AN EMPIRICAL STUDY ON PERCEIVED EFFECTIVENESS OF SUSTAINABLE DESIGN OF MOBILE APP ICONS

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DECLARATION

I declare that this thesis entitled "*An Empirical Study on Perceived Effectiveness of Sustainable Design of Mobile App Icons"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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First I would be grateful to Allah Almighty for the completion of my MS-Thesis. This thesis work is dedicated to my husband and my teachers throughout my education career who have not only motivated me but whose continuous encouragement have taught me to work hard for the things that I aspire to achieve. Finally I would like to dedicate this thesis to my valuable friends for their contributions to my intellectual growth.

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ABSTRACT

Sustainability has emerged as an important theme in society. And it is also becoming a source of benefit for HCI. However, the sustainability principles and the practice of sustainability in many areas like sustainable graphic design are at their starting stage. It has been explored by analyzing the currently proposed characteristics for app icons that, there are many important sustainable design characteristics that need to be considered while designing play store app icons. Thus, there is a dire need to raise the issues regarding sustainable interaction designs, so that user experience and satisfaction can be attained by addressing these issues. The narrative literature review was performed to analyze the existing characteristics that can relate to sustainable design and their effect on app icons. The process of NLR was performed based on previous academic research studies to identify the characteristics for the sustainable design of mobile app icons. Six characteristics related to sustainable design were identified. Furthermore, to evaluate the perceived effectiveness of identified characteristics of app icons among users, a controlled experiment was conducted. Results of the controlled experiment have increased the authenticity and effectiveness of identified characteristics. For designing stable and effective app icons identified characteristics will be helpful. Moreover, identified characteristics will help to increase user experience and satisfaction level that further contribute to improve the effectiveness of app icons. Thus the sustainable design of mobile app icons raises the perceived effectiveness among users.

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LIST OF ABBREVIATIONS

GUI	-	Graphical User Interface
HCI	-	Human Computer Interaction
ICT	-	Information and Communications Technology
NLR	-	Narrative Literature Review
SDAG	-	Sustainability Development Analytical Grid
GUIBAT	-	Graphical User Interface Behavioral Analysis Tool

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter describes the background of the research, problem statement, research questions and objectives along with the research scope, contributions and significance.

1.2 Background of Research

The use of mobile devices nowadays is getting growing interest [1]. Also due to the use of the internet, computing devices are now getting more popular because along with other functions they also allow communication. Availability of the internet and continuously increasing interest in different types of mobile phone applications that run on different devices has created many mobile application developers [2]. The researcher has explained that the search engine for mobile apps should perform the following tasks, firstly they should be able to categorize the apps into different classes, can understand what the user wants, and help the user to find the desired app. Some apps are there having characteristics to get suitable in different domains thus makes them more searchable than other apps [3].

Users have to find the app of their choice from several million apps [4]. Whereas user views and responses in written form help to increase the quality of an application by adding more features of their choice [2]. At this time according to the researcher, the total number of apps downloaded is 197 billion. Moreover, there is a prediction that the "global apps industry" will rise to 188.9 billion U.S dollars in 2020 [5].

Users nowadays are more dependent on graphical elements and icons of mobile applications as it provides the communication facility [6]. An icon is an image that serves as a concept or perception [7]. It is also believed that mobile icon communicates lots of information quickly and accurately [8]. Also, icons have a small display yet they are able to communicate the major functionality of the application [9]. Authors suggested that value-able icon design should be simple and clear [6], [10]. If the icon is complex then it will not be the choice of the user next time once it has been used [11].

For the effectiveness of an icon, it is necessary that it should be clear and explicit. In studies, it is found that intellectual and appealing icons have more influence on users. Icon's effectiveness also depends on the alignment of the icon's physical and intellectual features and how the icon depicts expected meaning [6]. The design of an icon is affected by icons interpretation, its first-time usage, and usage of the app for which the icon is designed. Icon designs of the app should depict the functionality of the app with the help of a symbol that is easy, clear, and accurately defining the purpose of the app [12]. But as time passes many changes have been noticed regarding icon's appearances and their usability [13]. Authors and developers are trying their best to find features that can be valued able for users and users urge to use them [14].

According to researchers, the designers can make the app icons better for users by identifying the design elements such as characteristics in design phase [1]. Practically a designer must know the key characteristics to design an icon. Till now there are many characteristics for icons that researchers have already identified [2]. According to researchers concreteness, familiarity, and other such characteristics

should be part of the icon for making it visually appealing [3]. For the success of an icon, it is important to make it from a realistic point of view or the icon should depict the real picture [4].

Previous studies have found that icon concreteness, simplicity, and complexity make it effective for the user [5]. But according to recent studies, an icon should be concrete, visually complex, and familiar from a searching perspective [4]. The study shows that few characteristics like semantic distance, familiarity, and complexity can help the user in icon recognition. Moreover in literature, the characteristics mostly found for effective icon design are complexity, concreteness, familiarity, meaningfulness, and semantic distance [6]. Previously icons were designed to get maximum user attention and for this, they assured the convenience, cognitive, and guidance facilities in an icon. Therefore the importance of an app icon can never be ignored [7].

Different people can interpret the same icon differently or they may have different understanding of the same icon this is called the 'ambiguity' of icon [8]. To reduce ambiguity, the icon should be more familiar by allowing users to use it frequently so that it may become more popular among users[9]. The search engines should also be very easy to use and should help users in finding appropriate app without creating confusion by showing apps of multiple categories at one time [10]. If the icons will not be designed by following a standard then it may lead to confusion for users of mobile applications [11]. According to researchers familiarity can reduce the level of ambiguity in users. When a user searches an app then visual complexity is the first thing that the user has to face if the icon is not recognizable [12].

Sustainability is now considered the main concern of the community [13]. According to the authors, sustainability is defined as "meeting the needs of the present without compromising the ability of future generations to meet their needs" [14]. There is a need for society and designers to be aware of sustainability, and sustainable designs should be there to meet the user's needs [15]. Sustainable icons are more clear, meaningful and comprehensive. Whereas the sustainable design of

icons have characteristics like effective communication, concreteness, familiarity, and resemblance with real objects. Sustainable designing of an app icon means that it will depict the true meaning of functionality the app holds [16]. If the ratings of sustainable design of app icon are concerned then there should be transparent and reliable criteria for it because user tends to use the thing more with which they are more familiar and reliable. If sustainability is not to be considered properly in the design phase then it is expected that it will lead to ambiguity [17].

As the number of mobile app users is increasing rapidly so there should be a link between the icon design and users [1]. There is a need to make app icons familiar for users so they can use the app easily [17]. The sustainable design of icons must-have characteristics of simplicity, meaningfulness, familiarity , comprehensiveness and user can interpret the icon same as others [16]. Researchers say that there is a link between ambiguity and unstable condition [18]. The industry is focusing to other perspectives of software but no attention is paid on how sustainability should be added in designing mobile app icons as the number of apps on the play store is increasing rapidly [13].

1.3 Problem Statement

The design of icon, and its associated characteristics are critical for users that greatly challenge not only the usability of the device, but also creates difficulty among users for understanding and usage [19]. The same icon can be interpreted differently by different people [8]. The apps that cannot attract the user through their icons are unable to gain popularity [5]. Moreover, characteristics of icons are necessary that provides sustainable design to app icons and help users to perceive the value of particular icon for usability [20]. As the number of apps on the play store is increasing rapidly and there are multiple icons for apps of the same category so it creates ambiguity and complexity among users for the selection of the required app. Due to this consequence, the effect on user perception leads toward uncertainty and inconsistency. Moreover, there is a need to enlist the characteristics that can

contribute towards icon designs so that less complexity, familiarity, and usability can be generated for a longer time.

1.4 Research Questions

This research opens the following research questions:

i. What are the key characteristics that exist in the literature for the sustainable design of mobile app icons?
ii. What is the contribution of perceived effectiveness among users for the identified characteristics of sustainable design of mobile app icons?

1.5 Research Objectives

Following are the research objectives for this research.

i. To identify the characteristics from literature for sustainable design of mobile app icons.
ii. To explore the contribution of identified characteristics and their effectiveness among users.

1.6 Aim of the Research

This research is aimed to investigate the characteristics that exist in the literature for the sustainable design of mobile app icons. After identification of characteristics, the study in hand is aimed to investigate the perceived effectiveness of these characteristics among users.

1.7 Scope of the Research

As icons are present on different interfaces and there are also different mobile phone brands with a huge number of different icon designs but this research has focused on Google play store icons. There are multiple categories of apps on the play store; among those the category of games has seventeen subcategories. Top downloaded subcategories of games are selected. Icons of top downloaded game apps will be selected. The focus will be upon taking user perception, there are also other parameters, but this research is focusing on user perception.

1.8 Contribution & Significance of Research

The first contribution of this study is providing the list of characteristics that exist in literature in the context of sustainable design of mobile app icons. The identified list of characteristics will help to improve the lifetime of icons by bringing enhancement in their design. Moreover, this will bring advancement in existing knowledge for the sustainable design of app icons.

The second contribution of this study is validating the identified characteristics by getting a perception of users in order to perform a comparison for the contribution of each of the characteristics. In future, this comparison will help designers to consider specific characteristics while designing mobile app icons.

1.9 Thesis Outline

This thesis consists of 5 main chapters.

Chapter 1 is composed of background, problem statement, objectives, research questions, scope, contribution & significance of the study, and thesis outline.

Chapter 2 is composed of a summary of the literature review that explains the existing literature on this research domain and details of sustainable design characteristics. Basic usability issues and proposed characteristics' discussion on mobile app icons and perceived effectiveness among users is also discussed. At the end of the chapter, the summary of proposed solutions is also given that exists in the literature.

Chapter 3 is composed of methodologies that are used in this research. Firstly, the protocol for Narrative literature review is adapted to describe the strategy and criteria for the selection process of literature. Secondly, the procedure of controlled experiment has been explained to find the perceived effectiveness among users.

Chapter 4 gives the results and discussions of methodologies that have been followed. List of characteristics is extracted and experimental results are also compiled for improved sustainable design of mobile app icons.

Chapter 5 is composed of the conclusion of this research. In this chapter, the research is summarized in a way that the accomplishment of research objectives, contributions, and limitations of the research are discussed. Moreover, recommendations are also proposed for the future. Recommendations will help to bring researcher's attention to the sustainable design of mobile app icons.

1.10 Summary

This chapter has explained the background of this research at an abstract level, problem statement, research questions, research objectives, contribution, and significance of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, the literature review is briefly reported. Characteristics that contribute towards perceived effectiveness among users for sustainable design of mobile app icons are discussed. Furthermore at the end of the chapter characteristics that contribute towards icon successfulness proposed by existing studies got compared and reported.

2.1 Introduction

HCI (Human-computer interaction) covers many areas like designing user interfaces (UI) emphasizes developing such interfaces that can improve the system performance. Human-computer interaction is always present to deal with technological changes in ICT (Information and communication technology) [21]. HCI has helped to make interaction easier and richer between humans and computers [22]. Information design is considered as the important domain of HCI, which examine ways for representing information, data classification procedures, and presenting meaningful interaction [23]. One of the most important purposes of any HCI interaction system is to provide efficient performance. For interface usability and other performance parameters during different tasks like timely learning,

response latencies and maintaining accuracy levels, particular emphasis is given by HCI [12]. In HCI graphic designing is considered a powerful tool that can decode the content of the message [24]. Because of this the quality of icons in HCI is considered more important for delivering the message as compared to other areas [25].

As the intelligent terminal product is becoming more popular on daily basis and cell phone is considered the most important terminal product, due to this UI designs are getting enough attention. The UI design of cell phones consists of interactive design, user research and other areas. Among them interface design is getting enough popularity for visual communication [26]. To communicate the information is the purpose behind development of icons for GUI [27]. A graphical user interface is a way for users to interact with devices through icons [28]. Generally, an icon consists of an image of something that can be recognizable [25], [29], [30]. In the world of computer, an icon is a small image that has some graphical notations and that can also symbolize the computer actions [6]. Icons are also essential for GUI (Graphical user interface)because they allow to access the function of various devices [6], [9]. Icons can also surpass the language barriers and are able to show meaning in a condensed way [8], [30]–[32]. Moreover icons allow to access the functional capabilities of the devices but little work has been done to investigate the effect of icons on adults of different age groups while using mobile applications [19].

Mobile interfaces have icons that help to represent the functionality to users so that they can perform their tasks [8]. Such interfaces that contain icons are believed to minimize the system's complexity if they are designed properly [33]. There are multiple benefits for using icons in mobile interfaces like saving display space, reduction of typing errors, are aesthetically appealing and importantly they reduce ambiguity as it is considered that picture is more worth than thousand words [23]. In the digital dissemination of information, icon design is important for computer interface design [34]. An effective icon design always reflects some information of a product or an interface [30].For this age of virtual interfaces,

effective icon design is vital for performing tasks like initiating actions, obtaining information, and navigation [35].

