn place an emphasis on UI content instead of its structure. So, here we need autistic users to focus on the content of UI rather than it's structure, that's why we used the same color for status bar, title bar and background with slight variations. Here, we measured the colors attractiveness to users using a questionnaire prepared in multiple choice format, Annex H. Users were presented with the questionnaire after they used each mockups depicted in Figure 5.30 – Figure 5.41 and Annex J. Users were allowed to chose multiple answers from the given alternatives. Each user has been given 10 minutes to use the mockups.

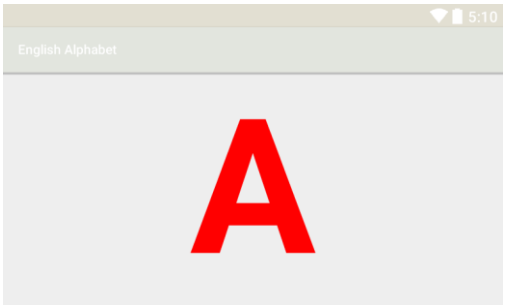

Figure 5.30: Red UI element

Figure 5.31: Yellow UI element

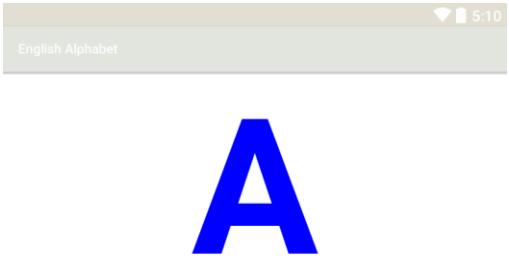

Figure 5.32: Blue UI element

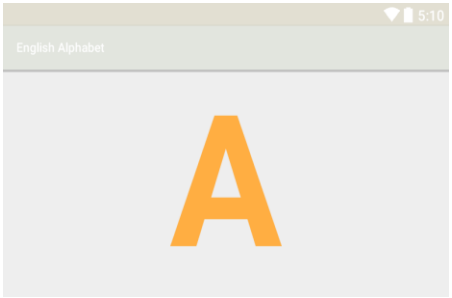

Figure 5.33: Orange UI element

Figure 5.34: Purple UI element

Figure 5.35: Green UI element

Figure 5.36: Red-Orange UI element

Figure 5.37: Red-Purple UI element

Figure 5.38: Yellow-Orange UI element

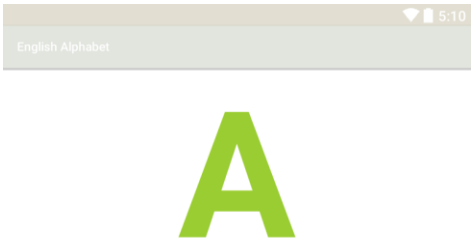

Figure 5.39: Yellow-Green UI element

Figure 5.40: Blue-Green UI element

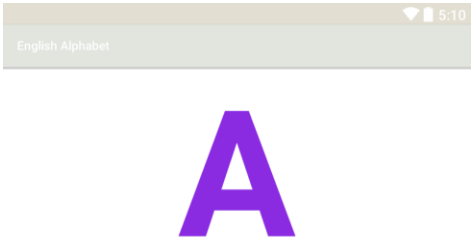

Figure 5.41: Blue-Purple UI element

The result from questionnaire 1, Table 5.6, shows the reactions of autistic users to different primary, secondary and tertiary colors and their variants. Concerning red color and it's variants, all test users (100%) chose the lighter version of red and ten users (50%) chose the grayish version of red and none of the test users chose the pure red color (hue) and the drakest version of red color (shade).

So this brings us to the conclusion that , from the different variants of red color, the lighter version of red color (tint) is found to be the most appropriate for autistic users.

As for the yellow color and it's variants , Table 5.6, 15 (75%) users chose the pure version of yellow color (hue), another 15 (75%) users chose the gray version of yellow color (tone), 20 (100%) test users chose the lighter version of yellow color (tint) and none of the test users chose the darker version of yellow color (shade). So, from the test we can conclude that from the family of yellow color, again autistic users are found to be most attracted to the lighter version of yellow color (tint).

Concerning the blue color and it's variants , Table 5.6, 20 (100%) test users chose the pure form of blue color (hue), 15 (75%) test users chose the grayish version of blue color (tone), 20 (100%) test users again chose the lighter version of blue color (tint) and none of the test users chose the dark version of blue color (shade) again. So, this brings us to the conclusion that, from the family of blue color, utistic users are most attracted to the pure form of blue color (hue) and the lighter form of blue color (tint).

As for orange color and it's variants, Table 5.6, 15 (75%) test users chose the pure version of yellow color (hue), another 10 (50%) chose the grayish version of orange (tone), 10 (50%) test users chose the lighter version of orange color (tint) and none of the test users chose the darker version of orange color (shade). So, this will lead us the conclusion that , autistic users are most attracted to the pure form of orange color (hue).

