

Design and Experience of Mobile Applications

Subjects: Mathematics

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With the tremendous growth in mobile phones, mobile application development is an important emerging arena. Moreover, various applications fail to serve the purpose of getting the attention of the intended users, which is determined by their User Interface (UI) and User Experience (UX). As a result, developers often find it challenging to meet the users' expectations. Various aspects of design and the experience of mobile applications using UX/UI are explored.

Keywords: mobile application development ; front-end ; user interface ; user experience ; human computer interaction

1. Introduction

Mobile phones are the most easily accessible hand-held devices used by the current generation. In 2021, global mobile phone shipment volume is predicted to reach 1.65 billion units, 6.3% higher than the previous year, while smartphone shipment volume is expected to increase 7.8% to 1.8 billion units in 2022. As a result, the Compound Annual Growth Rate (CAGR) for mobile phones and smartphones is anticipated to be 2.34% and 3.62%, respectively, during 2020–2025. According to [1], the global mobile application market was valued at USD 154.05 billion in 2019 and is expected to grow at a CAGR of 11.5% between 2020 and 2027. According to CAGR, the UI industry will grow by 16 percent during 2017–2027, reaching USD 50 billion. **Figure 1** shows the technological revolution in the smartphone industry by estimating the number of smartphone users worldwide and the global market size of mobile applications [2].

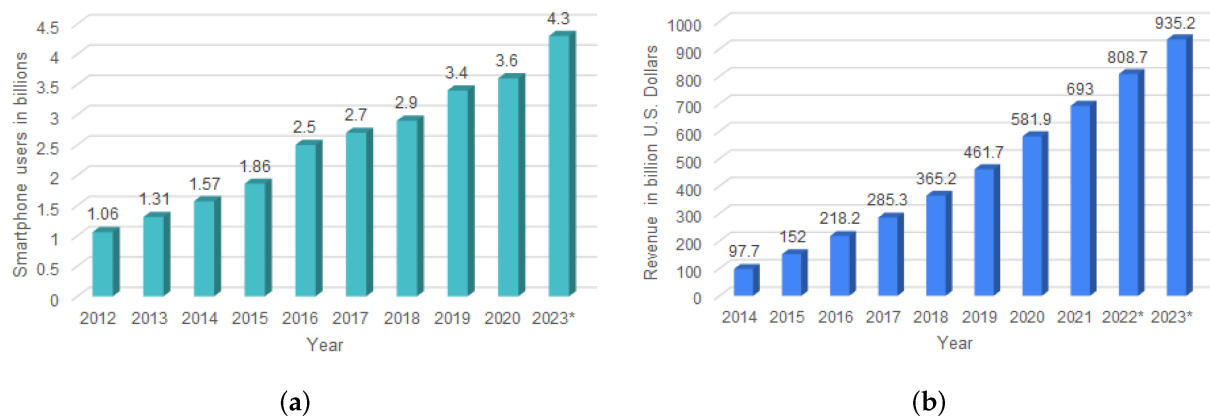


Figure 1. (a) available count of smartphone users worldwide [2]; and (b) global mobile application market size [1], where * represents the predicted value for 2022 and 2023.

The growing world of mobile phones and their applications at our fingertips requires better mobile interfaces that help to efficiently connect the physical world with the virtual world. The front-end of mobile applications has improved a lot over the years. Mobile phones and their increasing usage have transformed the conventional design into the user-oriented design of mobile applications. With the rise of chatbots, the Internet of Things (IoT)-based mobile applications, recommendation systems, and many more require a strong yet effective UI and UX to let users engage with the system. The seamless connectivity of the user with the system has to be the utmost priority of any mobile developer. A lot of research and analysis has been performed by the scientific community in this area. However, only a few have provided a concrete UI/UX guide to the mobile application developer.