These days people often interact with each other through mobile phones [6]. The interaction process through mobile phones involves both controls, visual and manual [34]. Due to this, a large market has emerged for mobile apps [6]. With this rapid development of the market for mobile apps, understanding the ways for making successful mobile apps has become important for mobile app designers and researchers [36]. Basically a mobile application is intentionally designed software for mobile devices [6]. These apps allow users to read and write emails, play games, can do banking, tracking their orders, and many other tasks [10]. Apps must be designed and developed by considering user's technological skills, abilities, and language proficiency. This emphasizes the designer to be conscious while designing icons to achieve maximum usability [37]. Already many designers follow certain guidelines while designing and developing such apps that are user-friendly and attractive enough to get the acceptance of users [37]. Due to this mobile apps are getting popularity and their demand is also increasing continuously. In 2001 the number of global downloads was 30.1 and it has increased to 200 billion in 2016 and revenue is also increasing dramatically [23].

Despite these positive reports of icon usage, there is little research published on app icons and requires further investigation [5]. Information system researchers and designers require understanding factors that can make mobile apps effective and can play their role in business and daily life. For this, they must need to understand the guidelines of successful icon design and for guidelines, interdisciplinary research efforts are needed so that users may not lose their interest [36]. Therefore, to retain users, mobile apps have become a great concern for designers and mobile app researchers [23]. When a customer finds any app in the app store, mostly they are not sure about the quality and functionality of apps. In this case, icons play a vital role in indicating the quality and signifying the functions of apps [36].

2.3 Mobile app icons

An app icon can alter the functional information of an app into signs that can be used for communication and are easily recognizable and understandable by the users. In other words, app icons are such images that are the basis for the transmission of information [26]. Due to app icons, users do not require to perform several steps to interact with an app instead they can perform a minimal number of steps to perform their task [23].

The design of icons for mobile app plays a vital role in the success of businesses because the initial contact of the customer is with icons and they can also visually evaluate the icons [38]. There is a sea of apps in the app store and users find it difficult to search a suitable app, due to this app icon is important [1]. The icon is not just meant to be beautiful but it should also communicate information [30]. Initially, the purpose of icon design was to deliver functionality and provide the ease that can help people to identify operating functions. App icon designs are capable to increase the recognition and propagation of information [1]. App icons provide an opportunity to get user engagement in the app store where there is high competition. In designing an app icon the designer is the main source for the transmission of information [26]. So the designers must be able to grab users attention towards its app instead of others [5], [26]. It seems challenging for the designers to add all information within a small space of the icon [38]. The industry is considering factors that can make it easy for icon's success but still the research needed to attract users is limited [36].

2.4 App icons usability

A large number of people use smart phones worldwide including younger and older [21]. For people to use smart phone initial icon usability is important because of interfaces and features available on mobile phones [19]. A usability product helps to achieve familiarity of the product among users and allows users to achieve their objectives easily [21]. For any product, usability is crucial because it engages users

by allowing them to achieve goals efficiently and effectively and removes the chances for users to find alternate ways to get their goals [21], [35]. There are many apps available on Google Play Store for every purpose but their success depends on their usability [39].

For the development of the mobile app, user's skills and technological abilities must be considered. Due to this developers are enforced to design carefully to increase the usability level [37]. Applications should be designed and developed in such a way that can provide easier accessibility. So to develop an interface that is user-friendly is useful. Moreover by decreasing the system's complexity and by enhancing user satisfaction and usability can make icons more understandable [11]. Huang revealed that there is a great impact of reliability and practical function on the usability of icons [12]. So by selecting an icon that is not ambiguous can assure the accurate functioning of mobile apps. Lin explored that visual icons must be meaningful, concise, associable, concise, and eye catching [33]. The measurement of usability can be done by the correctness of the tasks while execution by calculating the time for performing the task and how many times the help facility has been accessed [19]. According to author, an application is usable if it has a pleasing and understandable user interface that can behave according to user's expectations [40].

2.5 Sustainability

Sustainability has emerged as an important theme in society and in HCI because it has proved to be a critical and prominent theme [41]. Sustainability is "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". According to the definition, sustainability includes the management for distribution of resources in such a way that resources can be utilized, maintained, and improved in current as well as in future [42].Actually the term sustainability has multiple meanings as it covers various perspectives which include social, human, and environmental sustainability [43]. As technology is now involved in every aspect of our lives and in order to make it useful, there is a need to account the differences and preserving the environments

interact with the user. The researcher revealed that sustainability should be considered while designing new technology [41]. SDAG is used to assess graphical design practices. However, SDAG (Sustainability Development Analytical Grid) contains five different domains instead of three like social, ecological, economic, ethical, and governance. But three domains of sustainability are mostly preferred which constitutes the triple bottom line [42]. If sustainability is explored, many challenges and issues come forward that are related to the different fields of areas like technology and human interaction systems and they must be addressed [44].

The main goals of sustainability are environmental conservation, human well-being, economic development, and others. According to Martin, the characteristic of sustainability can be given "multiple interpretations" and its means inclusion of multiple interests [43]. Sustainability has been proved to be important in the design field and so it is considered vital in HCI. Sustainable interaction design gives motivating visions to carry out sustainability research [45]. But there is a lack of appropriate evaluation methods that can categorize sustainable design activities in multi-dimensional conditions [46]. HCI design and skills can be used for searching for ways to support longer use, responsible disposal, maintaining things to extend their lifetime, and less frequent replacement so that production of new things can be reduced [45]. The authors say that sustainability covers all aspects that are related to the environment, humanity, society and economics [41].As much as sustainability is discussed more issues and challenges of sustainability are explored to resolve, so that industry and businesses can flourish [44]. The sustainability principles and the practice of sustainability in many areas like sustainable graphic design are at its starting stage. Also, it is reported from the literature that there is a lack of education regarding the integration of sustainability in to graphic design not only at institutional but also at the industrial level [42].

2.6 Sustainable design

Sustainable design is about applying sustainability principles to various fields of graphic designing and it helps to make such processes, materials, and strategies

that value social, environmental, economic, and cultural responsibility [42]. According to definition sustainable design is such act that provides choices which are useful for the future as well [47]. However, sustainable interaction design also encourages the motivating visions for undertaking sustainability research in such situations where there is the interaction between human and mobile interfaces because sustainable interaction design for cell phones is largely ignored [45]. Basically the main aim of sustainable interaction design is to give such ways that can integrate the principles of sustainability to existing design methods or considering those principles in new designs of icons in order to bring them in to practice [47]. In literature, it was explored that the main challenges to sustainability are lack of guidelines for sustainability practices and less education on sustainability. There are many designers from different nations who are even not aware of sustainability and its importance in the designing phase, the challenges that come in practice when sustainability principles are not considered and how to present sustainable solutions. Even the situation at this time is worse because either the designers are not aware of sustainability concerns or they do not want to take responsibility to design for longer use. Graphic designers need to think about their responsibility regarding bringing sustainability principles into practice while designing mobile interfaces [42].

2.7 Sustainable design of mobile app icons

Every user interprets the icon or sign according to their own culture, familiarity level, and knowledge [27]. So along with visual features of icons, cognitive features are also important which include semantic distance, concreteness, familiarity, and complexity for the effectiveness of icons [29]. Most people like such icons with which they are familiar or the icon that are recognizable and also matches the real objects around [9]. However, users can not interpret the icons properly which are poorly designed, which indicates that removing cognitive difficulties and enhancing user experience can improve icon design [48].

With the arrival of smart phones, many applications are designed to integrate into user's lives. As demand for apps is increasing, due to this app's operation time is

also extending. In the mobile app store, there is high competition between apps and among them, the app with the appropriate icon design is getting importance [1]. Moreover, when icons of different apps seem together, some icons among them stand out and look more useful than others [36]. Ambiguous icons are icons that different users may interpret differently even though they are presented with the same icon [49]. In other words, those icons are easily recognizable and identifiable. These unambiguous icons make the apps successful [35]. On the other hand complex or ambiguous graphics hinder to interpret icons correctly [50]. Mostly those icons are successful that can present relatable associations with the actual function of the app and are not ambiguous in their intended meaning [27], [32].

Attentively designed icons enhance the performance on the other hand ambiguous icons raise many interaction problems [33]. If the visual perception of the icon is presented properly then the user can recognize icon instantly otherwise app could not get popularity [25], [51]. Therefore, graphic designers should embrace sustainability and understand the necessity of including sustainable design guidelines in practice to propose sustainable solutions [42]. Moreover the designers conceptual model should match the users mental model [35].

2.8 Mobile app icon characteristics

Mobile applications are designed for mobile devices. Within those applications, there are icons that are physically connected to a specific function or target. So icon represents the main function of the application in the same way as logos identify the companies [36]. Referential icons generally have conversions in order to allow users to get the purpose and meaning of any app through inference and association [26]. Now there is research that shows concern about the characteristics that can be considered to find ways to use the symbols. Some characteristics identified in literature include semantic distance, meaningfulness, complexity, concreteness, and familiarity [52]. There are many characteristics that have been identified to predict the performance of icons. Because by studying such characteristics that can increase the icon usability can give an advantage to both

designers and users. For this, there are also various guidelines and recommendations that are concerned about cell phone app icon design [4].

From literature, it is revealed that some characteristics help in increasing the usability of icons while others make icon understanding difficult for the users. For this numerous sets of guidelines are required to support designers and allow them to design such icons that are appropriate for users of different age groups [6].Some studies related to icon characteristics have explored that people respond more easily and quickly to simple icons than to complex ones [48]. There is also identification of many characteristics that affects the icon's usability for non-e-literate users group. Some of these characteristics include the ability to learn, paying attention, creating ability to remember new information, building association and other visual abilities. But icon usability can probably be affected by users less experienced with interfaces [50]. Some icon characteristics that can affect the user appeal include complexity, familiarity, semantic distance, and concreteness [3].The cognitive characteristics of users should also be considered because they consist of users perceptional memory, imagination, thinking abilities, and feelings [30].

Researchers are finding difficulties while examining the value of certain icon characteristics for usability and making a decision that how to identify and measure the value-able characteristics [2], [20]. There are very few number of publications that have particularly identified those characteristics for icons that can make mobile applications quite different from traditional software [53]. The complexity of graphics increases the difficulties to identify and interpret icons [6].Researchers argued that icon characteristics are needed that can help in the initial interpretability of icons for various age groups. Currently, little research work has been done to examine the effect of mobile app icons on users of different age groups to increase their level of learn ability because users with less energy level, memory abilities and, less vision cannot interpret icons quickly and easily [6]. Furthermore, present research is not enough to consider all user values like their age and culture that can affect icon characteristics interactions. So by bringing comprehension in the scope of research, icon characteristics can be identified that can enhance the interaction between people of different age groups [3].

2.9 Perceived Effectiveness

To influence the users perception, the visual design of physical products plays a vital role [36]. Physical appearance is concerned about graphical characters that are used to show the semantics of represented objects and users evaluation of graphical characters is performed by taking their perception [9]. Researchers are largely interested to examine ways to design mobile app icons in order to retain users [23]. Product design is considered creative when users find it meaningful and purposive. Users are involved to get motivated and inspired for designing products creative [38]. Perceived effectiveness is also concerned with performance expectancy. Performance expectancy is the level of benefit that a consumer gets while using technology by performing some activities [54],[5]. An icon is supposed to present small objects. These small objects show many functions and these functions are perceived by users according to their level of understanding [1]. To get user perception reviews with argument density and diversion are considered more useful [55].

Commercial requirements are extending the icon's role to match the perception of the user [25]. Moreover, app icons that get more downloads, clicks, purchases are perceived as more unique and realistic [5]. According to the author usability of icons and users satisfaction can be increased by decreasing the number of errors and complexity of icons and thus making icons more understandable [33]. Moreover icon's effectiveness is influenced by its cognitive and visual features [8]. The appearance of the icon also influences the number of downloads by users [36]. And the goal of user interaction design is to give a simple interface while reducing users short-term memory load [23].

Less attention has been paid to the visual and cognitive attributes of app icons that affect the downloading behavior of customers [36]. Older adults take time to understand graphics. Moreover older users find difficulties while operating handheld devices and the knowledge that concerns about the effect of age on perceived usefulness is limited. So there is a need to discuss gender differences and users perception regarding the sustainable design of app icons [56].

2.10 Contrast and comparison of existing studies

There are many studies conducted by different researchers as shown in Table 1. The most recent work is done by H. Jylhä and J. Hamari (2019), who conducted the vignette study using semantic differential scale and investigated the relationship between consumer perceptions about app icons and their effectiveness on icons success.