As for green color and it's variants , 20 (100%) test users chose the pure version of green color (hue), 10 (50%) test users chose the gray version of green color (tone), 10 (50%) chose the lighter version of green color (tint) and again none of the test users chose the darker version of red color (shade). So, from this we can conclude that, autistic users are most attracted to the pure form of green color (hue) from the family of green color.

As for purple color and it's variants, Table 5.6, 20 (100%) test users chose the pure version of purple (hue), 10 (50%) chose the gray version of purple (tone), 10 (50%) chose the lighter version of purple and none of the test users chose the darker version of purple (shade). This will lead us to the conclusion that, the pure form of purple color (hue) is the most attractive to the autistic users from the family of purple color.

As for red-orange color and it's variants, 20 (100%) test users chose the pure version of red-orange color (hue), 5 (25%) chose it's gray version (tone), 10 (50%) chose it's lighter version (tint) and none of the test users chose the darker version of red-orange (shade). This brings us to the conclusion that, autistic users are most attracted to the pure form of red-orange color (hue) from the red-orange color family.

Concerning yellow-orange and it's variants, 20 (100%) test users chose the pure version of yellow orange (hue), 10 (50%) chose it's gray version (tone), 10 (50%) chose it's lighter version (tint) and again none of the test users chose the darker version of yellow-orange (shade). So, from this we can conclude that, autistic users are most attracted to the pure form of yellow-orange (hue) from the yellow-orange color family.

As for yellow-green and it's variants, Table 5.6, 10 (50%) test users chose the pure version of yellow-green (hue), 15 (75%) test users chose the gray version of yellow-green (tone), 15 (75%) chose the lighter version of yellow-green and again none of the test users chose the dark version of yellow-green (shade). So, from this we can conclude that, autistic users are most attracted to the gray and lighter versions of yellow-green colors from yellow-green color family.

Concerning blue-green and it's variants , Table 5.6, 15 (75%) test users chose the pure form of blue-green (hue), 5 (25%) test users chose the gray version of blue-green (tone), 15 (75%) test users chose the lighter version of blue-green (tint) and again none of the test users chose the dark version of blue-green (shade). So, from this we can conclude that, autistic users are most attracted to the pure form and lighter version of blue-green from blue-green color family.

As for blue-purple and it's variants, 20 (100%) test users chose the pure form of blue-purple, 10 (50%) chose the gray version of blue-purple, 15 (75%) test users chose the lighter version of blue-purple and again none of the test users chose the darker version of blue-purple (shade). So,this will inturn lead us to the conclusion that, autistic users are most attracted to the pure form of blue-purple from the color family of blue-purple.

As for the last color, i.e., red-purple and it's variants, 15 (75%) test users chose the pure form of red-purple, 10 (50%) test users chose the gray version of it, 15 (75%) test users chose the lighter version of red-purple (tint) and again none of the test users chose the dark version of red-purple (shade). This will inturn lead us to the conclusion that, autistic users are attracted most the pure and lighter versions of red-purple colors from the family of red-purple.

So, from the color test, we can see that, all test users are not attracted to the darker versions of all the test colors, the reason for this is, the darker version of any color is almost similar with black color and autistic users see black color as they try to use the darker version of any color. We know that from previous research works, autistic users are repulsive to black color. So, based on the result from the test, Table 5.6, we recommend the following colors to be used in UI design for autistic users: lighter-red, lighter-yellow, pure blue, pure orange, pure green, pure purple, pure red-orange, pure yellow-orange, gray and lighter versions of yellow-green, pure and lighter versions of blue-green, pure blue-purple and pure and lighter versions red-purple.

Table 5.6: Summary of test result from questionnaire 1

Responses / Questions	A	B	C	D
Question 1	0 (0%)	0 (0%)	10 (50%)	20 (100%)
Question 2	15 (75%)	0 (0%)	15 (75%)	20 (100%)
Question 3	20 (0%)	0 (0%)	15 (75%)	20 (100%)
Question 4	15 (75%)	0 (0%)	10 (50%)	10 (50%)
Question 5	20 (100%)	0 (0%)	10 (50%)	10 (50%)
Question 6	20 (100%)	0 (0%)	10 (50%)	10 (50%)
Question 7	20 (10%)	0 (0%)	5 (25%)	10 (50%)
Question 8	20 (100%)	0 (0%)	10 (50%)	10 (50%)
Question 9	10 (50%)	0 (0%)	15 (75%)	15 (75%)
Question 10	15 (75%)	0 (0%)	5 (25%)	15 (75%)
Question 11	20 (100%)	0 (0%)	10 (50%)	15 (75%)
Question 12	15 (75%)	0 (0%)	10 (50%)	15 (75%)

Design Principle Five: easy navigation style

Autistic users might be confused with complex and unclear navigation styles because of their inability to understand complex interlinked objects. One mockup with two different navigation styles, Figure 5.42, is presented to test this design principle. The first navigation style is designed with gesture navigation and the second one is designed with a button. Each user has been given three minutes to use the mockups.