2. State of the Art

This section presents the state-of-the-art approaches taken to evaluate the existing works done in this arena. **Table 1** briefly explains those approaches. The existing literature provides a lot of detail about the UI and the UX. The papers

considered in the tabular comparison have been carefully selected keeping in mind the myriad of knowledge bases that they touch upon. Carefully designed literature is widely available and can help intermediate developers with a certain knowledge of design. However, for a beginner non-designer developer, it becomes challenging to develop a mobile application from square one without getting confused. A one-stop solution is required for those developers. Some of the literature, as discussed in **Table 1**, is beautifully written, discussing various knowledge domains for UI/UX designing. However, concise basic knowledge essential for a beginner to understand seems to be missing. Research papers focus on a multitude of aspects of UI/UX designing. However, it was observed that the mentioned seven points seem to have quite a high preference when it comes to the users. The authors wanted an inclusion of both visual and mental acceptability of mobile applications that made sense in today's world. There are so many papers, books, and conceptual studies available that dive deep into the subject, but for a beginner, it often becomes daunting to understand a tonne of concepts at once. This entry is an aid for developers searching for literature for basic knowledge of UI/UX.

Table 1. Comparative survey of state-of-the-art.

Ref.	Year	Objective	Pros	Cons	1	2	3	4	5	6	7
Researchers' proposed paper	2022	To study the effect of social media content on engagement behaviour of users	Analysis of the necessary context-based wants and preferences of users is discussed in the paper	Gives a general overview of UI/UX for mobile applications	•	•	•	•	•	•	•
[3]	2022	To propose an end-to-end evaluation framework for mobile application	Provides an end-to-end evaluation framework "perses" which was integrated into a DevOps to automate its execution	Heterogeneity of the scenario is missing	•	•	•	•	•	•	○
[4]	2022	To study the accessibility barriers in mobile apps	Proposes guidelines to prevent these issues.	The study specifically meant to mobile application development and not for UI/UX.	○	•	•	•	•	•	•
[5]	2022	To evaluate the dynamism of the digital content and tools used in mobile application development	Provides accessible projects	unpleasant interactions	○	•	•	•	•	•	○
[6]	2021	Investigated the effect of sequence of UI elements and type of forms	Effect of sequence of UI elements and type of forms	A very primitive design	•	•	•	•	•	○	○
[7]	2021	To conduct research to evaluate and explore the impact of the need for uniqueness, self-identification, and perceived performance risk on mobile application usage behaviour, and the mediating function of attitude toward mobile application design	Contains literature and information about different consumer perceptions and their impact on usage behaviour, giving helpful insights to application developers	Limited context, sample size and variables under consideration	○	○	•	•	○	○	○
[8]	2021	Using design thinking to produce a design that meets the needs of each user to achieve Goal 4 of the Sustainable Development Goals (SDGs)	Created a prototype of the UI/UX design for "Ideln," a web-based learning tool that strives to give equal access to quality education for all students	Limited context, region of interest and scope.	•	•	○	•	•	•	○

Ref.	Year	Objective	Pros	Cons	1	2	3	4	5	6	7
[9]	2021	To study the effect of social media content on engagement behaviour of users	Analyses how content and context affect the link between each type of material and user engagement and thereby proposed research hypotheses	Research restricted to two social media platforms, which may be commonly used on desktops	○	●	●	○	○	●	○
[10]	2019	To produce a form of experience in making a usability chemical application, using concepts of the UX	Gives useful insights for mobile application development using UX analysis	Restricted to chemical applications	○	○	○	●	○	○	○
[11]	2019	To offer a proposition for an agrarian information gathering framework that spotlights on UI and client experience (UI and UX) from all stakeholders	Extendable to other agricultural applications	Context limited to agriculture	●	●	○	●	●	○	●
[12]	2018	To propose a UI/UX tool and methodology (domain and device-independent model-based adaptive UI methodology)	Provides personalized services for various applications to improve the UX to meet the right level of user satisfaction	A rule-authoring tool for managing complex adaptation rules, as well as an unresolved UI presentation issue	●	●	●	●	●	○	●
[13]	2018	Prepare UI/UX and agile approaches for the design and deployment of a job tracking and assessment system.	Took Agile methodology and KPIs into consideration	Job domain specific research	●	●	●	●	●	○	○
[14]	2017	UI/UX research and design for a mobile e-commerce application prototype on Gramedia	Analyses the user's preferences and create a mobile application prototype	Restricted to e-commerce	●	●	●	●	○	○	●
[15]	2017	User interface generation by sketching	Obtaining a collection of sample graphical user interfaces (GUI) from existing open source programmes that are similar to or identical to an original designer's draft for an interface	Code search engines to be improved	●	○	●	●	●	○	○
[16]	2017	Design and construct a user-friendly mobile application that provides information and appeals to users	Competitive analysis, card sorting, personas, site mapping, wireframes, user testing, branding, and focus groups are all factors in the creation of mobile applications	Focus on UI missing	○	●	●	●	●	○	●
[17]	2016	An organised investigation of the user experience of mobile apps	Assist application developers and designers in concentrating on specific user interface and user experience challenges	Focus on UI missing	○	●	●	○	○	●	●