Table 2.1: Contrast and comparison of existing studies

Paper Reference	**Domain**	**Methodology**	**Contribution**	**Limitation**
H. Jylhä and J.Hamari ,2019[5]	Aesthetics in HCI	Exploratory and Survey Based Experiment	Predicted app icon's success through user's perception.	Only one domain of iconography is selected from all icon categories. Participants were not informed about the purpose of apps behind the icon in experiment. Limited external validity Behaviors of participants could also be tested in a real scenario.
Lin and Chen, 2018[18]	HCI	Exploratory and Experimental research	Explored the effect of design instability of mobile app icon on the success of the application	Used very simple app icon with limited shape and color for study. It is difficult to examine the stability of complex icons.
Malik et al., 2017[16]	HCI	Experimental research	Explored the effect of the unsustainable design of the icons on "Mentally retarded users"	Commonly used icons were used and just four mobile brands were focused. The population for study was taken from the small area of a country.
Burgers et al. , 2016[57]	Information and Communication Technology	Field study and experiment	Examined the contribution of online reviews and visual design characteristics	Less complex metaphors are used in the study. Lack of anthropomorphic app icons.

			for icon's popularity.	
Smythwood & Hadzikadic, 2019[4]	Aesthetics in HCI	Experimental Research	Proposed the effects of icon characteristics on search time	Only one domain of iconography is selected from all icon categories. Just consider the aesthetic qualities of icons.
Wang & Li, 2017[36]	Image processing	Exploratory and Empirical and Survey Method	Explored the visual attributes of mobile apps on download behavior of users	The data set was collected from a single platform. On different platforms, the effect of icon display on downloads also may differ. The effect of Icon appearance on the number of downloads may also differ across cultures.
McDougall and Reppa, 2008[12]	Applied Ergonomics	Experimental study	Identified the characteristics to make icons appealing	Few characteristics are examined. In repeated experiments participants may give biased responses because the material was identical in experiments. Evaluation of icon appeal was not aligned accurately with performance.
Nguyen et al., 2021 [58]	HCI	Survey Method	Proposed GUIBAT - a new tool that learns from users' perception to detect unexpected SR (Sensitive Resource) in Android apps.	UI elements were not considered on web view. Inter app interaction (App can launch another app) was not possible. Just focused commonly used icons.
Ma et al., 2015[9]	HCI	Survey Method	Classification of icons into action icons and knowledge	Knowledge icons and action icons are used in specific domains.

			icons	
Kamarulzaman et al., 2020 [59]	HCI	SLR	Comparative study and Proposed elements for designing icons	No interview, experiment or any other strategy was followed for verification. The design elements may not be applicable in real situations.
Flora., 2014 [53]	Computer Science	Survey Method	Characteristics to make mobile application different from traditional software	The survey was only conducted from the people who were agreeing to respond. The real population was not involved in survey. There can be biasness of communities in the responses
Duangpatra et al., 2021 [60]	HCI	Experimental	Contribution to the design community to use findings as a guide lines for designing interface. It also helps to improve the quality of life among older adults	Physiological devices can be used to test user satisfaction level. Tests are only examined on android users. Tests are only performed when user is in convenient posture.

The detailed description of the articles shown in Table 2.1 is reported below. In 2019 the auther used survey-based vignette experiment to find out the relationship between consumer perception and success of app icon [5]. 22 adjective pairs from aesthetic qualities were taken to know participant's choice and then participants willingness to like, click, download, and purchase the application was evaluated through likert scale. Results have shown that the icons should be of good quality, attractive, and appealing for consumer. Moreover, the icons of applications should be more realistic and distinctive.

The author has done the experiment in 2019 to study the instability of app icons through the download intention of the user. The researcher observed that the prevention and promotion perspectives should be kept in mind while developing the

app icon [18]. The result shows that consumers select the apps for which they are more familiar through advertisements and other ways.

In 2017 the author conducted an experiment on users with less cognitive abilities concluded that users with more age and less cognitive abilities face difficulty in recognizing icons from different brands of mobiles performing the same functionalities [16]. According to the researchers, there should be an emphasis on using characteristics of sustainable design of icons while designing the icon.

In 2016 the author conducted a field survey and experiment to explore the effect of online reviews and visual characteristics on a number of downloads of mobile app icons[57]. Researchers have used visual metaphors and anthropomorphism in an experiment to know user's choices. It was found that visual metaphors bring more positive attitude from user than anthropomorphism. The researcher concluded that online reviews of users and designers choices for using metaphors in the icon have a great impact on icons popularity.

In 2019, the author used an experimental method to examine the effect of characteristics on up-to-date mobile application icons. The data regarding icon characteristics were taken from previous studies. Then those characteristics found from previous studies were used to evaluate the search time of mobile app icons[4]. Purpose of this study was to create icons that can promote usability. The experiment was done by using mobile gaming applications and relevant characteristics were grouped together. Less familiar icons were selected for the experiment in order to keep familiarity consistent in the stimulus set. Results indicated that icons should be simple enough so that user can locate them easily. The aesthetic appeal of an icon increases its performance.

Effects of icon's aesthetic design on app downloads is the main issue discussed in a study by evaluating dataset that was collected from Chinese Android Websites [36]. The purpose of the study was to find out how icon display influences download behavior. Dataset was collected from one of the well-known and largest Chinese Android Websites. The icon was analyzed from three different aspects that

include color, symmetry, and complexity through image processing. Results indicate that applications designed with high brightness, high colorfulness, and low saturation have a large number of downloads. Designers should prefer simple icons.

Another study is conducted to examine the characteristics of icons for determining appeal and their extent of processing fluency [12]. Experiments were conducted to know the processing fluency of the user. Initially, the icon display was held constant and ease of processing was continuously monitored and manipulated by varying the familiarity and complexity of icons. Participants were asked to rate the icon appealing or unappealing on a 1-5 scale. Accuracy, response time was calculated. The author analyzed that search time was faster for simple and more familiar icons. Accuracy and response time gets reduced as the participants of the experiment learned the relationship between icon and its function. According to author ease in icon processing not only detects user performance but also helps in predicting icon appeal.

Object-oriented icon taxonomy has been presented by the author to classify the icons into knowledge icons and action icons [9]. Firstly the knowledge regarding icons has been collected from the literature regarding the taxonomy of computer icons. Data regarding the taxonomy of icons on user's perceptions has also been collected. Based on the data collected a new taxonomy is presented by the author on application purposes in computer science. Moreover, icons were categorized into two types' knowledge icons and action icons. Knowledge icons help in providing visual-way to describe and spread knowledge and through visual-support it becomes easy and simple to convey knowledge. On the other hand action icons have a long history as they have been used for a longer time to grab user's attention through visual representation. In spite of showing long textual information these icons attract user attention and give them information as well. Also, the fields in which action and knowledge icons can be applied are explained in order to make them more effective. This icon taxonomy will contribute to system construction of an icon for visualizing purpose and knowledge-centralized interaction.

In 2019 a comparative study was conducted to explore icon designs in literature and to propose elements for good icon design [59]. A systematic literature review was conducted to collect data for icon design of mobile applications. For this, the articles selected were between 2014 and 2019. From the SLR ten common icon design elements were finally selected out of forty-two for mobile applications. These elements include color, recognizable, uniqueness, concreteness, semantics, familiarity, simple, aesthetics, shape, and consistency. These elements will be helpful for designers to enhance user experience and provide effectiveness.

Another survey was conducted by an author from the mobile development and research community to classify characteristics that contribute to making good mobile application designs [53]. Mobile application categories and their types are defined and then key characteristics that exist in the literature are identified. Afterward a survey was conducted to get input for new practices during the development stages of mobile applications. For this an extensive questionnaire was prepared for mobile companies, mobile expert researchers, and other concerned stakeholders. The findings shows that mobile application designs are quite different than desktop applications. The characteristics identified are classified into three types: Hardware characteristics, Software characteristics and Communication characteristics. These characteristics will be helpful for designers to know current trends in application development for mobiles.

An experimental study was conducted to improve the quality of life among older adults [60]. When people grow older they meet physical declines such as blurred vision, tremor in hands, and arms. This age related problems affect their patterns to live and use the smart phone. The author has tried to examine how older adults use smart phone with lower competencies than normal older adults. For this experimental study has been conducted in which 26 older adults were participants. Results indicate that by making icon of optimal size, clear and stable can reduce older adult’s difficulty in using smart phone and will improve usability among older adults.

Another survey was done by authors to analyze that how real world users perceive an app data access whenever they interact with GUI (Graphical User Interface) [58]. For this an automated tool was developed named GUIBAT (Graphical User Interface Behavioral Analysis Tool) which can detect the sensitive resource accesses that violates user's expectations. It was analyzed that mostly apps had at least one sensitive resource accesses. This analysis lays a clear foundation for modeling expectations of a user based on UI elements.

Recent studies indicate that now values are changing and the majority of user's prefer brands and things that are socially and environmentally long lasting and responsible. However, there is lack of manufacturing processes that are cost effective [61]. Moreover, now users rely on past experiences for a particular product and if they have not experienced before then they prefer online reviews rather than relying on the opinion of others [57].

2.11 Summary

This chapter has explained the literature review by exploring current existing issues regarding characteristics for sustainable design of mobile app icons. The literature review covers the already identified characteristics (Cognitive and aesthetic) for icon successfulness. Furthermore, icon taxonomy is also discussed.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Overview

This chapter explains two research phases which are narrative literature review and controlled experiment. Details of narrative review, controlled experiment, and user reviews are also reported in which design and execution is discussed.

3.2 Research Design and Procedure

The research procedure aims to solve the research problems systematically. It can be considered as the science to study the research process scientifically. Basically, research uses scientific procedures to discover answers to the questions. The main aim is to discover the undiscovered and to determine the truth [62].

The research methodology consists of 6 steps as shown in the figure. The very first step is conducting Narrative Literature Review. It is already explained in last chapter. The second step is prerequisite of experiment conduction. As shown in figure the first step has provided the list of characteristics along with their explanation. Moreover after the identification of Google play store top games categories in second step, an experiment is conducted in third step. To conduct an experiment

, questionnaire is generated and utilized in order to get perception of participants. In the fourth step, data is collected through analysis. In the fifth step, contribution of each characteristic is evaluated to know the perceived effectiveness among users for identified characteristics of icons. Finally in the last step, conclusions of results and future directions regarding this research are reported.

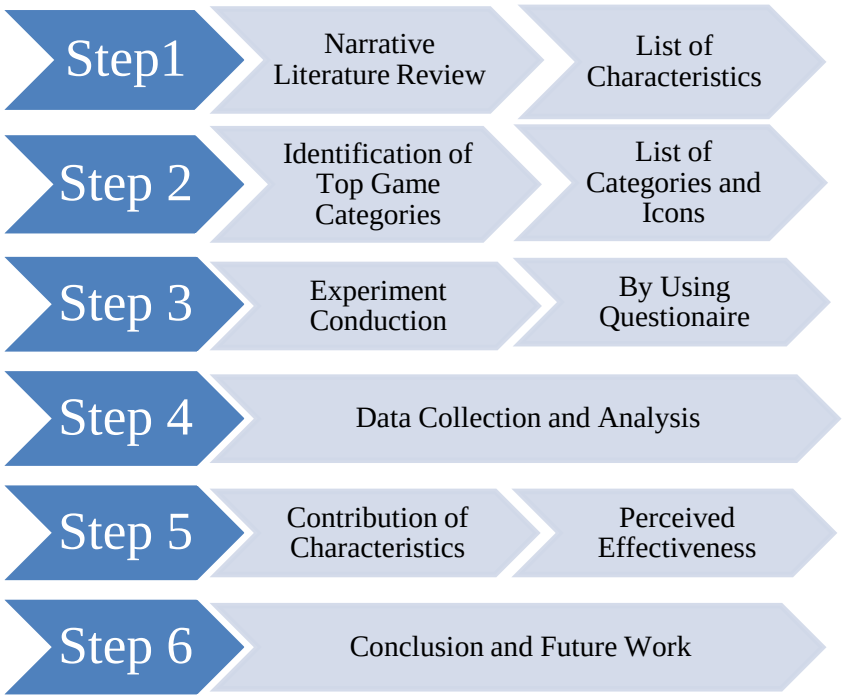


Figure 3.1: Procedure of Research Methodology

3.3 Narrative Literature Review

A narrative literature review is considered important for academic research. It is a well-known type of descriptive review and takes fewer resources and time [63]. Narrative literature reviews can be referred to as “literature reviews” or “traditional reviews”. Many published articles use narrative reviews for data gathering [64].

The narrative literature review is useful to gather data from the literature in a particular area, also it helps to synthesize and summarize the collected data. Its purpose is to give comprehensive background to the reader so that they may know its significance and can understand the knowledge that is up to date [65]. Narrative literature reviews combine the studies that can answer the research questions [66]. Moreover, these reviews help to identify and summarize the published literature without duplications and try to explore new studies from the deficiencies reported before [62].

3.3.1 Reasons for Adapting NLR

There are many reasons to conduct Narrative Literature Review. In this research Narrative Literature Review is adapted for the following reasons.

i. As NLR is use for the selection of required material [65], so it helped to interview and analyse the current studies for identification of the characteristics for sustainable design of app icons.
ii. For choosing the top Google Play Store app to conduct the experiment.
iii. NR can address multiple questions [62], so it is adapted to evaluate the results.

3.3.2 Important Features of Narrative Literature Review:

The most important features of the narrative literature review are reported below as according to Rossella [62].

i. NLR describes the published articles and other papers but it is not necessary to adopt a method to select the articles.
ii. Search the maximum number of articles that are relevant to the topic.
iii. Provides the verifiability of selected studies.

iv. Defines the objectives of research to stay focused.

v. Organize the information collected from selected articles.

vi. Citing and listing all the references searched from literature.

vii. Document the searching strategy.