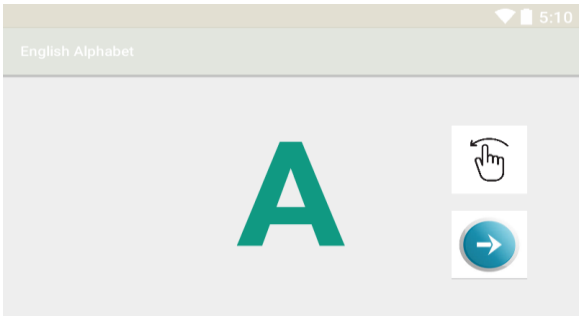

Figure 5.42: Different navigation styles

To measure the learnability of the UI , questionnaire 2, Annex I, has been prepared and distributed to test participants. The test participants have also been observed as they used the mockup. The result from the questionnaire, Table 5.7, shows that 90% of the test users choose gesture navigation, while the remaining 2% choose button navigation. Most of the test users have been observed using gesture navigation instead of button navigation, when they are asked to go to the next screen. Using gesture navigation also minimizes the risk of tapping on an unneeded area as it covers a much wider space on the screen than buttons.

Table 5.7: Summary of test result from questionnaire 2

Responses / Questions	A	B	C	D
Question 1	2 (10%)	18 (90%)	-	-
Question 2	20 (100%)	0 (0%)	-	-
Question 3	20 (0%)	0 (0%)	0 (0%)	0 (0%)

Design Principle Six (New): appropriate failure reporting mechanism

The mockups in Figure 5.43 and Figure 5.44 are developed to test autistic user's reaction to different failure reporting mechanisms. Here, two ways of failure reporting mechanisms are presented to know which failure reporting mechanism is safe for autistic users.

The mockup in Figure 5.43 shows failure reporting with an "X" mark and the mockup in Figure 5.44 shows failure reporting with an "incorrect, try again" sound.

The users were asked to tap on the alphabet on the mockup and not on the other area of the screen. If the user misses the alphabet, the "X" mark or the "incorrect, try again" voice is presented to the user. Each user has been given five minutes to use the mockups.

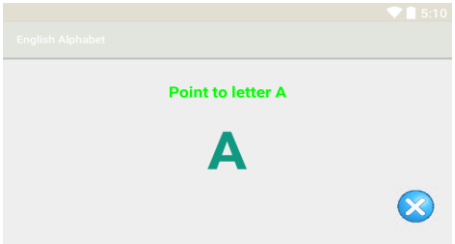

Figure 5.43: Error reporting with x metaphor

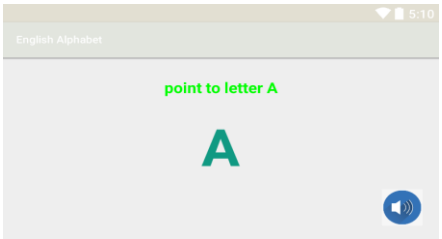

Figure 5.44: Error reporting with sound

The result from the questionnaire 2, Table 5.7, confirmed that autistic users would react safely to failure reporting in Figure 5.43 than failure reporting mechanism in Figure 5.44. All of the test users have been observed working well with the mockup depicted in Figure 5.43.

The users have been observed, frustrated, and angry when they brought up with the mockup in Figure 5.44. So, based on the test result, Table 5.7, it is better to use a metaphor such as X marks to report failure than voice.

Design Principle Seven (New): safe and appropriate loudness of sound

The mockups from Figure 5.45 – Figure 5.48 are developed to measure the loudness of a sound comfortable to autistic users. As discussed in Chapter Four, the sound that is normal or barely perceptible to non-autistic users can be loud and noisy to autistic users. Therefore, it is important to measure and quantify the loudness of a sound appropriate to the autistic user's community.

Here, we used the loudness of sound, i.e, 60DB , identified as an appropriate loudness of sound for non-autistic users by [50], as a bench mark and we took three intervals each decreased by 10 from the loudness of sound above it to identify the appropriate loudness of sound for autistic users.

Besides the development of English alphabet teaching android application, doing so helps to develop other android applications like Augmentative and Alternative Communication (AAC) apps for autistic users with communication difficulty.

We used an Android app "sound meter" from google play store (https://play.google.com/store/apps/details?id=com.gamebasic.decibel&hl=en&gl=US) which measures and records the loudness of a sound in DB.

The app measures the loudness of a sound external to the android device on which the measurement is taken, so what we did was, we used two android phones for this task. One for measuring the loudness of a sound and the other for operating the task being measured.

The task is when the user taps on the Alphabet the application says the name of the alphabet and the other android phone with a sound meter measures the loudness of the sound produced by the other phone. The measurement was taken in a quiet room where there are no external noises. Here four mockups with different DB measurements are presented and tested on autistic users. Each user has been given five minutes to use the mockups.

