USER ADOPTION OF INTERNET OF THINGS:
DETERMINING FACTORS THAT DIRECTLY AFFECT INTERNET OF THINGS SERVICE ADOPTION AND APPLYING THEM TO AN EXISTING SYSTEM

by

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Bachelor of Computer Science Engineering, Anna University, 2009

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Abstract:

Internet of Things (IoT) is defined as a convergence of multiple technologies that interconnect physical and virtual objects over a network to improve our quality of life. These services deal with numerous interactions between devices, each having its own functionality and user flows. A large emphasis has always been placed on the technical aspects of IoT but very little importance has been given to researching factors that could have a significant effect on a user's intention to use and adopt these services. Technology Acceptance Model (TAM) and Value-based Adoption Model (VAM) are two of the most widely used models to discovering the potential user's intention to use a new technology. This paper examines these models to provide insight into determining factors that directly affect IoT service adoption by users and applies it to developing a coherent and engaging user interface for an existing IoT system.

Acknowledgements

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Dedication

To my parents, who have given me their unflinching support and for having complete faith in me. Without them, none of this would have been possible.

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Chapter 1

Introduction

1.1 Thesis Statement

Internet of things (IoT) can be plainly described as the connection of devices to the internet. More specifically, it can be defined as the convergence of multiple technologies that interconnect physical and virtual objects over a network and deal with numerous interactions between devices, each having their own functionality and user flows. Kevin Ashton (2018), who coined the term in 1999, describes it as "using the internet to empower devices to sense the world for themselves". What he envisioned at that time raised more questions than answers about IoT services due to major gaps in technology. Today, most, if not all of those gaps have been filled and according to Gartner (2018), there will be over 14.2 billion devices connected to the internet by the end of 2019 and that number is expected to reach 25 billion by 2021. Despite this growth, 60 percent of IoT initiatives are stalled at the proof of concept stage and a third of the projects completed were considered as a failure (Cisco, 2017). Cisco's research also found that three out of the four main reasons for an IoT project to succeed were related to human factors, people and relationships. This is a strong indication that focusing primarily on technology and not giving importance to the user's needs lead to a lack of success for IoT services. Therefore, it is of extreme importance for IoT service providers to have a better understanding of what leads a user to use and adopt their services to ensure that the products they create are successful.

This paper is an exploration of factors affecting the adoption of IoT services. It also presents an overview of why these factors play an important role in the design of the user interface for an IoT system and the potential benefits it affords a user to continually use the service. In addition, this paper also investigates if using the fundamental principles of User Experience (UX) design is the best way to apply these theoretical factors to actual design and development of the product. UX design in this context is defined as the practice of designing user experiences surrounding a technology that are primarily focused on human needs. Furthermore, these factors are applied in the design and development of the front-end of an existing IoT device to confirm the value of the identified factors in successful user adoption. These objectives are divided into the following three parts.

1. *Investigate User Adoption Models to Identify Factors:* The two models used in this study to predict the components that lead to successful user adoption are Technology Acceptance Model (TAM) and Value Based Adoption Model (VAM). TAM and VAM are two of the most widely used models in information technology to define elements that improve user adoption because of their simplicity and clearness. A literature review of existing scientific papers were conducted to get a better understanding of the two models and to validate that the factors described by these models positively

impact the user's intention to adopt new technology. The review also highlights the shortcomings of the models and the ideal way to overcome them.

2. *Investigate if UX Design Principles can be used for Implementing Adoption Factors:* An additional literature review was conducted to understand the principles of UX design and to investigate if using it would be the most efficient way to apply the theoretical factors identified for user adoption. This formative research will also be used to provide insight on how to develop a cohesive strategy to implement the identified components to the actual design and development of a front end system for an existing IoT service.

3. *Implement the Adoption Factors on an Existing IoT Service:* The existing IoT service to which these user adoption factors will be applied to is the LUCID Respite chair. Lucid Inc. is a Toronto based tech startup driving innovation at the crossroads of mental health, machine learning, music and AI. They are developing a multi-sensory wellness solution, the Respite chair, that utilises auditory, visual and tactile stimuli to compliment the music experience to lower anxiety, increase focus and unlock human potential. This curated wellness experience delivers rejuvenation in as little as 4 minutes (LUCID, 2019). Respite chairs use sound, light and vibration to relax users and encourage a state of calm or focus depending on the user's choice. The music is personalised to each individual and their unique wellness needs by using biometrics and machine learning. Working in collaboration with Lucid, this project aims to develop a front end system that not only works seamlessly with the IoT chair but also implements all the components that are identified to positively impact user adoption.