3.3.3 The Process of Narrative Literature Review

The process of writing the narrative literature review can be distilled to a sequence of five simple steps [67]. For this research, the guidelines of Gregory & Denniss [67] are followed to conduct the narrative literature review. In order to get the relevant data, keywords are used in searching strategy. These keywords helped in exploring papers from different journals and other sources. By following the steps of the narrative literature review it becomes easy to explore the unexplored data and to find the facts. The figure shows all the steps of narrative review that are performed in their respective positions to get appropriate data.

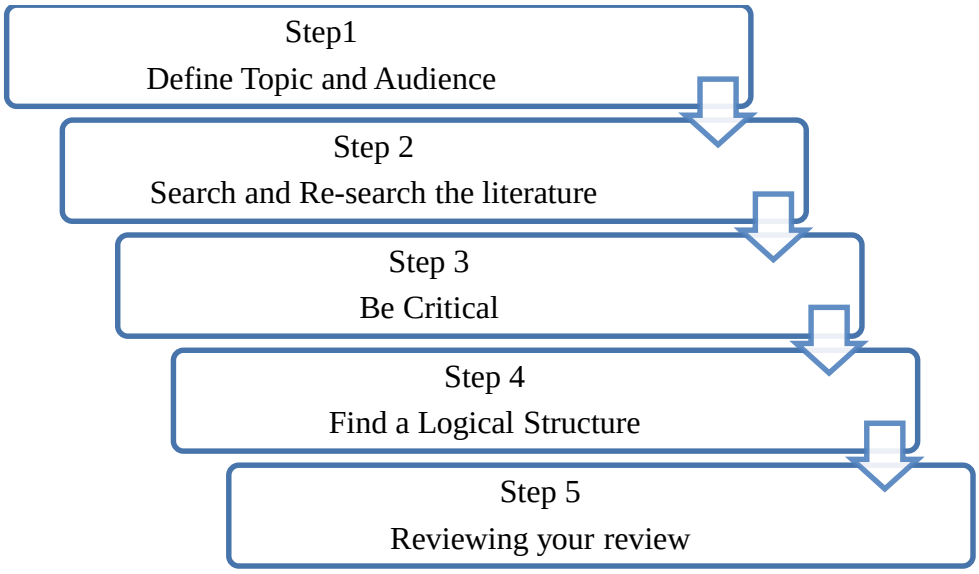


Figure 3.2: Steps of Narrative Literature Review [67]

The narrative literature review has several steps. Each step has its own significance. According to Kitchenham a review involves three main stages:

planning the review, conducting the review, and reporting the review[63]. In the process of conducting narrative literature review firstly the topic and the audience are defined. The topic should be interesting for the researcher and should also be useful for other readers. After selecting the topic and identifying the audience the process of searching related articles starts. Literature should be searched thoroughly to get fine results and to make sure that the searching process is carried out effectively. Searching and reading the papers is a critical process that should be carried out carefully. To get better results the area of interest should not be ignored while reading and searching papers. After reading papers thoroughly, the next task is to write the review in an effective manner. The final step is reviewing the written review. Overall to conduct this review guidelines of Gregory & Denniss [67] are followed.

3.3.4 Need for a Narrative Review

The need to conduct narrative literature review arises in order to organize the large volume of information, lack of consensus on a specific topic, divergent views, and to explore new knowledge [62]. In this research the narrative review is used to explore existing characteristics and their effect on mobile app icons.

3.4 Controlled Experiment

In research, there are many conditions that an icon needs to meet for effective selection. These conditions include comprehension, legibility, and reaction time [6]. Icons are very important for communicating information and perceptions through figurative expressions [59]. Literature has focused on analyzing icon communication from different perspectives [68]. As the amount of information is continuously increasing so designers should focus on giving more design solutions that can match user’s requirements [50].

Users view the app icons at first glance in an app store and for increasing the user interest app icons are considered important. If the app icon is not well designed and appealing then it may lose the popularity of the app [1]. There are many researchers who have tried different procedures for the evaluation of graphical icons [69]. Still little investigation has been carried out to explore the influence of graphic icons on mobile app user perceptions[8].There is also a lack of research regarding the effect of graphical icons on people of different age groups who uses either mobile phone icons or other icons [6]. A major obstacle that researchers faced often is to quantify the symbol characteristics so they can be controlled experimentally. One suggestion to resolve this issue is by assigning subjective ratings to each characteristic which will give a good way of controlling these characteristics experimentally. Still, than differences in findings for even similar tasks may arise because of differences in end user experiences, these differences emphasize to performing the selection part of researches in some studies and searching part of those tasks in others [20].

This study will identify the characteristics in literature for the sustainable design of mobile app icons. Moreover, user perception will be helpful to explore the contribution of identified characteristics for icon's success. Recent studies support the use of the experimental methodology for the research in which there is a need to investigate the perceived effectiveness of mobile app icons [1],[16]. For this, a controlled experiment methodology is conducted to investigate the effect of identified characteristics among young and old age people of Pakistan. Figure 3.3 shows the details of the controlled experiment.

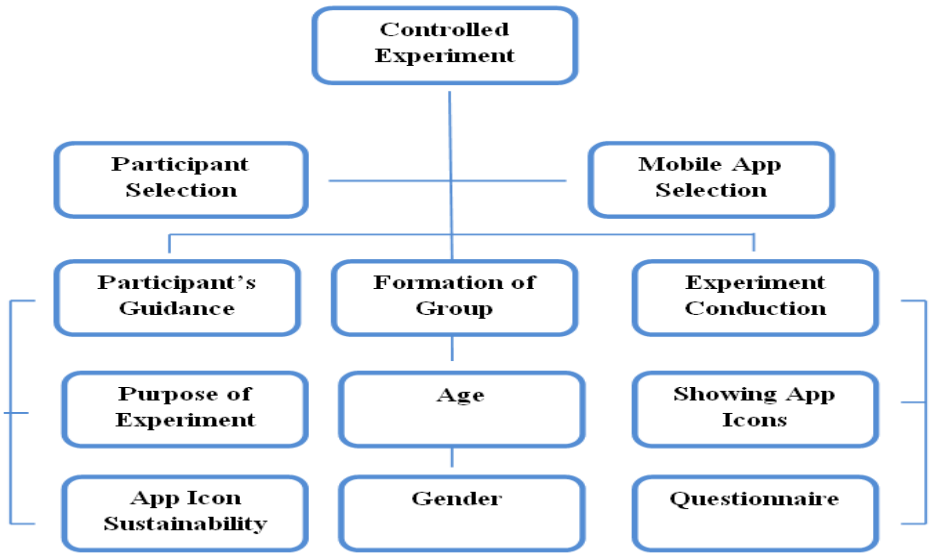


Figure 3.3: Controlled Experiment

3.4.1 Participant Selection

This study has involved the participants having computer science background. All the participants also possessed cell phones for more than one year [69]. All participants have normal vision, although some participants wore glasses. Total 28 participants took part in the experiment.

3.4.2 Providing Guidance to Selected Participants

After the selection of participants, a small session is conducted to guide the selected participants about the purpose of the study. As participants are already familiar with the computer and mobile app icons so it will be easy to guide them and get their perception of mobile app icons. Participants will be informed about the procedural details of the experiment and guidance will be given at each step.

3.4.3 Group Formation

Two groups are formed in which there are total 28 participants. Participants in the groups are divided on the basis of age and gender. Participants having ages between 18-31 are placed in one group named as young age group and the participants having ages between 32-47 years are placed in the old age group [16].14 participants will be part of each group including 7 male and 7 female participants. The information regarding group formation for this experiment is described in Table 3.1. The table is composed of four columns. The first column explains the 'group category' which includes old age participants and young age participants. The second column shows the number of participants, taking part in the experiment. The third column named 'Participant Gender' represents the number of male and female participants. And the fourth column illustrates the range of ages for the participants.

Table 3.1: Information Regarding Groups Formation

Table 3.1 Information Regarding Groups Formation				
		Participant Gender		
Groups category	Number of Participants	Male	Female	Age
Young Age	14	5	9	18-31
Old Age	14	5	9	32-47

3.4.4 Mobile App Category Selection

App Store is considered a good source to provide information about apps that benefits customers, users and businesses [70]. Presently the two most prominent app markets are Android App Store, and Apple App store [71]. There are multiple apps in these stores that belong to different categories but still, competition between apps is very high. Here competition refers to those apps that offer same function and user have the choice to select the appropriate one [72]. Google play store consists of millions of apps. Billion and trillion of users download and use these apps [73]. In these apps, app space is quite different from other software development spaces

because in these apps granularity is neat and provides ready source of information by just paying a small amount or checking other customer ratings or with a little data mining for the required features. Moreover, for empirical analysis these attributes helps in making app space ideal [70]. With continuously increasing number of users number of downloads is also increasing. There is also an option for users to rate the apps or give reviews [72]. People usually downloads such apps that have high ratings because high ratings shows that those apps are more value able [73].

According to the author popular apps on play store are those that provide entertainment and relaxation to the users like Angry Bird, Candy Crush, and also those apps that are use for communication like Whatsapp, Facebook and Skype [74]. Games are considered as the most downloaded software among other categories on the Google play store [75], [76]. The total number of downloaded apps from app stores till today in all over the world is approximately 197 billion [5]. In 2018 the total number of games downloaded was 29.4 billion in which games from Google Play Store were 39% of total downloads. The world had 2.2 billion mobile gamers in 2018. The users of ages between 18-20 have made this category the second most category by raising its proportion to 66% [76]. India was ranked as the leading market for downloading over 5 billion games in 2018 [72], [76].Annual number of global downloads has grown 45% in the last 3 years since 2016 [77]. Although the games category is popular still research is limited to explore the accessibility of some games [75].

To conduct an experiment for this research, games category is selected and game app icons will be used as the stimulus item of the research because of several reasons. First reason is that internally they are the homogenous categories of graphics because they share the same size and almost same color space. Secondly, games app icons are already more familiar to people and it will help participants to effectively imagine these icons as in their normal life. Thirdly games icons show more heterogeneous behavior as compared to icons uses for utilitarian apps; due to this game app icons can afford more external validity or generalize ability. The fourth reason is that current game apps show a great timely phenomenon. According to several statistics now games app category is the most popular category [5]. Due to

the significance of game app icons, this research will focus only this category (games) [71].

There are 17 sub categories of mobile game apps on Google play store these are action, adventure, arcade, board, card, casino, casual, educational, music, puzzle, racing, role playing, simulation, sports, strategy, trivia and word [5]. The selection process of icons for the study is separated in two stages, the first stage involves the identification of the top games app sub categories on the basis of number of downloads and the second stage involves the icon selection from selected sub categories [78]. In this research, the top 5 most downloaded games categories from Google Play Store were selected [79]. Before 2016, top categories of games apps was Adventure with 80.18% increase in monthly downloads, followed by Role playing at 79.36%, Educational at 47.45%, Board at 59.23%, and Trivia at 47.45%. The next step was to ensure that the icons represent the attributes well [71].

In 2019 Arcade games were on top by contributing 47% of total games downloading figure. Puzzle games were at 21%, Casual games were at 15% , Action games were at 8% and Shooter games were at 3% [77]. In the first half of 2020 the top game category by number of downloads was Casual at 38%, Puzzle at 15%, Arcade at 12%, Simulation at 11% and Action games at 7%[80].

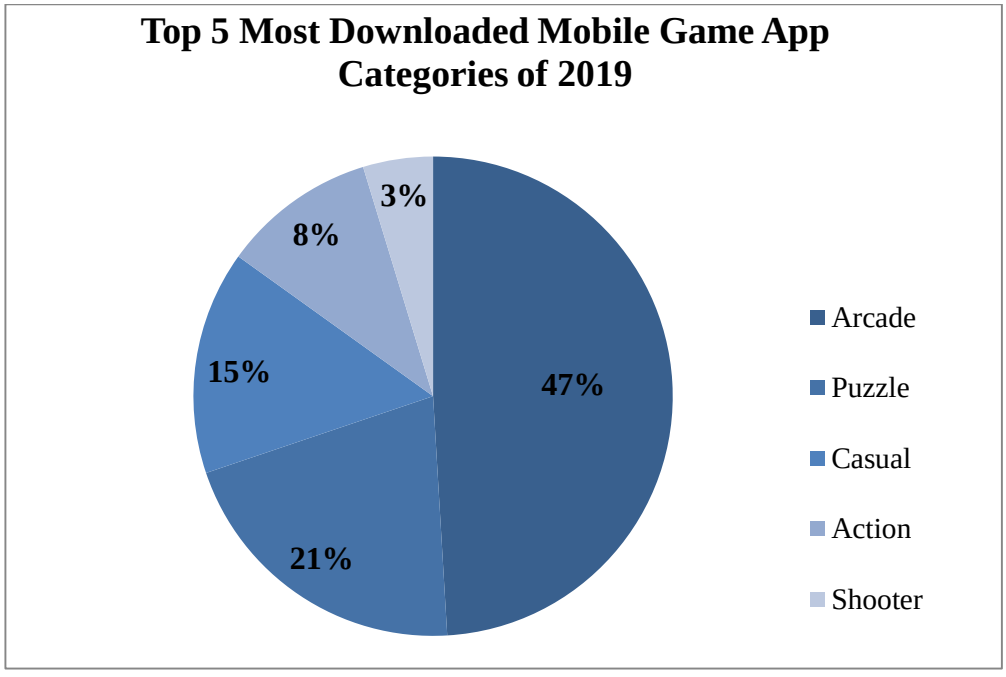


Figure 3.4: Top Downloaded Games App Categories

3.4.5 Mobile App Icon Selection

As the app icon is the visual item that the user see first in the app store for the evaluation of the app. So to convince the customer to closely look at the app within a short time is important [74]. The app icon is not just considered as the artistic creation but its aim is to communicate the app's functional information. This functional information is encoded in an icon and it depends how the icon is represented to deliver the information correctly to the user so icon can be realized for the purpose of information transmission [26]. For this experiment icons of the top downloaded games were selected from the year 2019. These game app icons belong to the top most downloaded games categories of same year. The top downloaded games of 2019 were Greena Free Fire, Pubg, Subway Surfer, My talking tom 2, Sand ball, Ice age village, Pokémon go, Color bump 3D, Happy glass and Home Scapes [81]. Table 3.2 shows the categories of games and the icons selected for the experiment.