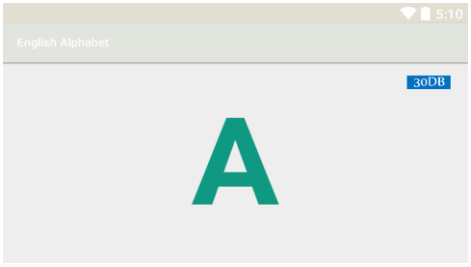

Figure 5.45: Loudness of sound with 30db

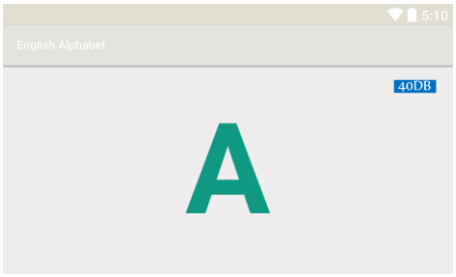

Figure 5.46: Loudness of sound with 40dp

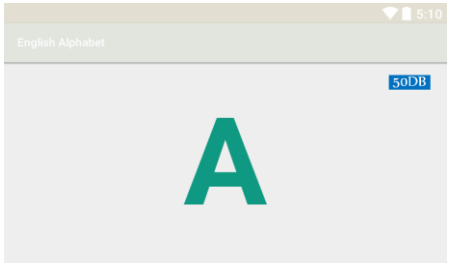

Figure 5.47: Loudness of sound with 50dp

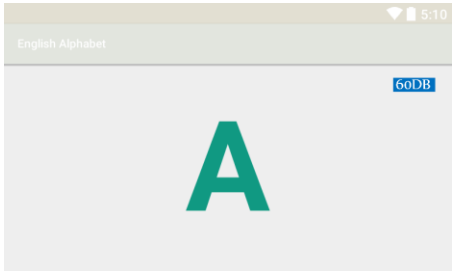

Figure 5.48: Loudness of sound with 60dp

Results from a questionnaire 2, Table 5.7, showed that the loudness of sound with 50 DB is appropriate for autistic users. All of the users have been observed working safely with the loudness of sound depicted in Figure 5.47. The loudness of sounds depicted in Figure 5.45 and Figure 5.46 were found to be difficult for autistic users to be heard. On the other hand, the loudness of sound depicted in Figure 5.48 was found to be very loud to the autistic users.

Design Principle Eight (New): longest time possible for time-sensitive tasks depending on the nature of the task

The mockups from Figure 5.49 - Figure 5.52 are developed to test how much time autistic users need to complete a given task. As discussed in Chapter Four, autistic users spend too much time on a given task. Here, to evaluate the efficiency of the users, we measure the time they spend on the given tasks and report back the result.

The tasks depicted in the mockups are the same tasks but with a different difficulty level. In Figure 5.49 the user is asked to identify the desired alphabet from two lists, in Figure 5.50 from three lists, in Figure 5.51 from four lists, and in Figure 5.52 from five lists. Then, the time it takes each user to finish the specific task is measured and documented.

Twenty non-autistic users are also recruited in this test. Their age is the same as autistic user's age. So, in this case, a comparison was made between the two user groups to know how much time autistic users spend on a given task compared to non-autistic users of the same age. Each group of users has been given 10 minutes to use the mockups.

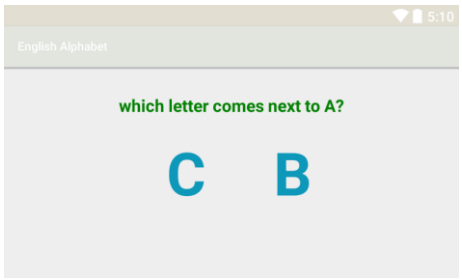

Figure 5.49: Tapping to identify from two objects

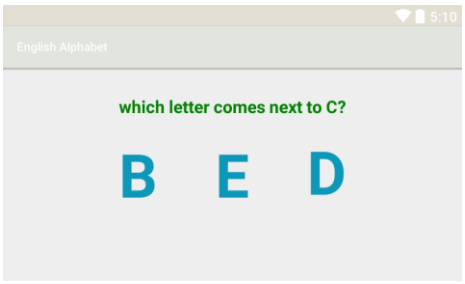

Figure 5.50: Tapping to identify from three objects

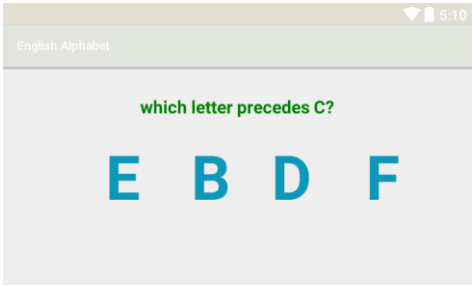

Figure 5.51: Tapping to identify from four objects

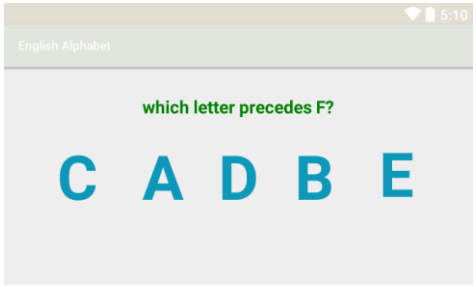

Figure 5.52: Tapping to identify from five objects

The time it takes each group of users is measured and reported in Table 5.8 and Table 5.9. As reported in Table 5.8 the average time autistic users take for the given tasks from Figure 5.49 - Figure 5.52 is 3.2 seconds, 4.45 seconds, 7.75 seconds, and 9.6 seconds respectively. As discussed in Table 5.9, the average time non-autistic users take for the given tasks from Figure 5.49 - Figure 5.52 is 1.6 seconds, 1.65 seconds, 2.5 seconds, and 2.6 seconds respectively.