● : Area covered in the surveys; ○ : Area not been covered. 1. visualisation/graphics; 2. context, 3. user behaviour/emotions/control; 4. usability; 5. adaptability/flexibility; 6. language; 7. responses/notifications/feedback.

According to [3], a heuristic evaluation is a usability inspection method which identifies the usability problems in UI design. It examines the interface and judges its compliance with recognized usability principles, i.e., heuristics. A major objective

of heuristic evaluation is to identify various design-related problems in the UI. Authors have proposed an end-to-end evaluation framework "perses" for mobile applications which were integrated into a DevOps to automate its execution, but it fails to provide a heterogeneous scenario. Moreover, [4] evaluated the dynamism of the digital content and tools used in mobile application development. In the same way, authors in [5][6][7] investigated the effect of the sequence of UI elements and type of forms, the impact of the need for uniqueness, self-identification, and perceived performance risk on mobile application usage behaviour. Authors in [8], proposed a prototype of the UI/UX design for "IdeIn," a web-based learning tool that strives to give equal access to quality education for all students, but it had limited context, interest, and scope. According to [9], the authors analysed the effect of social media content on the engagement behaviour of the user. Authors in [10] provide useful insights for mobile application development using UX analysis. Authors in [11][12], proposed a UI/UX tool and used a domain- and device-independent model-based adaptive UI methodology, which provides personalized services for various applications to improve the UX to meet the right level of user satisfaction. This is a rule-authoring tool for managing complex adaptation rules, as well as an unresolved UI presentation issue.

3. Taxonomy: Design and Experience of Mobile Applications

In this section, researchers discuss a solution taxonomy: the design and experience of mobile applications. **Figure 2** depicts the detailed layout of the same.

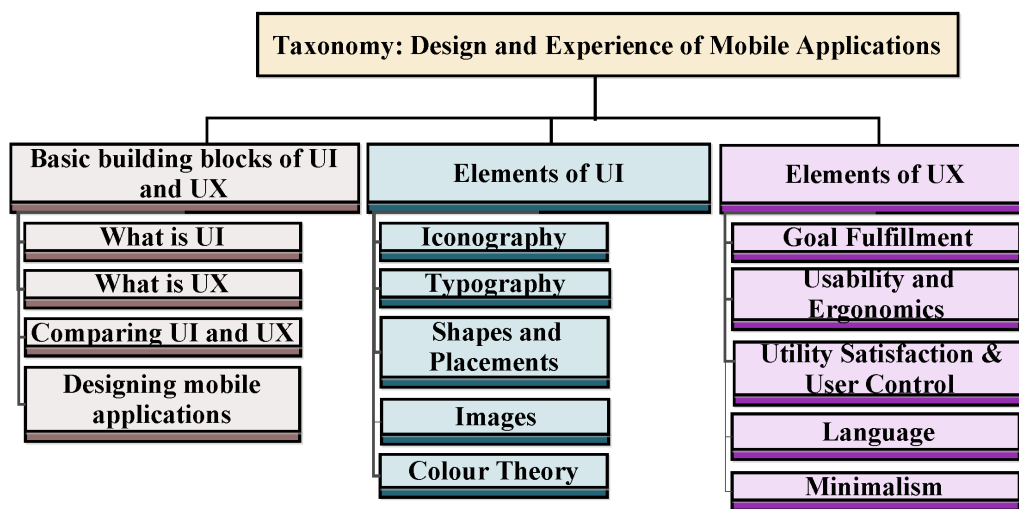


Figure 2. Taxonomy: design and experience of mobile applications.

3.1. Basic Building Blocks of the UI and UX

In this section, researchers discuss the basic building blocks of the UI and UX to give insights about the role of the UI and UX in mobile applications, a comparison between the UI and UX, and the role of the UI/UX for designing mobile applications in detail.