Table 3.2: Mobile App Icons used in this Study

App Category	Sub Category	Game App Sub Category	Most Downloaded Games of 2019
Entertainment	Games	Arcade	• Subway Surfers • Color Bump 3D • Stack Ball
		Puzzle	• Sand Ball • Happy Glass • Roll the Ball
		Casual	• My Talking Tom 2 • Homescapes • Candy Crush Saga
		Action	• Mario Kart Tour • Aquapark.io • Pokemon Go
		Shooter	• Garena Free Fire • Pubg • Call of Duty®: Mobile

3.4.5 Experiment Conduction

Data from participants is collected through a controlled experiment. Each participant will fill the questionnaire through an online web based tool. App icons will be shown to the participants and several questions will be asked. There will be three sections of the questionnaire. The first section will ask about the demographic information of the participant. In the second section, general information of participants will be collected to know their expertise. In the third section of the questionnaire, the participants have to evaluate the game app icons. Participants will have to rate the icons based on questions containing sustainable design characteristics. Following open-ended questions will be the part of the questionnaire. This icon is concrete as it has a resemblance with real-world objects. Second, this icon is meaningful as it reflects the functionality associated with it. Third, this icon is familiar as it is easily recognizable. Fourth, this icon is transparent as it is easily interpretable. Fifth, this icon has a close relationship with the functionality it holds, and sixth, this icon accurately reflects information so that the user can correctly understand it. Rating responses of participants will be collected through likert scale. The criteria of likert scale are 1—Strongly Disagree, 2—Disagree, 3—Neutral, 4—Agree, 5—Strongly Agree. The mean scoring will be performed and composite mean values of app icons will also be calculated.

This questionnaire will be implemented via Survey Lab, an online survey tool. All content of the questionnaire is in English. The questionnaire will take approximately 10 minutes of the participant to fill. The data will be analyzed with MS Excel 2016.

3.5 Summary

This chapter highlighted the complete research methodology of this research. An overview of NLR is conducted with all its steps along with the conduction of a controlled experiment. The next chapter presents the results of the NLR and controlled experiment.

CHAPTER 4

CHARACTERISTICS IDENTIFICATION

4.1 Overview

Chapter 3 reported the NLR technique and controlled experimental study. This chapter documents the findings of NLR and controlled experiment. Chapter 4 formulates the gathered information into a list of characteristics, exists in literature for sustainable design of mobile app icons. Identified characteristics are discussed in detail and results of experimental study depicting the perceived effectiveness for characteristics among users are also reported in this chapter.

4.2 Narrative Literature Review Execution

In this study, NLR is used to identify the characteristics that can improve the mobile app icon design. In NLR, knowledge regarding icons is discussed in detail. Moreover, NLR is used to identify and extract the characteristics from literature. The protocols of NLR and controlled experimental study are described in chapter 3.

4.3 Characteristics of Sustainable Design of Mobile App Icons

In the process of NLR execution, several steps are followed to get the list of characteristics. The identified characteristics can be helpful for the sustainable design of mobile app icons. According to researchers, sustainable interaction design is useful for a longer time [45]. The main aim of sustainable interaction design is to give such ways that can integrate the principles of sustainability to existing design methods or considering those principles in new designs of icons to bring them in practice [47]. Sustainable design of app icon is now considered important as it provides a positive impact on users of different age groups. It allows users to interpret the icons more easily by giving icons resemblance with the real world objects thus making them familiar for the user. In literature a large number of characteristics are identified for icons from an aesthetic point of view. Little research has been conducted to explore characteristics for the sustainable design of mobile app icons. In this research some characteristics are identified from literature to express their usability for the effective design of icons. The list of characteristics found is shown in figure 4.1. The detail of each characteristic identified for sustainable design of mobile app icon is explained in the following section.

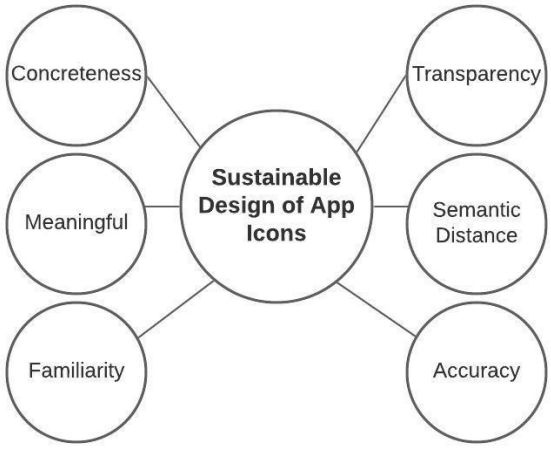


Figure 4.1: Characteristics of Sustainable Design of Mobile App Icons

4.3.1 Concreteness

The purpose of the icon is to help users to get information more rapidly and effectively [38]. Some authors have demonstrated that users react more quickly and precisely to concrete icons. Concreteness is mostly seen as an important property of icons [8]. Concreteness is defined as the concrete degree of an app's icon representing the item in the real world [9]. Icons are considered as concrete if they illustrate real objects and materials [29]. Because concrete icons portray objects that allow users to use their all knowledge of surroundings to understand them[2]. A simple icon having a higher degree of concreteness and familiarity can easily provoke the user's aesthetic appeal [9]. On the other hand abstract icons have less connection with real-world objects [2]. For mobile app, concrete icons provide essential representation and are significant [36]. Researchers prefer three characteristics in designing icons concreteness, semantic distance, and labeling [6]. Concrete icons allow users to determine their meanings even if they are used for the first time [52].

Icons should be designed to reduce user perception difficulties, memory difficulties and to enhance the user's understanding level [34]. Icon must be identifiable and differentiate able for the user [29]. Concreteness is considered an important determinant to identify icons quickly and accurately [12]. Icon identify ability increases the life of an icon [34], [52]. Moreover decisions made at initial design phase specify the economic and environmental impacts of future decisions [82]. Concrete icon tends to be more obvious as they depict objects with which user is already familiar within the real-world. Due to this quality concrete icons can be more durable [52]. Concrete icons are more environment friendly as they allow viewers to translate an icon to real-world example [83]. Research also indicates that users give response more quickly to concrete icons [27].

4.3.2 Meaningful

Graphical symbols can help readers to recognize and identify a specific message quickly [5]. The main features of the icons should express the specific meaning ,according to the specific requirements of the function [30]. Knowledge about the action of these objects in real-world can help users to get the meaning and function of icons [20]. Meaningfulness refers to the level judges perceive an icon to be meaningful [29]. Icons must be learnable, meaningful, memorable, understandable, and used consistently. Moreover, the meaning of an icon must be easy to guess [5].The features related to interaction levels allow researchers to design such icons whose meanings are very easy to learn and memorize [6]. Huang et al. realized that for designing qualified icons locate ability and meaningfulness are more significant than other factors. According to Lin, icons should be concise, identifiable, meaningful, associable and symbolic. Sanders and McCormick proposed that icons must convey easier meanings for the people to comprehend [25], [33].

Well designed icons help in reducing the need of further instructions for users by making icon more identifiable [33]. However, difficulties may arise in interpretation because individuals cannot clearly define set of rules that can remove ambiguity from icon meaning [20], [52], [83]. The icon is considered more meaningful if the relationship between icon representation and its function is closer(reduces gap) [12]. Icons are integral component of mobile interfaces but their understanding and recognition in integration with sustainable design of icons is necessary [16]. There can be different messages that the icon can be communicating at a time but if the user can get the intended idea than the icon is meaningful [83]. The meaning of icon should be stable [25]. Sustainable development refers to "maintaining the conditions for quality development" not only for present but for future generations as well. Sustainability ensures that the use of resources is done efficiently all the time and the society's productive base is more preserved over time [84]. Graphical perception provides direct communication so that users can know the icon's meaning with just one glance. Due to this meaningful icon makes the interaction easier between users and interfaces. This results in increased icon's lifetime which indicates that resources are utilized efficiently [51]. According to the

authors meaningfulness also increases quality of icons design which will help users to perform operations [25].

4.3.3 Familiarity

People connect everyday occurrences with familiarity to something and leads to efficiency and usability [85]. Icon familiarity is considered an important characteristic for appropriate icon identification and interpretation [32]. According to the author familiarity of icons refers to the frequency of use which directly relates to experience with an icon set [2]. Familiarity deals with users cognitive understanding of icon and uses iconic representation usage [9]. When an icon is used frequently user's not only get familiar with the icon's function and its position but they also do not require to decode its meaning [35]. The more commonly a user places an icon or the object representing icon, the more icon will have a higher degree of familiarity [21]. If the users are unable to understand icons meaning from familiarity or operation experience, then icon are considered to lose their significance completely [34]. Therefore 'Icons should be familiar to the users' [19]. Study reveals that familiar icons and their resemblance to the real-world objects maximize their recognition [6]. Another study reports that truly recognition rates are mostly higher in familiar icons [32]. The basic principle of recognition is that the icon design should accurately show the corresponding operation. This explores that when you see an icon you can easily understand what does it means [30]. With this principle icon achieving 60% recognition rate are considered identifiable [35]. Researchers claimed that a familiar icon helps user to recognize its intended meaning, distinguish it from other icons, and also remains in line with local and global standards [86].

To support the sustainability of the icon's identity recognition, familiarity and continuing attachment is important [87]. The quality and equality principle of sustainability supports motivation for reuse, achieving longevity of use, sharing with others for maximal use and achieving long-term usage status [47]. The social dimension of sustainability is also understood as the presently existing positive condition or such goal that remains to be achieved for future as well [88]. Researchers have argued the importance of familiarity with both the icon design and

the function associated. They suggested that familiar icons have long term effects to determine response times because they can be accessed easily in long-term memory representation due to the number of repeated presentations and thus are capable to sustain for longer time [27]. So by integrating criteria of social sustainability from the start of the development process it is possible not only to make it successful among users but it also reduces environmental pressure and increases economic prosperity by reducing future efforts and will help users in recognition [88].

4.3.4 Transparency

As the identification and interpretation of icons require their correct association to a reference function [89]. There are many guidelines regarding icon designs that have also been published and illustrate that icons should be designed in a way that they can easily identify the objects or the concepts they represent [19]. Transparency is also considered to identify objects easily. One of the recent publications has defined transparency as a term used to convey information to the users [90]. In order to show uncertainty by making objects less murky, transparency is used in visual elements as a representation dimension [91]. There are two aspects of transparency the semantic transparency and pictorial transparency. Pictorial transparency is necessary for correct identification and semantic transparency is significant for correct interpretation. So for the icon to be designed well, both aspects pictorial transparency and unambiguous semantic transparency should be included concurrently [32].

Transparency is intertwined with sustainability because it has been used many times to portray concepts or objects more accurately by reducing uncertainty. Therefore, transparency in visual representation is a set of social, economic and environmental problems for which a minimal level of performance is needed therefore it relates to the issues for which transparency is important. The sustainability literature has reflected an emphasis on transparency that presents transparency as significant and as connected to required characteristics for instance accountability. If the standard model is absent to evaluate transparency in

sustainability communication then the genuine effort may not be perceived correctly for presenting the visual objects to be transparent. Concepts such as accessible and effective communication connects social accountability with transparency [24]. So if the transparency is to be enforced, then display icons, visual representations of objects for communication should be designed carefully because they will be incorporating possibly complex information. Transparency should also be imposed in real-time to make icons less complex and more understandable for users [90].