The task seems very easy for non-autistic users, but this is not the case for autistic users. For instance, if we compare the time they took for the task in Figure 5.49, autistic users are 1.6 seconds late than non-autistic users.

This shows that UI designers should give the longest time possible when they design apps with time-sensitive tasks for autistic users

Table 5.8: Time report on a given task for autistic users

users **tasks**	Task 1	Task 2	Task 3	Task 4
User 1	3 seconds	5 seconds	7 seconds	10 seconds
User 2	4 seconds	5 seconds	8 seconds	10 seconds
User 3	3 seconds	4 seconds	8 seconds	9 seconds
User 4	3 seconds	5 seconds	9 seconds	10 seconds
User 5	3 seconds	4 seconds	7 seconds	10 seconds
User 6	3 seconds	5 seconds	8 seconds	9 seconds
User 7	4 seconds	4 seconds	7 seconds	10 seconds
User 8	3 seconds	4 seconds	8 seconds	9 seconds
User 9	3 seconds	5 seconds	8 seconds	10 seconds

users **tasks**	Task 1	Task 2	Task 3	Task 4
User 10	4 seconds	5 seconds	7 seconds	10 seconds
User 11	3 seconds	4 seconds	7 seconds	9 seconds
User 12	3 seconds	4 seconds	8 seconds	10 seconds
User 13	3 seconds	4 seconds	8 seconds	10 seconds
User 14	4 seconds	5 seconds	9 seconds	9 seconds
User 15	4 seconds	5 seconds	7 seconds	9 seconds
User 16	3 seconds	4 seconds	8 seconds	10 seconds
User 17	3 seconds	4 seconds	7 seconds	9 seconds
User 18	4 seconds	5 seconds	9 seconds	10 seconds
User 19	3 seconds	4 seconds	8 seconds	9 seconds
User 20	3 seconds	4 seconds	7 seconds	10 seconds
Total time	64 seconds	89 seconds	155 seconds	192 seconds
Average time	3.2 seconds	4.45 seconds	7.75 seconds	9.6 seconds

Table 5.9: Time report on a given task for non-autistic users

users \ **tasks**	Task 1	Task 2	Task 3	Task 4
User 1	2 seconds	2 seconds	2 seconds	3 seconds
User 2	1 seconds	1 seconds	3 seconds	2 seconds
User 3	1 seconds	2 seconds	3 seconds	3 seconds
User 4	1 seconds	1 seconds	2 seconds	3 seconds
User 5	2 seconds	2 seconds	3 seconds	3 seconds
User 6	2 seconds	2 seconds	2 seconds	2 seconds
User 7	2 seconds	1 seconds	2 seconds	3 seconds
User 8	1 seconds	2 seconds	3 seconds	2 seconds
User 9	2 seconds	1 seconds	3 seconds	2 seconds
User 10	2 seconds	2 seconds	2 seconds	3 seconds
User 11	1 seconds	2 seconds	2 seconds	2 seconds
User 12	1 seconds	1 seconds	3 seconds	3 seconds
User 13	2 seconds	2 seconds	3 seconds	3 seconds
User 14	2 seconds	1 seconds	3 seconds	2 seconds
User 15	1 seconds	2 seconds	3 seconds	3 seconds
User 16	2 seconds	1 seconds	2 seconds	3 seconds

users **tasks**	Task 1	Task 2	Task 3	Task 4
User 17	2 seconds	2 seconds	2 seconds	3 seconds
User 18	1 seconds	2 seconds	3 seconds	3 seconds
User 19	2 seconds	2 seconds	2 seconds	3 seconds
User 20	2 seconds	2 seconds	2 seconds	3 seconds
Total time	32 seconds	33 seconds	50 seconds	52 seconds
Average time	1.6 seconds	1.65 seconds	2.5 seconds	2.6 seconds

Chapter 6 : Conclusion and Future Work

6.1 Conclusion

Different studies show that autistic users are fascinated by technology for learning rather than traditional means of learning. Technological devices, especially smarthphone technology, could be of great help in this regard. However currently available smarthphone applications, especially the android ones, are difficult to use while they also demand more learning and operation efforts. The challenge is related to the UI design process, which arises from improper UI design decisions and improper use of UI elements which is the result of lack of usability guidelines and principles. Besides, the existing UI design principles that are there to develop android applications for autistic are insufficient and some of them even lack autistic users characteristics consideration in some aspects.