1.2 Contributions

By 2021, Gartner (2018) forecasts that 25 billion connected things will be in use. This will have a huge impact on digital innovations and technologies. Companies that embrace IoT technology and aim to provide IoT services that positively influence quality of life for users will have the opportunity to be the leaders in their businesses. A large emphasis has always been placed on the technical aspects of IoT but very little importance has been given to researching factors that could have a significant effect on a user's intention to use and adopt these services. Overlooking the human element is one of the major reasons for the failure of a number of IoT products (Cisco, 2017). This research investigates the factors that causes people to accept a new technology and provides recommendations on how to integrate them into the design and development of IoT products for successful user adoption. It also highlights some of the key facets that IoT service providers need to address in order to maximise user retention.

1.3 Roadmap

Chapter 2 provides a background on Internet of Things, its basic architecture and why focusing on human-centric design could potentially elevate the value of these services for the customer. Chapter 3 consists of the literature review conducted to identify factors that increase user adoption and to understand if the principles of user experience design can be used to integrate these factors in actual design and development of an IoT product or service. Chapter 4 details the way in which the identified adoption factors were incorporated in the front-end design of the Lucid Respite chair, an existing IoT product. Chapter 5 describes the limitations of the study and future work.

Chapter 2

Background

2.1 Internet of Things

The Internet has become an integral part of modern society. It is constantly evolving and growing in importance day by day as multiple new technologies rely heavily on it for functionality. At its inception, the internet started as the *Internet of Computers*, a global network through which computers were connected and services such as the World Wide Web were build on. This has evolved into the *Internet of People* in the last few years as more and more people connected to the internet started creating and consuming content making way for the creation of the Social Web (Coetzee & Eksteen, 2011). Due to rapid advancements in technology, the boundaries of the internet are constantly expanding. Broadband internet connectivity has become exceedingly cheap and there are multiple tech companies working toward providing high-speed internet connectivity to all corners of the earth (Perry, 2018). At the same time, devices are being fitted with sensors that enable them to connect to the internet giving them the capabilities to sense, compute and act. Additionally, everyday objects are being incorporated with tags that could be sensed by these smart devices. The combination of these factors that connect everyday objects over a network through sensors on smart devices has lead us into the era of the *Internet of Things* (Coetzee & Eksteen, 2011).

2.2 IoT Architecture

IoT devices consists of three layers architecturally: the device layer, the connection layer and the application layer (Bandyopadhyay, Balamuralidhar & Pal, 2013). The *device layer* consists of the devices which form the basic infrastructure of IoT. These devices typically contain technologies like Radio Frequency Identification (RFID) tags, Near Field Communication (NFC) chips and Bluetooth connectivity. The main function of the device layer is to collect data from things and pass them over the connection layer. The *connection layer* includes the core network through which the devices are connected to the internet. This layer allows communication with other devices and is responsible for data being passed back and forth between the device layer and the application layer. The *application layer* consists of objects that are sensor equipped. The main function of this layer is to link the gap between the users and the applications. Of the three layers, the application layer is the layer that is the closest to the end user as it is the layer through which the user interacts with the IoT device (Chin-Lung & Chuan-Chuan Lin, 2018).

2.3 User Interfaces for IoT

User interfaces and user interactions form an integral part of how a software or a system is being used. IoT is rapidly becoming a part of our everyday lives and yet, not enough research has been done to determine the best practices to be used in the development of the front-end for these applications. As with previous technologies like the web and mobile, user interfaces for IoT will play an important role in user acceptance and adoption (Brambilla, Umuhoza & Acerbis, 2017). Developing a coherent and cohesive user interface for IoT applications become challenging as an IoT ecosystem typically consists of two or more devices with each of them having their own functionality and user flows. Therefore, the user interface not only has to be consistent but also intuitive as IoT services are tightly connected to the physical design of each device. If there is no consistency then moving from one device to another would result in a very jarring experience for the user. As the ultimate goal of any technology is to provide value to the user, not giving enough importance to the design of the user interface will result in the user not placing enough value on the IoT service directly impacting user adoption rates (Brambilla et al., 2017).