3.1.1. Role of the UI in Mobile Application

The User Interface is the way a mobile application appears to its users, along with its visual design. The primary controller for determining the appropriateness of a user interface is the target audience and the context of the mobile application. Now, the question is, what really is meant by context? In a unique wireless environment characterized by mobility, flexibility, and personalization, [18] defines context as any real-time information or entity (can be a user, a location, a time, an action, or an item) that influences the interaction between mobile device users and mobile applications, as well as potentially changing the preferred behaviour of those applications. To find the application's context, researchers may think: "What is the main user base"? The best interface is the one which is very close in terms of the relationship to its context. User interface design becomes an effective one only when the communication of the user with the system is effortless; that is, the system improves rather than obstructs the workflow and encourages the active involvement of its users [19]. The user interface also refers to the subjective psychological sensations that users generate while using products or services, such as their beliefs, feelings, desires, attitudes, physiology and psychology, behaviour, and so on, and it spans the front, middle, and late stages of service or product usage [20].

The aesthetics of any mobile application are determined by the various frameworks used. Currently, the most often used frameworks are dart, React.js, JavaScript, Cordova, Java, Swift functionalities in a flutter, Kotlin, React Native, Ionic, and Xamarin environment. A pleasant UI enhances the user experience, with the utmost priority given to effective interfaces,

yet keeping the design simple ^[21]. For any non-designer programmer, application development is a tough one. A non-designer does not have common designing knowledge but has moderate coding knowledge. So, it is necessary for the front-end developer to have an understanding of basic UI fundamental elements. Several constraints ^[21] must be addressed when designing the UI for any mobile application.

- Technology-related (device-related) constraints: Supporting Operating System (OS) version, limited processing power, screen size, and resolution.
- User-related constraints: Limited attention spans during mobility, changing locations and context.

According to the current trends, Adobe XD, Adobe Illustrator, Figma, and Sketch are the most used software platforms for designing the interactive interfaces of application prototypes. Various UI kits are readily available on numerous platforms to offer drag and drop facilities that help when a user interface is to be prepared in a short time while maintaining the UI/UX standards. This is the most effortless way for beginner front-end developers to design the mobile application all by themselves. The key interface combinations are haptic and have audio/visual experience. The main goal is Following the eye, i.e., preventing the users' eyes from diverting and letting their minds stay focused. NetBeans, Visual Studio, and Eclipse are some of the modern development environments that support UI generation ^[15]. In addition, some technologies allow users to utilize sketches as input to create stunning user interfaces such as JavaSketchIt, SILK, MobiDev, and REMAUI. Moreover, UI integration is an equally important component to be considered for mobile application development ^[22].

3.1.2. Role of the UX in Mobile Application

The term 'User Experience' is not restricted to any aspect but has many meanings attached to it ^[23], ranging from traditional usability to beauty, cognitive-driven, experiential, and effective technology use. In simple terms, the UX is all about how the mobile applications perform their functionality. It wants to know how "effect" plays a part in the technology used as an antecedent, a consequence, and a mediator. Furthermore, it places a strong emphasis on happy feelings. One of the key motives of a cognitive-driven perspective on Human-Computer Interaction (HCI) is to prevent any frustration or dissatisfaction amongst the users ^[24]. The intention of HCI design is to make the interaction between the system and the user feel more natural. It will make the user's experience more enjoyable in the long term. Giving a positive experience to the users enables them to seamlessly interact with the mobile interface without any hindrances ^[25]. Experience, function, and form have a triangular relationship where they are all connected. Aesthetics and functionality must understand the psychological and behavioural patterns of the target user(s), which plays a major role in the UX/UI ^[7].

To create an efficient UX-based mobile application, appropriate planning needs to be followed by utilizing the essential benefits of the UI features ^[26]. A fun experience categorization such as PLEX during the creation and assessment of interactive mobile applications may aid in concentrating on the joyful parts of the UX, which in turn may help in defining goals for experience-driven personal product design ^[27].

Additionally, context-aware mobile applications are used to enhance the UX by evolving the user input, i.e., it perceives the user input and enables a suitable interaction mechanism between user and mobile application. It acts as a major driving force for a better user experience, contributing to user satisfaction. Moreover, it aids in developing smarter mobile devices by allowing them to identify and comprehend their usage environment to respond proactively and intelligently ^[18].