Design principles are often extracted from best practices, from testing existing software applications against the target users and user profile. The approach we followed in this research paper is, we extracted the UI design principles from users profile, in this case, autistic users profile. After we extracted the design principles we tested them against autistic users to prove their effectiveness. We used usability metrics, questionnaire and observation as evaluation mechanisms to conduct the test. The following design principles are devised based on the test tesult:-

- Appropriate touch target size
- Reduced number of touch targets per screen
- Limiting the UI content to the most important elements
- An alternate color usage other than black
- Easy navigation styles
- Appropriate failure reporting mechanism
- Safe and appropriate loudness of sound
- Longest time possible for time sensitive tasks depending on the nature of the task.

Design principles are effective in paving the way the UI should be designed for target users. They will lead the UI designer in a better way if they are carefully crafted based on target users' characteristics. We are not saying they are the only means or the major means to design and develop usable software applications, but together with other techniques and mechanisms, it is obvious they will contribute a great deal in solving usability issues related to software application development.

In the same way, the design principles identified in this research paper will not provide a single solution to the usability issues of android applications developed for autistic users, but as we can see from the results of the experiment, we do believe that they will contribute their part in alleviating usability issues related to android applications developed for autistic users.

6.2 Major Contributions of the Work

The main contributions of this research paper are outlined as follows:

- Autistic users' characteristics that affect android application development are identified
- Usability attributes that relate to autistic user characteristics, therefore, should be considered during software application development for autistic users are identified.
- Design principles are identified based on autistic user characteristics and usability attributes (major contribution).

6.3 Future Work

In the future, we have a plan to improve and refine the design principles identified in this research paper by considering more alternatives and conducting more experiments. Specifically concerning the design principle connected with color and touch target sizes; we will consider testing more colors to identify other appropriate colors that should be used in UI design for autistic users; concerning the touch target sizes, in this paper we identified the minimum touch target sizes and the minimum space that should be used between them; we didn’t specify the target size, so this will be considered as a future work.

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Annexes

Annex A: Source code for the mockups testing the first design principle

```
<!-xml Source code for one element per screen -->

 <?xml version="1.0" encoding="utf-8"?>
<LinearLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    android:orientation="vertical"
    android:weightSum="100" >

                <TextView
                android:id="@+id/ha"
                android:layout_width="wrap_content"
                android:layout_height="wrap_content"
                android:text="ሀ"
                android:textColor="#109982"
                android:layout_gravity="center"
                android:gravity="center"
               android:textSize="100dp"
                android:textStyle="bold" />

</LinearLayout>
```

```
<!-xml Source code for three UI elements per screen -->


<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:text="ሀ"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/hababpic"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:layout_below="@+id/ha"
        android:src="@+drawable/habab_pic" />

    <TextView
```

```
        android:id="@+id/hababtext"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:text="ሀባብ"
        android:layout_below="@+id/hababpic"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

</RelativeLayout>
```

<!--xml Source code for six UI elements per screen-->

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:gravity="center"
        android:text="ሀ"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/hababpic"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:gravity="center"
        android:layout_below="@+id/ha"
        android:src="@+drawable/habab_pic" />

    <TextView
        android:id="@+id/hababtext"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:text="ሀባብ"
        android:layout_below="@+id/hababpic"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <TextView
        android:id="@+id/hu"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_toRightOf="@+id/ha"
        android:gravity="center"
        android:text="ሁ"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />
```

```
    <ImageView
        android:id="@+id/huletpic"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:layout_toRightOf="@+id/hababpic"
        android:src="@+drawable/hulet_quter" />

    <TextView
        android:id="@+id/hulettext"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:text="ሁለት"
        android:layout_toRightOf="@+id/hababtext"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

</RelativeLayout>
```

Annex B: Source code for the mockups testing the second design principle

```
<!--xml Source code for black UI element in a white background -->

<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:background="#000000" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="100dp"
        android:layout_height="100dp"
        android:gravity="center"
        android:text="ሀ"
        android:textColor="#FFFFFF"
        android:textSize="70dp"
        android:textStyle="bold" />

<!--xml Source code for two black UI elements -->

</RelativeLayout>

<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:text="ሀ"
        android:textColor="#000000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/hababpic"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:layout_below="@+id/ha"
        android:src="@+drawable/habab_pic" />

    <TextView
        android:id="@+id/hababtext"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:text="ሀባብ"
        android:layout_below="@+id/hababpic"
        android:textColor="#000000"
```

```
        android:textSize="70dp"
        android:textStyle="bold" />
</RelativeLayout>
```

<!--xml Source code for two UI elements in blue and green -->

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:text="ሀ"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/hababpic"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:layout_below="@+id/ha"
        android:src="@+drawable/habab_pic" />

    <TextView
        android:id="@+id/hababtext"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:text="ሀሳብ"
        android:layout_below="@+id/hababpic"
        android:textColor="#00FF00"
        android:textSize="70dp"
        android:textStyle="bold" />

</RelativeLayout>
```

Annex C: Source code for the mockups testing the third design principle

<!--xml Source code for a UI element with 150dp -->

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="150dp"
        android:layout_height="150dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:text="ሀ"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