2.4 The need for Human-Centered Design

The potential of IoT to transform our lives is vast. But according to an Accenture (2014) study, 87% of consumers don't actually know what the Internet of Things is. The study also noted that the top barrier to mass adoption of this technology is a lack of both awareness and value perception among consumers. To surpass these hurdles, focus needs to be placed on human-centered design (HCD). Human-centered design is an approach to interactive systems development that aims to make systems usable and useful by focusing on the users (International Organization for Standardization [ISO], 2019). In the late 90's and early 2000's, the advancements in website design propelled the use and adoption of the World Wide Web by users. Similarly, IoT service providers need to design their systems in a way that connects the end user with the value their product can provide. A human-centered approach leads to the creation of products that resonate with the end users and ensures that the design of the technology meets the needs and capabilities of the people for whom they are intended. Understanding what causes users to accept or reject new technology could be vital to the success of IoT services.

Chapter 3

Literature Review

2.1 Technology Acceptance Model (TAM)

The technology acceptance model (TAM) is a predictive and robust model that was proposed by Davis (1989) to explain a user's intention to use a new technology. It is a widely used model in information technology because of its simplicity and understandability. It is based on the Theory of Reasoned Action (TRA) which is a psychological theory that seeks to explain user behaviour (Hill, Fishbein & Ajzen, 1977). According to Davis (1989), the measures commonly used to access usage behaviour for a technology is predominantly subjective and that little attention has been paid to the quality of said measures and how well they correlate to successful user adoption. He adds that basing important business decisions on such unvalidated measures could lead to misinformation about the acceptability of a system for users which directly contributes to the failure of a product or service. Therefore, he proposed the TAM model as a method for defining better and reliable measures for predicting and explaining use. The model focuses on two theoretical variables, *perceived usefulness* and *perceived ease of use*, as being the fundamental determinants of system use. These two predictors directly influence a users behavioural intention. Behavioural intention, according to TRA, is closely linked to the actual behaviour of a user.

Perceived Usefulness

Davis (1989) states that perceived usefulness is the "degree to which a person believes that using a system would enhance his or her job performance". This stems from the definition of the word useful - "capable of being used advantageously". Within the context of IoT products and services, a system that rates high in perceived usefulness for users will translate to higher chances of system reuse and adoption because high usefulness directly correlates to the system enhancing their quality of life. As IoT services focus on improving performance and efficiency at work or home, they can be considered as task-oriented technologies and perceived usefulness is associated with increasing the extrinsic motivation of a user to continually use the system. Fogg (1988) noted the difference between how users perceive extrinsic and intrinsic motivation. He says that extrinsic motivation comes from doing something to achieve something that improves aspects of everyday life while intrinsic motivations stem from a need for personal growth or enjoyment. Additionally, Chin-Lung and Chuan-Chuan Lin (2018) report that if a system is deemed useful by the users, they are more likely to establish trust and be more engaged. Consequently, the users will also be more willing to forgive shortcomings of the system. King and He (2006) conducted a statistical meta analysis of TAM using 88 published studies and identified that the influence of perceived usefulness on behavioural intention to use a system was profound and without it the probability of users rejecting a technology was very high.

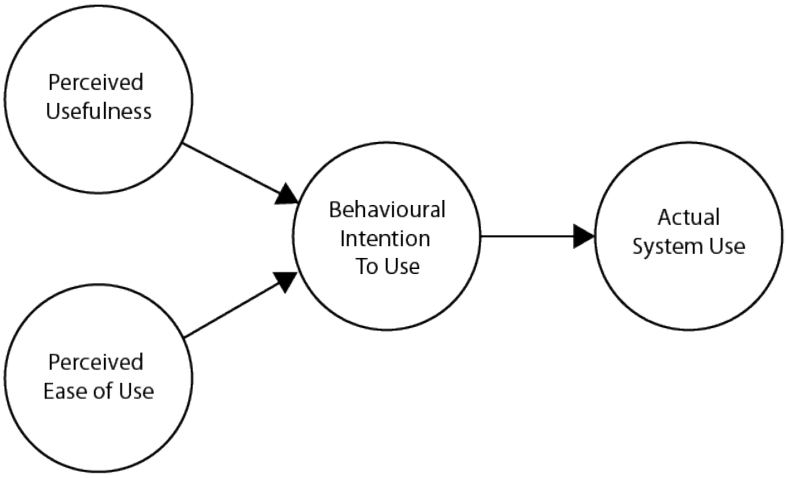

Figure 2.1: Technology Acceptance Model (Davis, 1989)