It is critical for app developers and businesses to perform a thorough comparative study of current applications with the existing work ^{[16][28][29]}. Developing a Graphical User Interface (GUI) of any mobile application involves UI design, wireframing, prototyping, and interactive design skills ^[30]. The UI design process gives insights as to what factors the developer can keep in mind to build a visually appealing design for mobile applications. The primary aim of the proposed survey is to provide necessary insights and suggestions for the UI/UX to the mobile application and UI/UX developers, thereby providing efficient designs and interactive modules for the mobile applications. It also provides information regarding the technologies that can assist the UI/UX development. An ineffective interface design not only causes user misery but also reduces user awareness and willingness to utilize it ^[20]. Hence, an efficient and likable user interface is needed to enhance the experience of a mobile application. The user experience is a result of the users' internal condition, the attributes of the planned system (complexity, purpose, usability, functionality), and the context (or environment) in which the interaction occurs (organizational/social setting, activity relevance, usage readiness) ^[24].

3.2. Elements of the UI

Fabricating a UI is a design-centric process where mobile users' content type and display modalities often vary during mobile operations. Users have control over multiple content display characteristics based on various factors, for instance, place, time, situation, interest level, and cost [21]. As per the survey results, **Figure 3** represents the major factors affecting mobile application designs.

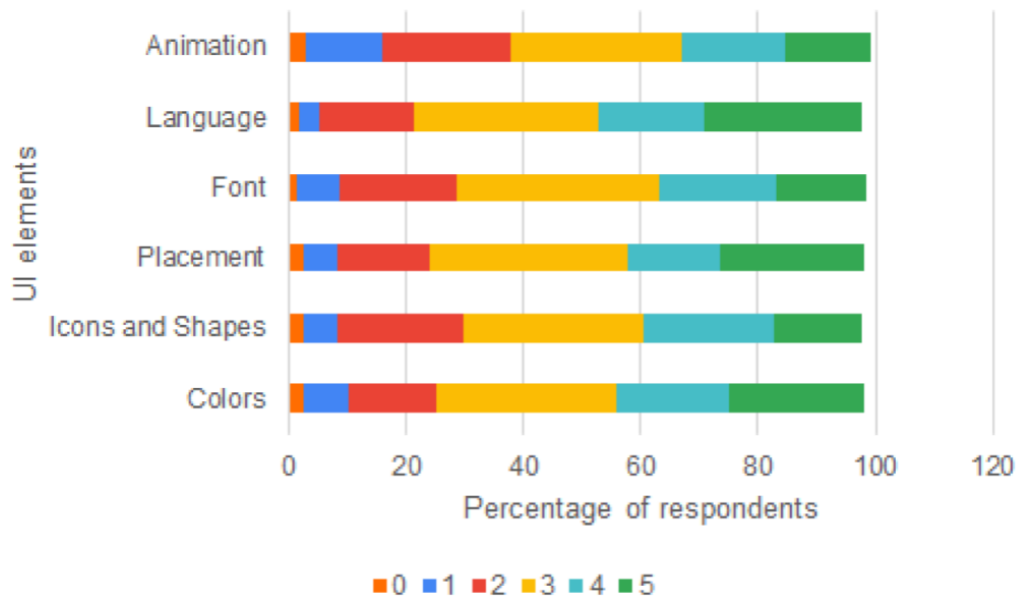


Figure 3. UI elements perception.

3.2.1. Iconography

Iconography is all about the icons used in mobile applications which can be logos or any visual images used to display a clickable/non-clickable button, which create a huge impact on users. They are responsible for the mobile application's first impression on the users. The mobile application logo is a subtle indication of what it does. Creating icons that represent genuine perceptions of events or activities makes the system more interesting, engaging and involving local users [19]. Therefore, it is important to transform information into relevant keywords and design icons in a way that is easily understandable by the mobile users [19]. Some icons have more than one meaning, which may be synonymous with the actual meaning [19]. Hence, ensuring the correct interpretation of the icons' use is non-trivial. Age and gender also have a notable role in the process of designing icons for mobile devices [31].