4.3.5 Semantic Distance

An icon enables interaction so it is considered as an essential part of mobile interfaces [8]. Graphical symbolic icon requires careful designing to increase preciseness for semantics [92]. A recent study has depicted that 'semantic distance is the closeness of the relationship between icon and function' and it is necessary for determining success of the icon usability [20], [27], [29], [35], [50], [52]. Icons that have more resemblance to their intended function tend to have greater IRR value [35]. Icons that can be interpreted correctly are easy to learn and help in performing several tasks on the mobile phone. Moreover, icons having semantically close meanings are more preferred [6], [27]. It is also accepted that semantic memory helps in improving performance [33]. Icons having close semantic distance provides easy identification, enhances recognition time and comprehension [27], [48]. The icon's effectiveness in showing its intended meaning highly depends on the mapping between the physical form of an icon and a function called "articulator distance" [8]. The semantic approach helps in keyword-based searching in which user can find intended information without typing exact search terms [27]. The use of relevant icon is an important factor that ensures the appropriate functioning of mobile apps [8]. Semantic relations among apps and their functional explanation let the hierarchical organization of apps in extensible abstraction, where the user can also zoom in and out of related functional categories [10].

Different people may have different interpretations in different ways regarding the same icon; this can be termed as 'ambiguity' of the icon. There should

be an automatic and independent learning relationship between an icon and its intended meaning [8]. There are also evidences that describes an important role of semantic distance in determining interpretability [2], [27]. It is verified that the semantic memory directly affects comprehension because recognition is enhanced with the processing of stimuli in semantically substantial way [9], [31]. The user's cognition can be affected if the semantic distance is not considered properly during designing process of an icon. In a research, author revealed that the most important socio-economic variables are gender and age, while the most significant icon characteristics is semantic distance and aesthetic appeal for user's understanding of icons [68]. Whereas user's attention is also significant in driving advertisement pool or increasing income revenue in order to sustain the mobile apps life. Due to this mobile apps are becoming popular. Moreover, mobile app designers and publishers are looking further for best strategies to sustain their app designs[93].While focusing on respondent's socio-economic profile for selecting icon characteristics independently, the researcher revealed that semantic distance is statistically important for the selection of icons that can represent the requirement globally. Designing for durability reuse, localization, efficiency, interpretability, and for easy assembly and disassembly are sustainability goals [61], [94]. Semantics distance is also considered the most important characteristic for the disassembly, upgrade, reuse, interpretability and reparability requirements [68].

4.3.6 Accuracy

Icon design is not only intended to pursue beauty but it should also be learnable by users quickly [38]. Icons on a mobile phone that can be interpreted correctly are important in learning because they help in performing a task [7]. Mobile apps give users ways to enter data in an accurate manner [94]. Moreover, for the success of an icon, it is important that the user can accurately identify the icon object and also interpret icon meaning easily [25]. Accuracy is a qualitative performance characteristic that is present in any function or component of a mobile app gives expected results precisely and with consistency [94]–[96]. In simple words, accuracy is "the relation between what is perceived and what is actually" [97]. Accuracy

includes both trueness and precision whereas inaccuracy leads to biases and imprecision. [95], [96]. According to the researcher, icon access is more accurate and much faster when icons are introduced through location-centered training [98]. Recent approaches in computer graphics allow the creation of such models that are accurate and are without inconsistencies [99]. Accuracy provides a higher degree of confidence and reliability to the decisions made for design [95]. Tasks like level of accuracy, time to learn are particularly important for interface usability and performance measures [19]. Accuracy provides independent verification of contents with the primary source of information [36].

An app icon that is successful cannot just accurately give the functional information but also makes it extraordinary among similar apps. This also depends on the designer's accuracy of using the image, content, and representation form of icon design [12]. A successful app icon design should transform the functional information of the app into symbols appropriate for communication, recognition and are understandable by the users. Therefore the designer should take accuracy as the primary goal in information transmission in app icon design [12]. According to researchers, designing is an activity that should be transformative and future-oriented. Moreover, it uses a strong stock of tools and approaches, which gives strength to the transformative capability of design to build a fair economic, social and ecological purpose. Design that integrates the principles of sustainability is able to make ecological and social changes in the future [100]. Perceptual accuracy reduces with distance when presented with a monoscopic picture. Graphic symbolic icon requires to be designed carefully in terms of semantics in order to increase accuracy [25], [91], [101]. Recognition time and accuracy are considered important for intelligent user interfaces [11], [102]. For an icon to be reliable the factors including accuracy, efficiency, and time and user experience are important. They help users to search quickly the relevant information. It is examined that communication load, environmental condition, and cognitive load affect input accuracy and efficiency. Accuracy is also important for users to correctly give input with minimum errors [27]. Greater emphasis is given on accuracy and response time for correctly identification of icons in order to make them stable for a longer time [26].

4.4 Perceived Effectiveness of App Icons

The perception regarding ease to use the app and the perceived usefulness of the app are considered important for the success of a particular app [59]. If icons are ambiguous, the user may not interpret them as the designer intended [49]. This effective icon design is crucial because through it users will be able to understand the purpose of the app in order to achieve their goals efficiently [10]. Moreover, there is a great increase in the number of users from different age groups for using new technologies and use of the internet at home. Every user on the internet might not be literate and does not belong to the computer science background so they may face difficulties while operating different icons with the same or different functionalities. The number of apps on the Google play store is also increasing rapidly which may also create ambiguity in novice users. There is a need to resolve this issue by making the design of app icons more stable. This research has identified few characteristics for the sustainable design of app icons. A controlled experiment was conducted to get the perception of the participants about the effectiveness of characteristics for app icons. A total of 15 icons were investigated with 28 participants who were divided into two groups. The low scoring shows that participants found difficulty in understanding the icon as the respective characteristics like concreteness, familiarity, meaningful and accuracy were not found in that icon. Contrarily high scoring shows a high level of characteristics of sustainable design was found in app icons.

4.5 Findings and Analysis

Data gathered from responses of participants through controlled experiment was analyzed by taking average. The detail for findings and results is described in this section.

4.5.1 Result of Young Participants

It is a common perception that young people can learn new technology easily but still there are some people who have not enough interaction with apps and other things on the internet [101]. In this controlled experiment, participants with computer science backgrounds were selected to know their perception regarding the sustainable design of app icons as they are familiar with apps and icon design. Among them, some participants were fond of playing game apps and they were also aware of few icon designs. The data compiled for young age participants is shown in the figure. Results show the mean scoring of 14 participants for six identified sustainability-associated characteristics. Results demonstrated the high response from young participants towards a clear perception of icons and their functionalities. This indicates that participants found it easy to interpret the correlation of app icon designs and the respective characteristics.

The average scoring from young participants indicates that if the icon design is familiar to the user then the user can easily perceive the functionality of the app. The average scoring of familiarity characteristics from young participants was 3.67. Therefore icon design with familiarity characteristics has a great positive impact on interpretation. Participants also preferred concreteness in icon design by ranking it with 3.63 mean values. As concreteness refers to association with real-world objects so participants found it useful for the understanding purpose of icons. In addition icons with semantically close meaning had also a positive impact on interpretation among young participants. The low values from participants show the ambiguity in their perception of icon designs.

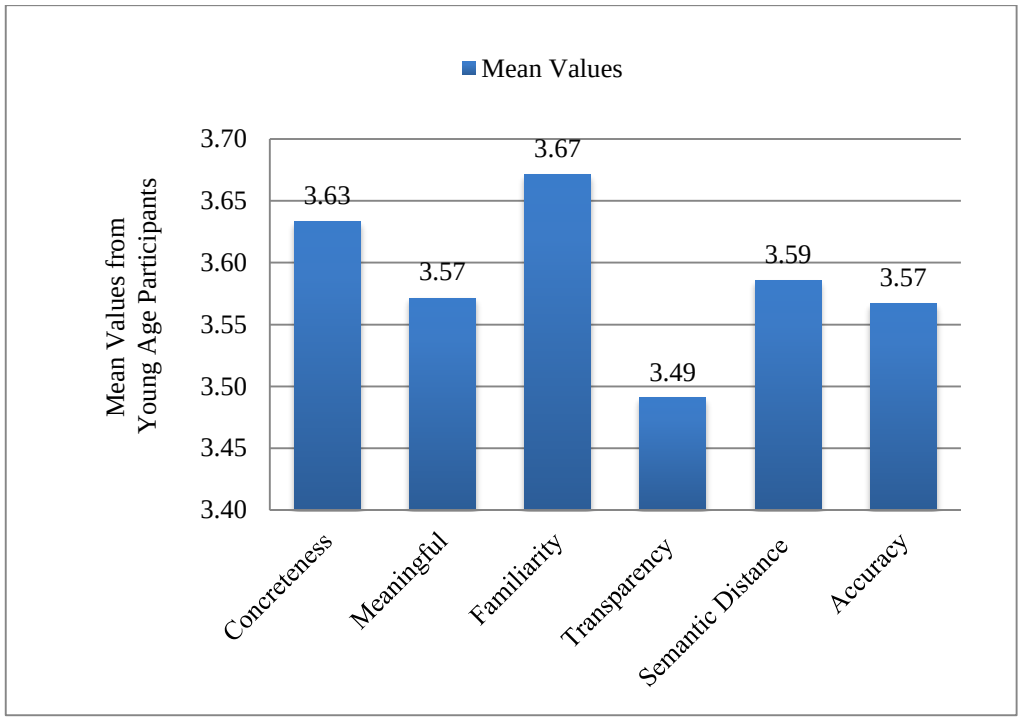


Figure 4.2: Mean values of app icons from young group participants.

4.5.2 Results of Adult Participant

Adults mostly do not use new technologies and handheld devices, due to this they have less knowledge about the icon design which makes it difficult for them to understand and interpret icons [95]. In this controlled experiment male and female adults participated to give their perception for identified characteristics of sustainable design. All adult participants were computer literate and used apps from Google Play Store.

There were a total of 14 adult participants among them there were 5 male and 9 female participants. The data compiled for adult age participants is shown in the figure. The result illustrates the average scoring of 14 participants for six characteristics. Low response from adult age participants represents that they had an unclear perception about icons and their function. Moreover, it also indicates the ambiguity among participants about icon design and its correlation with characteristics.

Adult participants found familiarity as an important characteristic for app icon design by giving it the highest aggregate of 3.56. According to them, the app icon design should be familiar so that users can understand the purpose of the app. From adult data, it is deduced that meaningfulness in icon design is also necessary. Participants had given an average of 3.36 scores to this characteristic. Icons with semantically closer distance had also a positive impact on adult participants. They had given an average score of 3.3 to this characteristic which illustrates its importance among adult users. Adult participants less preferred the accuracy and concreteness in app icon design.

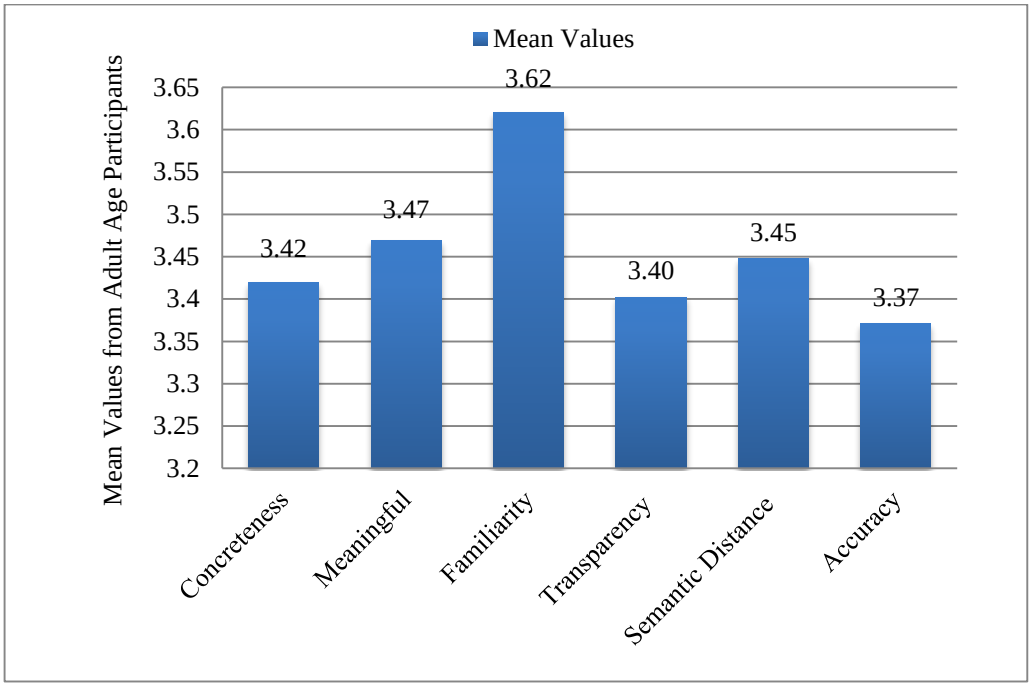


Figure 4.3: Mean values of app icons from adult group participants.

4.5.3 Comparative Results of Young and Adult Age Participants

Young people take more interest to learn new technologies and upcoming trends in the field of information technology. Contrarily, adults take less interest and more time to work with new technology. In this controlled experiment participants of both age groups selected familiarity characteristics as the crucial requirement for the sustainable design of app icons. Familiar icon design enhances the success rate

of the app in which it is used [7]. It means icons that are more familiar tends to be more successful as people of young and adult age groups can easily recognize them.