</RelativeLayout>
```

<!--xml Source code for three UI elements each with 70dp -->

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:text="ሀ"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/hababpic"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:layout_below="@+id/ha"
        android:src="@+drawable/habab_pic" />

    <TextView
        android:id="@+id/hababtext"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:text="ሀባብ"
        android:layout_below="@+id/hababpic"
```

```
        android:textColor="#00FF00"
        android:textSize="70dp"
        android:textStyle="bold" />

</RelativeLayout>
```

Annex D: Source code for the mockups testing the fourth design principle

```
<!--xml Source code for UI with gesture and button navigation -->

<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:text="U"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/swipe"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_toRightOf="@+id/ha"
        android:src="@+drawable/swipe_toleft" />

        <ImageView
        android:id="@+id/nextbutton"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignRight="true"
        android:layout_alignBottom="true"
        android:src="@+drawable/next_button" />

</RelativeLayout>
```

Annex E: Source code for the mockups testing the fifth design principle

<!--xml Source code for error reporting with x mark -->

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:text="U"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/xmark"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignRight="true"
        android:layout_alignBottom="true"
        android:layout_toRightOf="@+id/ha"
        android:src="@+drawable/x_mark" />
```

<!--xml Source code for error reporting with sound -->

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:text="U"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/xsound"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignRight="true"
        android:layout_alignBottom="true"
        android:layout_toRightOf="@+id/ha"
        android:src="@+drawable/x_sound" />
```

Annex F: Source code for the mockups testing the sixth design principle

<!--xml Source code for identifying two objects from the list of two -->

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:layout_gravity="center"
    android:paddingLeft="10px"
    android:paddingRight="10px"
    android:paddingTop="10px" >

    <TextView
        android:id="@+id/questions"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_alignParentTop="true"
        android:layout_centerHorizontal="true"
        android:layout_marginTop="40dp"
        android:gravity="center"
        android:text="ሁለት ቂጥር የቱ ነው?"
        android:textColor="#000000"
        android:textSize="20dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/habab_pic"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_below="@+id/questions"
        android:layout_centerHorizontal="true"
        android:layout_marginTop="52dp"
        android:gravity="center"
        android:src="@+drawable/habab_pic" />

    <ImageView
        android:id="@+id/huletquter"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignTop="@+id/ habab_pic "
        android:layout_marginRight="65dp"
        android:gravity="center"
        android:src="@+drawable/hulet_quter" />

</RelativeLayout>
```

<!--xml source code for identifying a desired object from the list of five -->

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:layout_gravity="center"
    android:paddingLeft="10px"
    android:paddingRight="10px"
    android:paddingTop="10px" >

    <TextView
        android:id="@+id/questions"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_alignParentTop="true"
        android:layout_centerHorizontal="true"
        android:layout_marginTop="40dp"
        android:gravity="center"
        android:text="ሂሊኮፕተር የቱ ነው?"
        android:textColor="#000000"
        android:textSize="20dp"
        android:textStyle="bold" />


    <ImageView
        android:id="@+id/habel_pic"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignTop="@+id/hilicopter_pic"
        android:layout_marginRight="33dp"
        android:layout_toLeftOf="@+id/hilicopter_pic"
        android:gravity="center"
        android:src="@+drawable/blue_bracelet" />

    <ImageView
        android:id="@+id/hilicopter_pic"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignTop="@+id/habab_pic"
        android:layout_marginRight="24dp"
        android:layout_toLeftOf="@+id/habab_pic"
        android:gravity="center"
        android:src="@+drawable/hili_copter" />

    <ImageView
        android:id="@+id/habab_pic"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_below="@+id/questions"
        android:layout_centerHorizontal="true"
        android:layout_marginTop="52dp"
        android:gravity="center"
        android:src="@+drawable/habab_pic" />
```

```
    <ImageView
        android:id="@+id/walkingman"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignTop="@+id/habab_pic"
        android:layout_marginRight="17dp"
        android:layout_toLeftOf="@+id/huletquter_text"
        android:src="@+drawable/man_walking" />

    <ImageView
        android:id="@+id/huletquter_text"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignParentRight="true"
        android:layout_alignTop="@+id/walkingman"
        android:layout_marginRight="48dp"
        android:gravity="center"
        android:src="@drawable/hulet_quter" />
</RelativeLayout>
```

Annex G: Source code for the mockups testing the seventh design principle

<!--xml source code for for UI with sound volume of 30dp -->

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
        android:id="@+id/ha"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:text="U"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/thirtydb"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignRight="true"
        android:layout_alignParentTop="true"
        android:src="@+drawable/thirty_db" />

        <ImageView
        android:id="@+id/sound"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignRight="true"
        android:layout_alignBottom="true"
        android:layout_gravity="center"
        android:gravity="center"
        android:src="@+drawable/x_sound" />