3.2.2. Typography

Font style, size, and decorations of any mobile application play a subtle role in shaping the mental perception of the users. Choosing the appropriate font is determined by the context and the target audience. According to the mood and age of the target audience, the correct typeface and most readable font size have to be chosen. For example, an application for connecting with employers around the globe cannot have stylish or elegant font styles. It needs to be quite formal and straightforward.

3.2.3. Shapes and Placements

The various shapes, sizes, and placement on the screen create a memorable visual impact on the human mind. Unfortunately, many mobile platforms have small-sized displays with low-resolution. The amount of display size needed for a UI design depends on the size of the actual interactors, the arrangement of the window interactors, and the distribution of interactors between multiple windows [32]. According to all these factors, the appropriate choice of lines, objects, padding, margins, spacing, and so on are to be decided.

The various shapes, sizes, and placement on the screen create a soothing visual impact on the human mind. According to Gestalt Theory [33], images include positive and negative space in a figure-ground relationship. The element of duality while maintaining a clean and clutter-free design is equally important. Hence, maintaining lesser chaos and providing more apparent choices is preferred. The way the users hold their mobile phones and what part of the screen their eyes get drawn to also play a considerable role. Fingers directly interacting with the screen, that is, haptics, create the necessity for motion and require a fluid relationship between the various states of any screen. If the same element appears on more than one screen, then to maintain consistency, the same scale and the same place of the element must be ensured. In

addition, buttons with similar functionality but different states should be visibly similar enough so that the user does not have difficulty identifying the similarity between them. A few points that need to be addressed while selecting icons, shapes, colour, spacing, and other elements of a UI/UX design.

- Categorize the users and mobile phones based on their preferences and needs.
- Keep the clickable area large enough for comfortable use.
- Do not let the user lose focus due to too many focal points. Maintain center of attraction by preferably keeping it in the most viewed region of the screen (major center).
- Ensure the layout, placements, and sizing do not vary too much when switched between landscape and portrait mode of mobile phone.
- Show what is necessary. Items of less priority can be hidden and made accessible only when called for.

3.2.4. Images

The type of images, their colour scheme, and the way they are used in an application determine the main focus of any mobile application. The dominant discourse about the growth of the mobile Internet and app-centered media uses the symbol of freedom, empowerment, and autonomy for app users and producers ^[34]. A picture says much more than words and in less time. Furthermore, users might not go through the entire written content of mobile applications, but they surely go through most images in the application. The relevance and appropriate usage of images (stationary/moving) positively impact users' minds, capturing their attention and interaction with the mobile application interface. Selecting the suitable size images, along with the number of images to be fitted on a screen of a mobile device, needs to be efficiently analysed and discussed between mobile application and UI/UX developers.

3.3. Elements of the UX

Fabricating the UX is a user-centric process. The real underlying motivations for the use of technology are insight, pleasure, and social exchange. Emotions and impressions are the real effects of the UI/UX in the development of an interactive mobile application ^[29]. The UX is highly beneficial in verifying commands, keywords, and icons. The user and the community's language, cognition, and social interpretations should be considered while building useful mobile apps ^[19]. **Figure 4** represents the overall idea of UX design ^[24].

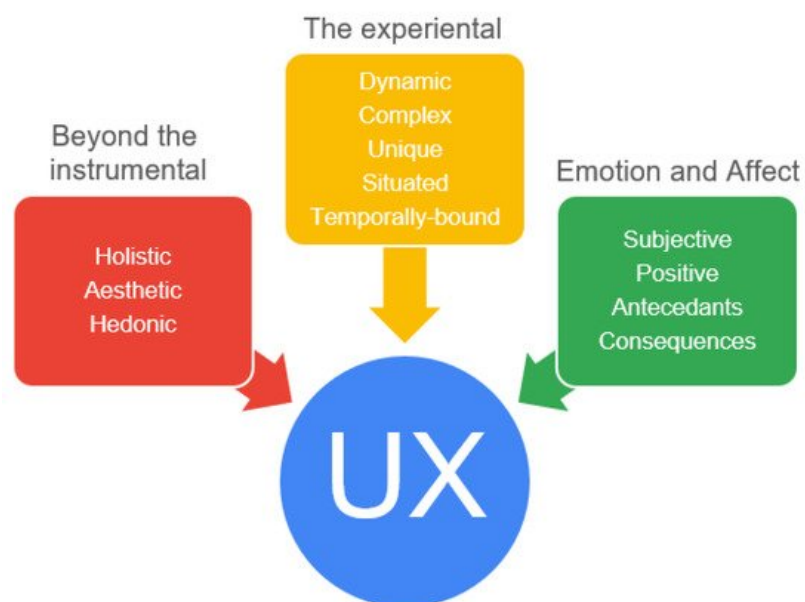


Figure 4. Facets of the UX.