The data collected from the two age groups is shown in the figure. From the data collected through a controlled experiment, the average response rate of young participants was high than the adult participants. The average calculated from data of young participants was 3.58 and the average calculated from the responses of adult participants was 3.3 which is comparatively low than young age group participants. The result shows that adult age people, in general, are less satisfied with app icon designs. Both age group participants selected familiarity characteristics as important for icon design. For icons to be concrete the responses of both groups were different. The young age group preferred icons to be concrete. Both age group participants revealed transparency as the least important characteristic for an app icon design. Overall, young participants were more satisfied and confident in giving responses than adult age participants. From the results, it is evident that adult participants find it difficult to interpret app icons.

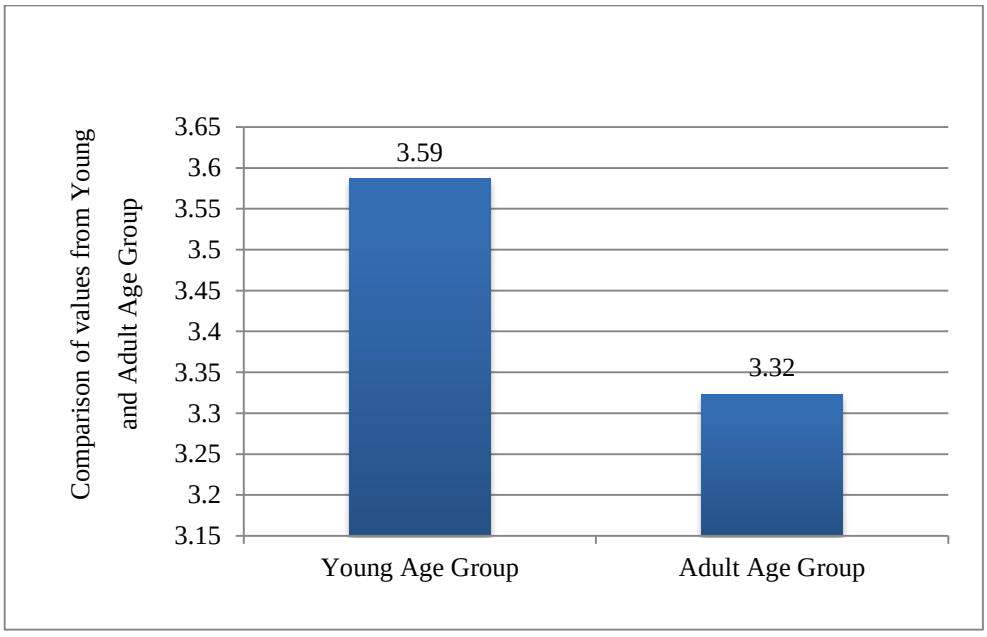


Figure 4.4: Comparative mean values from young and adult group participants.

4.5.4 Combined Scoring of App Icons by Young and Adult Age Participants

The mean of combined scoring from young and old participants for characteristics will give an overall result. Figure shows the combined mean from both age groups. Participants from both age groups preferred the familiarity characteristics more because it helps in easy recognition of apps through their icons. According to responses meaningfulness is also as important characteristic for icon design to be sustainable. The close relationship between icon design and app functionality allows user to interpret icon easily so lesser the semantic distance more will be the stability of app icon. If the semantic distance between icon design and function will be more than it will lead towards ambiguity. Therefore in order to make icon design sustainable characteristics like familiarity, meaningfulness and semantic distance must be considered.

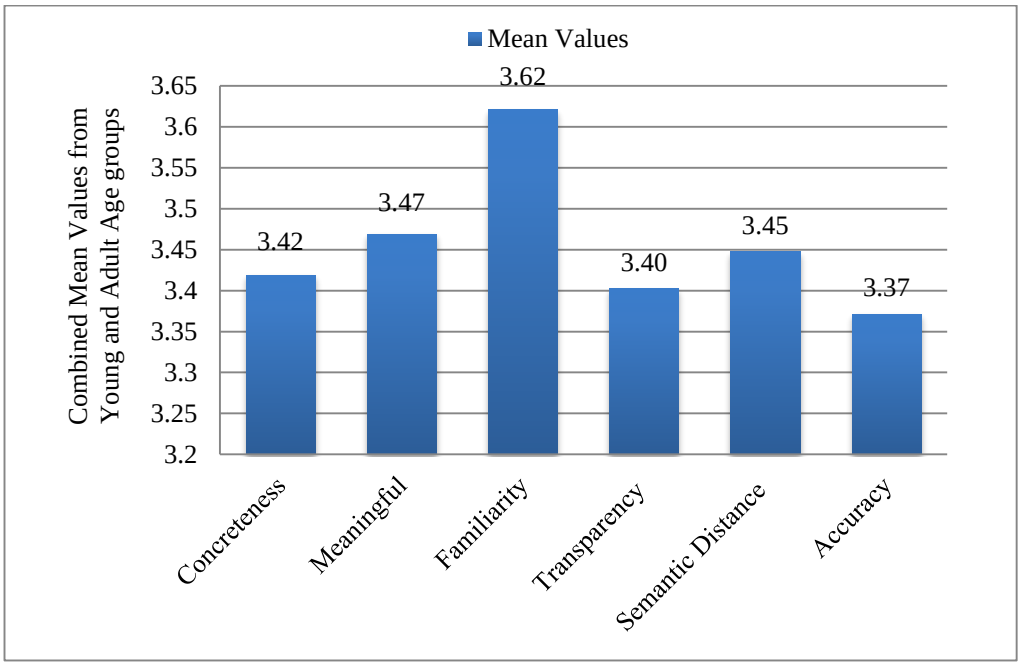


Figure 4.5: Combined Scoring of app icons.

4.5.5 Comparative Results of Male and Female Participants

There were total 18 female participants who responded for the icon design and their level of association with identified characteristics of sustainable design. Figure4.6 shows the average combine scoring of app icons by male and female participants. The average mean rate from female participants was 3.44 which show

they have interpreted icons more easily than male participants. There were total 10 male participants of all both age groups and their response rate was 3.43 which were comparatively less than female participants. In comparison of response rate between male and female participants, it was found that female participants tend to understand icon design and their correlation with sustainability related characteristics than male participants.

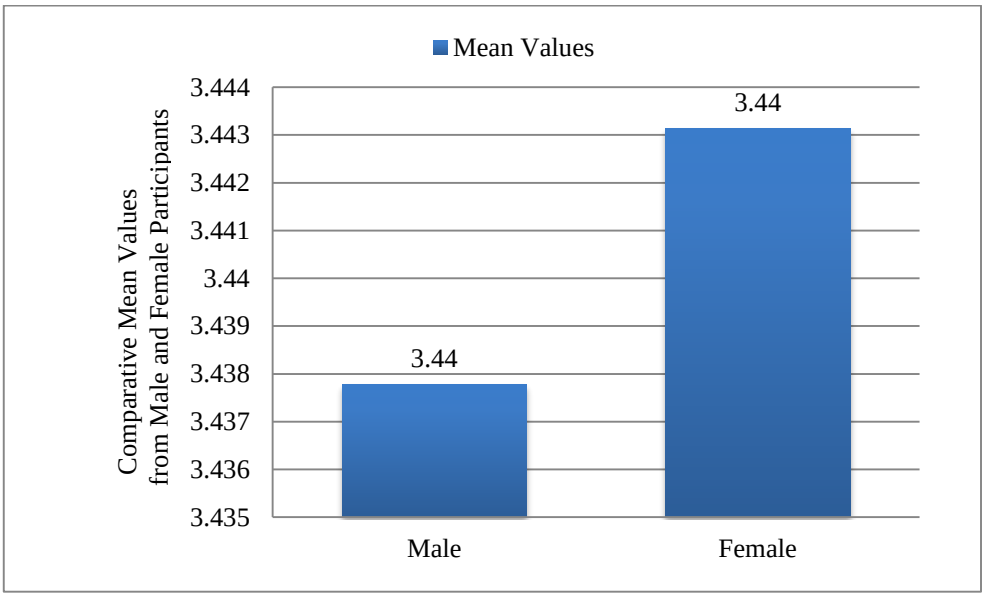


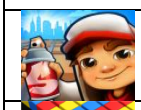
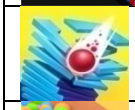
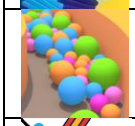
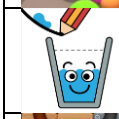
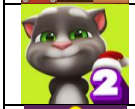
Figure 4.6: Comparative mean values.

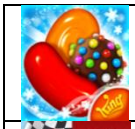
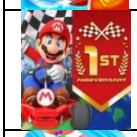
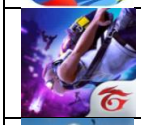
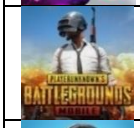
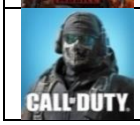
4.5.6 Composite Scoring of Participants Responses

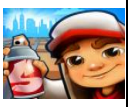
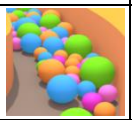
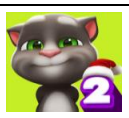
A total of 15 games app icons were investigated with 28 participants who were divided into two groups. The data regarding the composite scoring of participant's responses are mentioned in Table 4.1. This table shows the scoring of all participants for the top game icons of the Google Play Store. The low average value from participants refers to the difficulty of participants in icon concreteness, in getting meaning of app icon, familiarity, accuracy, transparency, and semantic distance. Whereas high mean values show a high degree of concreteness, meaningfulness, familiarity, transparency, accuracy, and semantic distance. High scoring shows that participants found the sustainable design characteristics of in-app icons and also the design of icon is stable. Based on calculations and analysis

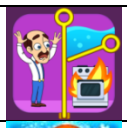
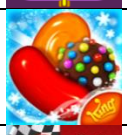
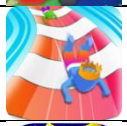
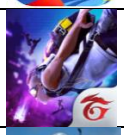
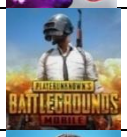
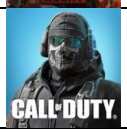
comparatively low response is achieved from the adult age group participants. Mean values from the young age group were mostly greater than 3 which indicates they have a higher understanding level for app icons. As a researcher through this controlled experiment, it is observed that participants found the characteristics for sustainable design effective but according to them, app icon design is not mapping with the characteristics. Like one participant had given a review after the experiment that "Arcade Icon 1 is familiar but it is not meaningful enough from a design perspective". Similarly, another review was "I could not relate Action icon 1 with transparency characteristics but it is concrete enough so I have selected agreed option of Likert scale". Most of the adult participants found it difficult to relate sustainable characteristics with icon design. The reason they stated was that they do not frequently play games but they use smart phone and android apps. Younger participants were enough familiar with the icons and for them, it was easy to interpret.

Table 4.1: Composite scoring of participants for app icons

Icons	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P9	P10	P11	P12	P13	P14
	2.83	1.67	4.17	3.67	2.83	4.00	3.00	1.83	4.00	4.00	4.33	4.00	5.00	2.50
	4.17	4.17	4.50	3.33	3.83	2.00	3.50	4.17	3.67	3.67	3.83	4.00	1.83	4.67
	3.83	2.00	3.83	2.67	4.67	2.00	3.33	4.33	2.33	3.00	4.00	4.00	2.00	4.67
	4.67	4.17	4.50	2.33	2.67	4.17	3.17	4.00	4.00	3.67	4.17	4.00	4.00	4.83
	4.17	1.83	4.67	4.00	3.17	1.83	1.83	4.00	4.00	3.67	4.17	4.00	4.17	4.50
	4.33	2.17	4.67	3.33	4.00	1.83	4.00	4.83	3.83	3.67	4.00	4.00	3.83	4.67
	2.83	3.00	4.50	2.67	3.50	4.33	2.67	2.67	4.17	4.00	4.00	3.83	3.83	3.67
	4.83	2.50	5.00	3.67	4.17	1.67	4.00	4.00	3.00	3.00	3.83	4.33	3.83	4.50

	4.17	1.83	5.00	3.33	2.17	1.67	2.67	4.00	2.67	2.67	4.17	4.17	4.00	3.33
	5.00	4.50	3.67	3.33	3.50	4.17	4.00	2.33	3.33	4.00	4.33	3.83	3.33	4.83
	4.33	3.33	2.33	3.33	3.33	1.83	4.00	4.00	2.67	3.67	4.50	4.00	3.83	4.83
	3.50	1.67	2.00	2.67	1.67	1.83	2.83	4.00	3.17	2.33	4.67	4.00	2.00	2.00
	2.00	2.50	3.83	3.50	4.50	4.33	2.33	4.00	2.67	2.67	3.83	4.00	3.17	4.17
	5.00	2.00	4.50	2.50	3.67	2.00	4.83	4.00	3.83	4.00	4.67	4.17	3.67	4.00
	4.00	2.64	3.56	3.11	3.14	2.64	3.44	3.72	3.06	3.22	4.36	4.03	3.33	3.86