</RelativeLayout>
```

<!--xml source code for for UI with sound volume of 60dp -->

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent" >

    <TextView
```

```
        android:id="@+id/ha"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_gravity="center"
        android:gravity="center"
        android:text="U"
        android:textColor="#FF0000"
        android:textSize="70dp"
        android:textStyle="bold" />

    <ImageView
        android:id="@+id/sixtydb"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignRight="true"
        android:layout_alignParentTop="true"
        android:src="@+drawable/sixty_db" />

        <ImageView
        android:id="@+id/sound"
        android:layout_width="70dp"
        android:layout_height="70dp"
        android:layout_alignRight="true"
        android:layout_alignBottom="true"
        android:layout_gravity="center"
        android:gravity="center"
        android:src="@+drawable/x_sound" />

</RelativeLayout>
```

Annex H: Questionnaire 1

Hi, my name is Abreham Bekele, I am a second-year software engineering student at Addis Ababa University. I am currently conducting a research on developing design principles for autistic android application users. I request all autistic users to please chose the suitable color presentation from the given alternatives. You can choose multiple answers from the given alternatives. This little effort of yours might help someone live a better life.

1. chose the color presentation you found pleasant (red and it's variants)

A.  B.  C.  D.

2. chose the color presentation you found pleasant (yellow and it's variants)

A. B.  C. D.

3. chose the color presentation you found pleasant (blue and it's variants)

A.  B.  C.  D.

4. chose the color presentation you found pleasant (orange and it's variants)

A.  B.  C.  D.

5. chose the color presentation you found pleasant (green and it's variants)

A.  B.  C.  D.

6. chose the color presentation you found pleasant (purple and it's variants)

A.  B.  C.  D.

7. chose the color presentation you found pleasant (red-orange and it's variants)

A.  B.  C.  D. 

8. chose the color presentation you found pleasant (red-violet and it's variants)

A.  B.  C.  D. 

9. chose the color presentation you found pleasant (yellow-orange and it's variants)

A.  B.  C.  D.

10. chose the color presentation you found pleasant (yellow-green and it's variants)

A.  B.  C.  D.

11. chose the color presentation you found pleasant (blue-green and it's variants)

A.  B.  C.  D.

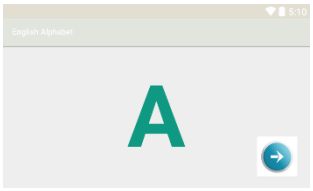
12. chose the color presentation you found pleasant (blue-violet and it's variants)

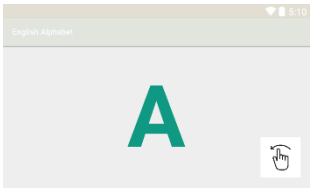
A.  B.  C.  D. 

Annex I: Questionaire 2

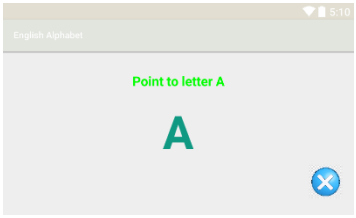
Hi, my name is Abreham Bekele, I am a second-year software engineering student at Addis Ababa University. I am currently conducting a research on design principles for designing user interface of Android Applications to autistic users. I request all autistic users to please use the Application prototypes and then fill this questionnaire. This little effort of yours might help someone live a better life.

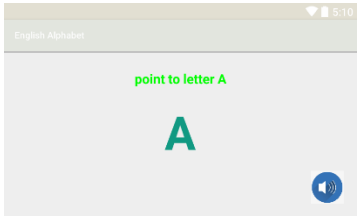
1. Which navigation style do you prefer?

A. 

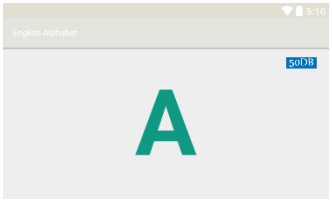
B. 

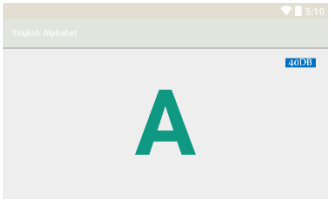
2. Which failure reporting mechanism do you prefer?

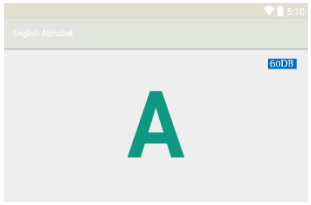
A. 

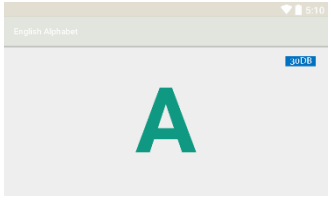
B. 

3. Which loudness of voice is appropriate to you?

A. 

B. 

C. 

D. 

Annex J: Main Colors and their Variants

1. Variants of Red

2. Variants of Yellow

3. Variants of Blue

4. Variants of Orange

5. Variants of Green

6. Variants of Violet

7. Variants of Red-Orange

8. Variants of Red-Violet

9. Variants of Yellow-Orange

10. Variants of Yellow-Green

11. Variants of Blue-Green

12. Variants of Blue-Violet

Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university and that all sources of materials used for the thesis has been duly acknowledged.

Declared by:

Name: Abreham Bekele Eshetu

Signature: _____

Date: _____

Confirmed by Advisor:

Name: _____

Signature: _____

Date: _____