Golden rule is that a good user experience is a result of satisfying human needs for independence, competence, excitement (self-oriented), relatedness, and popularity (others-oriented) through interaction with a product or service (hedonic quality: stimulation, identification, and evocation). Users' mental psychology and thinking are equally important factors in determining the appropriate UX for mobile applications. In addition, design thinking is integral to designing a UI for an optimum UX. It comprises the stages empathize, define, ideate, prototype, and test ^[8].

The user experience assessment, known as the User Experience Questionnaire (UEQ) ^[35], can be used to evaluate the UX. The QUIS surveys are used to measure the users' overall satisfaction with the suggested approach ^[12]. The UEQ enables a quick evaluation of the UX by asking users to share their feelings, impressions, and attitudes after using a product. It assesses both traditional usability and user experience. It has been used by various companies to evaluate their products and has been believed to be a good measure of evaluation ^[12].

3.3.1. Goal Fulfillment

The UX originated from the do-goals and be-goals mentioned in Ref. ^[36]. The achievement of be-goals can influence a mobile developer to create more interactive mobile design interfaces. However, lack of usability may impede the achievement of active be-goals; thus, to achieve effective be-goals, one must adapt independence, knowledge, connection to others, inspiration, and popularity through the use of technology ^[25]. All objectives of be-goals must be completed while keeping the target audience in mind. From a design perspective, a highly interactive product should support the accomplishment of do-goals; nevertheless, without a consistent proposition of hedonic quality (the product's perceived potential to service the achievement of be-goals), a product stays dull. All this revolves around improvising the comfort and ease of the end user. Hence, their emotions and psychological state play a crucial role in fabricating the UX of any mobile application. Therefore, it is essential to consider and understand the importance of an effective system for a broad spectrum of UI/UX design processes, such as human decision making or subjective well-being ^{[24][37]}.

3.3.2. Usability and Ergonomics

The different features of the International Organization for Standardization (ISO), such as stability, learnability, understandability, and operability, denote how user friendly a mobile application is. Furthermore, the Nielson model in ^[38] takes the ISO model one step ahead by incorporating more features, such as taking into account efficiency, satisfaction, learnability, memorability, and errors, to improvise the UI/UX design patterns. Then, People At the Centre of Mobile Application Development (PACMAD) is proposed by ^[39] that not only includes the attributes of both the ISO and the Neilson model but also takes into account the cognitive load, hence providing a holistic approach for usability testing. Furthermore, obtaining useful feedback and insights from unacquainted users as early as possible helps the developer to improve the usability of the mobile application quickly. The simplest and most effective approach to enhance usability is to conduct interface evaluations that include three essential components, such as users, their activities, feedback, and user evaluation ^[20]. Nielsen's usability heuristic is one of the most widely used usability evaluation methods ^[40]. Heuristic evaluation is a usability inspection method that identifies the usability problems in a UI design. It examines the interface and evaluates its compliance with recognized usability principles, i.e., heuristics. A major objective of heuristic evaluation is to identify various design-related problems in a UI. Usability testing techniques are a basic system with 10 scales that provide a glimpse of the overall aim of usability ^[41]. The System Usability Scale (SUS), which employs a Likert scale questionnaire, is used to assess the system's grade usability ^{[8][14]}.

According to a study mentioned in ^[42], pleasant emotions and memories are measured by behavioural intentions and appear to be a good predictor of product design performance. As the popularity of mobile application design grew, high usability became connected with positive feelings associated with the UX, and its benefits on behavioural intentions increased. However, the impact of the UX has remained consistent throughout time ^[42]. All the user-centered research and evaluation methodologies aim to supplement current product quality models with non-instrumental features to build a more accurate and integrated HCI application ^[24].

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