Icons	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28
	4.00	1.50	4.50	2.67	1.67	3.67	3.83	4.00	3.17	3.83	4.00	3.17	2.00	3.00
	3.33	1.83	4.33	4.33	1.67	3.67	3.50	4.67	3.67	3.67	3.00	3.33	5.00	1.33
	2.67	4.50	4.33	4.00	5.00	3.67	3.50	4.00	4.33	3.33	3.67	3.00	4.00	1.50
	4.17	4.17	4.00	4.17	5.00	3.67	3.33	1.67	4.17	4.00	3.33	3.33	4.00	1.83
	3.00	2.00	3.83	3.33	1.67	3.50	3.67	3.00	2.83	4.00	3.33	3.17	4.00	3.17
	2.83	1.83	4.17	3.83	1.67	3.50	2.83	5.00	3.50	2.67	3.33	2.83	5.00	3.83
	4.00	2.33	4.50	3.83	3.67	4.33	2.83	5.00	4.17	3.00	4.00	3.50	2.17	2.67

	2.67	2.00	4.50	3.33	2.33	4.00	3.33	4.17	3.33	3.33	4.00	3.17	4.00	1.83
	5.00	3.33	4.50	2.67	4.33	4.00	3.33	2.83	4.00	3.33	4.00	3.50	4.33	1.00
	3.33	1.83	3.17	3.67	1.67	3.83	3.67	5.00	4.83	3.67	4.00	2.33	1.83	3.50
	3.33	2.50	3.00	2.00	5.00	3.50	3.67	3.67	4.33	3.67	4.00	2.33	4.00	3.50
	2.50	2.33	3.17	3.67	1.67	3.67	3.33	2.17	3.33	2.33	4.00	2.83	4.33	4.00
	3.33	1.50	4.00	3.67	1.67	4.17	2.67	2.33	3.67	4.00	4.00	2.33	4.17	3.33
	4.17	2.67	4.00	3.67	5.00	4.17	3.83	3.17	4.00	4.00	4.00	1.33	4.00	2.83
	3.61	2.36	3.64	3.22	3.22	3.89	3.42	3.19	4.03	3.50	4.00	2.44	3.78	3.03

4.6 Discussion

Using 5 points Likert scale this study investigated the contribution of characteristics related to the sustainable design of mobile app icons among 28 participants. Six characteristics were identified from the literature and those characteristics if considered can ensure the consistency and stability of app icons. The six characteristics identified were concreteness, meaning, transparency, semantic distance, familiarity, and accuracy. A controlled experiment was conducted to get the perception of the user for the identified characteristics. Results of the experiment show that familiarity is the most important characteristic for an app icon to be sustainable. There was variation in the mean score of adult and young participants for familiarity characteristics but overall this characteristic was rewarded the highest mean value from both groups of participants. The mean value from the young participant for this characteristic was 3.7 and 3.6 was rewarded from old participants.

Familiarity plays a vital role in cognitive performance on tasks like recognition and visual search [103]. Also from literature, it is proved that adult people find it more difficult to interact with unfamiliar icons than younger ones [7]. Among male and female participants, female participants had given more importance to familiarity as a characteristic than male participants. Empirical findings illustrated that after familiarity, meaningful app icon designs are important. An experiment was conducted to find the effect of meaningfulness on icon's concreteness the resulted mean was 3.30 which shows that meaningfulness and concreteness in icon design are correlated and both are vital for stable icon design [26]. In this experiment, adult participants had given this characteristic an average of 3.4 whereas young participants had given 3.6 average values. These average values show that adult participants considered this characteristic more valuable than young participants. Moreover, female adult participants found it more useful than other participants. According to the researcher icon's usability can be determined by the level of meaningfulness of the association between its function and display[55]. Another characteristic identified was transparency. From the results, it is revealed that young participants found it more useful with a mean value of 3.5 and adults had given the mean value of 3.3. According to the literature, transparency is very important for the correct interpretation of app icons [36]. Transparency is not only important for end-users but is also beneficial for the developers [89]. Transparency is used in visualization to remove uncertainty from objects by making them less opaque for young as well as adult users [90]. Transparency means among male participants was 3.41 and among female was 3.39 which shows male participants found it more useful for sustainable design of an app icon as compared to females. Concreteness was a more important characteristic for young participants as the mean value for concreteness from young participants was 3.6 and from adult responses, it was 3.2. Concreteness symbols are more visually clear for young and adult people as they show the objects that are already well known in the real world. The mean value for concreteness from users' responses was 3.26 which is more than the mean value of complexity thus depicting its importance for icon display [55]. Among male and female participants there was a little variation between mean values as the mean value from male participants was 3.41 and from female participants, it was 3.49. Another characteristic with which the app icons were analyzed was accuracy in the icon design. The mean value from adult participants was 3.18 and young participants

had given this characteristic the mean value of 3.57. The reason that accuracy mean is quite less from adult's responses is that adults could not found accuracy in games app icons. They need to consider this characteristic important for sustainable design instead they could not find this characteristic in presented app icons. From the literature, it is clear that accuracy in the design of app icons is vital as it provides clarity to the design and also clears the perception of the user. Accuracy is used for identifying and interpreting icon design [101]. To increase accuracy in graphics, app icons should be designed carefully from a semantic perspective [91]. The mean value for accuracy characteristic from responses of male participants was 3.39 and from female responses, it was 3.49. In some situations where symbols are not learned, their semantic distance is must be considered in icon design [33]. From the findings of this research, it is revealed that young participants found semantic distance characteristic more important by giving the mean value of 3.59 and adults had given a mean value of 3.31 to this characteristic. The close relationship between icon display and function helps the adults in understanding the purpose of the icon [27]. From the comparison of male and female mean values, females were more satisfied with these characteristics by giving the mean value of 3.50 than the male with a mean value of 3.42. From the results, it is seen that older users have problems in understanding and interpreting icons may be due to technological changes [26]. Icons should be easily understandable by younger and older users [25]. Older adults face difficulties while interacting with a graphical interface that is not easily interpretable [7], [25]. Results illustrated that icon concreteness, familiarity, semantic distance, and meaningfulness are all interrelated [7], [26]. Moreover, empirical findings illustrated that to get the behavioral intention of users to use the graphic interface, perceived usefulness is the major predictor and if the interface is easy to use then it will greatly influence the perceived capability of users [58].

4.7 Summary

This chapter reported the findings and results compiled from Narrative Literature Review. In the solution the effectiveness of characteristics related to sustainable design is examined from user perception. Moreover contribution of each characteristic for app icon is analyzed. All results from user responses are explained briefly. The evaluation of proposed solution is reported in next chapter.

CHAPTER 5

CONCLUSION

5.1 Overview

This chapter documents the conclusion, limitations, future work and contribution of research. The conclusion is drawn to evaluate whether the two research questions are answered. Limitations of this research are highlighted. Moreover, future recommendations are also presented.

5.2 Conclusion

People can afford smart phones but some people do not prefer to use smart phones just because they experience difficulties in operating them. They found it difficult to operate an interface that is not familiar to them or they cannot understand the meaning and purpose behind the interface [53]. For the smart phone interface, ease of use plays an important role in making it useful for the user. Therefore, mobile apps are designed with a simple and easy interface for the user by giving them priority features [9], [37], [88]. Appropriate icons are important in this regard which can depict the correct functionality of the app to invoke the intended meaning of the icon in the user's consciousness. The icon should display the intended meaning in the user's mind conveyed by the designer in order to make the desired meaning the same in minds of both. During the development of an app icon, the purpose should be to

produce functional icons that can be recognizable and interpretable by the user for improving performance [6].

As the proportion of adults is growing in developing countries but they experience a slight decline in few abilities like cognitive and perceptual abilities [25]. There are many icons on Google Play Store which should be redesigned as young people can understand them but they are not understandable by adult people. Icons have many visual details like dots and lines which makes it difficult for adults to understand. Secondly, the icon is a pictorial representation of an object that represents a concept so there should be a strong link between the icon and its correct interpretation [25]. Because the specifics of the design for the app icon have a great impact on the ease of use [88]. Studies also revealed that app quality is highly influenced by app icons [4]. On the other hand, instability in app icon design leads to a decrease in users' intention to download the specific app whereas sustainable design leads to stability of app icon [9]. So user's perception greatly affects the app icon's success from a cognitive perspective [5]. In order to make icon design stable and effective, this study has identified few characteristics related to the sustainable design of mobile app icons.

Using NLR (Narrative literature review) characteristics related to sustainable design of app icons were identified from the literature in this study. The identified characteristics from the literature were concreteness, meaning, familiarity, transparency, semantic distance, and accuracy. According to the literature, these characteristics might be helpful in making app icons more stable and effective for the users. In order to examine the effectiveness of these characteristics for sustainable design, a controlled experiment was arranged. Top games app icons of the recent year from the top five categories from the Google Play Store were selected for the controlled experiment. For the conduction of the controlled experiment, a questionnaire was prepared. The questionnaire contained three sections. The first section was about the demographic information of participants. The second section of the questionnaire mapped out the smart phone usage and interest of participants in mobile games. The third section was about getting the perception of participants for characteristics and their level of influence on app icons. A five-point Likert scale was

used to get the responses of participants. An online survey tool was used to get user views about identified characteristics and their effectiveness. A total of 28 participants were selected to conduct the experiment. All participants were from a computer science background and were familiar with smart phone apps. Participants were from two age groups adult and young. Among them, there were a total of 10 male and 18 female participants. The age criteria for the participants of young and adult were different. Most of the participants were a student of bachelor and master level.

Data gathered through a controlled experiment was analyzed by taking the mean of values. The results of responses from the young age group were high which depicted that they were more satisfied with the app icons design than the adult age participants. Comparison among male and female participants illustrated that female participant had a higher level of understanding of app icons than males. From the results, the contribution of each characteristic for the sustainable design of app icons is also analyzed. Among characteristics related to sustainable design, familiarity characteristics got the highest score from both groups and were found necessary for the app icon to be stable. There were different mean values for other characteristics which were assigned according to their effectiveness among participants. Familiarity, concreteness, and semantics distance have a strong influence on understanding the meaning of an icon [104]. The conclusion and findings of this study relate to the literature that some app icons on Google Play Store need to be designed again especially for adult users so that they can correctly perceive the functions behind icon design [25]. This research has presented the reason that why the design of app icons is important from a sustainability perspective. Moreover, the industry must need to focus on the sustainable design of app icons and considering the specific characteristics while designing an app icon. Sustainable design of mobile app icons will be helpful for adults to understand the purpose of app icons. By making app icons more effective, mobile devices and app stores are likely to be more usable.

From the results, it is concluded that many icons need to be redesigned for adults in order to make them able to use the icons. Also, this research has presented

characteristics that ensure good icon design and reveals interface usability which is particularly important for mobile devices used by this population.

5.3 Contributions and Significance of the Study

This section presents various unique contributions of this research. The contributions of this study are more towards the mobile app icon design. The contributions are presented in terms of academic and practical perspectives.

5.4 Academic and Practical Contribution

The first contribution was done by identifying the list of characteristics for sustainable design of mobile app icons from literature. As a result, six characteristics were identified that were related to sustainable design through Narrative literature review. From the literature it is examined that these characteristics can make app icon design more effective and useful by ensuring stability, consistency and appropriateness. By identifying these characteristics this research has filled the gap of lack of existing studies that report the usability of mobile interfaces.

The second contribution of this study was the validation and investigation of the most influential characteristics related to sustainable design by conducting a controlled experiment. Participants were involved in controlled experiment to get their perception for identified characteristics in order to know the influence of each characteristic on app icon effectiveness.

5.5 Limitations of the Research

In this section, study limitations are reported. Many research papers were reviewed to get appropriate data for the identification of characteristics. But still, it

might happen that some of the significant studies in the field of are missed regarding characteristics of sustainable design.

For getting user perception regarding effectiveness of these characteristics controlled experiment was performed in which participants were involved. A total number of participants were 28 in which there were 18 female participants and 10 male participants. It was tried to have an equal number of participants with respect to gender but after many reminders it could not be managed to arrange more female participants. Although all of the participants were smart phone users but it would be better to get response of participants of equal figure with respect to gender.

5.6 Future Work

Icons are important part of app store however the effectiveness of app icons depends on the characteristics which makes their design sustainable[16]. This study has focused on the characteristics for sustainable design of mobile app icons. Further research can explore more characteristics that can relate to sustainable design. Controlled experiment is conducted to check the effectiveness of identified characteristics on games app icons of Google play store. Such metrics should be evaluated for other app stores like iOS app store and Black Berry App stores. This research is empirical based and had taken user views through questionnaire. Another qualitative research can interview users to have their perception for the effectiveness of sustainable design characteristics. So by designing and performing evaluation of sustainable design characteristics, new research pathways could be generated[16].

5.7 Summary

This chapter reported the conclusion of the whole thesis. Results are analyzed and it is found that the identified characteristics from NLR are useful for the sustainable design of app icons. In order to make app icons stable and effective these characteristics must be considered in design phase.

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