Perceived Ease of Use

In contrast, Davis (1989) defines perceived ease of use as "the degree to which a person believes that using a particular system would be free from effort". This stems from the definition of the word ease - "freedom from great difficulty or effort". Everything else being equal, TAM claims that a product or system that is perceived to be easy to use in comparison to another is more likely to be accepted by the users. According to King and He (2006), in the context of internet applications the correlation between behaviour intention to use a system and ease of use was extremely high. This can be attributed to ease of use providing intrinsic motivation for the users to continually use a system since intrinsic motivations are derived from enjoyment and personal growth (Fogg, 1988). Davis also noted that even if users believed that a system was highly useful, if it wasn't easy to use then users would reject the technology. This indicates that the performance benefits of system usage does not outweigh the effort a user has to put in for using the system. Therefore, along with perceived usefulness, Davis theorised that perceived ease of use also has a big influence on user adoption.

The importance of these two theoretical factors - perceived usefulness and perceived ease of use as determinants of user adoption has been established by various lines of research. TAM has been applied to a wide range of systems in a variety of settings. These include internet banking, online shopping, mobile advertising, adoption of e-health and e-learning to name a few (Gao & Bai, 2014). Although, TAM was originally intended to be used to predict user adoption in IT usage in the workplace, this shows that TAM can be successfully applied to different systems in various settings to predict user behaviour. Therefore, TAM can also be used as a foundation for understanding user adoption for IoT systems.

2.2 Value Based Adoption Model (VAM)

The value based adoption (VAM) model was proposed by Kim, Chan and Gupta (2007) to explain user adoption from the perspective of value maximisation. They report that although the technology acceptance model (TAM) is very well known and widely used, it was primarily developed for explaining the user adoption of traditional technologies. They state that the adopters of traditional technologies usually tend to be people who use these technologies in a work place or in an organisational setting. But in contrast, users of newer technology tend to use it in the personal setting as well as in the work place. They are consumers and not just technology users and Kim et al. (2007) argued that this requires a user adoption model that comes from a value maximisation perspective. Since IoT services are used in the workplace as well as in personal settings, the value based adoption model could be to determining the factors that lead to user adoption. VAM considers that the perception of value as the main indicator of a users intention to adopt a technology and that all other factors are mediated though the perceived value of the product or service. It proposes that *benefits* (usefulness and enjoyment) and *sacrifice* (technicality and perceived fee) as being the main determinants of user's perceived value and intention to use a new technology and offers a clear understanding of the factors that influence value perception and how that directly leads to user adoption. This model is based on cognitive evaluation theory (Deci, 1971) that classifies motivations into extrinsic and intrinsic as these factors have been found to influence value perception and behavioural intention.

Perceived Benefits

The benefit component of VAM consists of two factors - *usefulness* and *enjoyment*. This is because a customers evaluation of a product or service always includes both cognitive and affective elements. The hedonic factor of the product is as important as the utilitarian factor for the user (Kim et al., 2007). Therefore, usefulness and enjoyment are proposed to be part of the benefit components of perceived value in VAM. Usefulness here is defined as the total value a user gets from using a new technology. As with TAM, usefulness is closely associated with extrinsic motivation as it mainly focuses on task accomplishment. It reflects that the user would engage with a technology to receive external rewards, i.e., the product's usefulness is determined by how well it serves the user's needs. Therefore, higher the user perceives the usefulness of a product, higher they perceive the total value of the product.

Similarly, enjoyment also has a positive impact on the perceived value of a product. Users who experience joy and enjoyment from using a technology are more likely to adopt the technology and will use it more than others. Because this aspect is not connected to any external rewards and is purely based on the emotional value the user places on the technology, enjoyment is closely associated with intrinsic motivation to use a technology. Past research has shown that enjoyment and fun both have a significant effect on a user's intention to adopt a new technology. This differs from ease of use as it isn't about the effort required to use a system but is more about the 'fun' the user receives while engaging with the system.

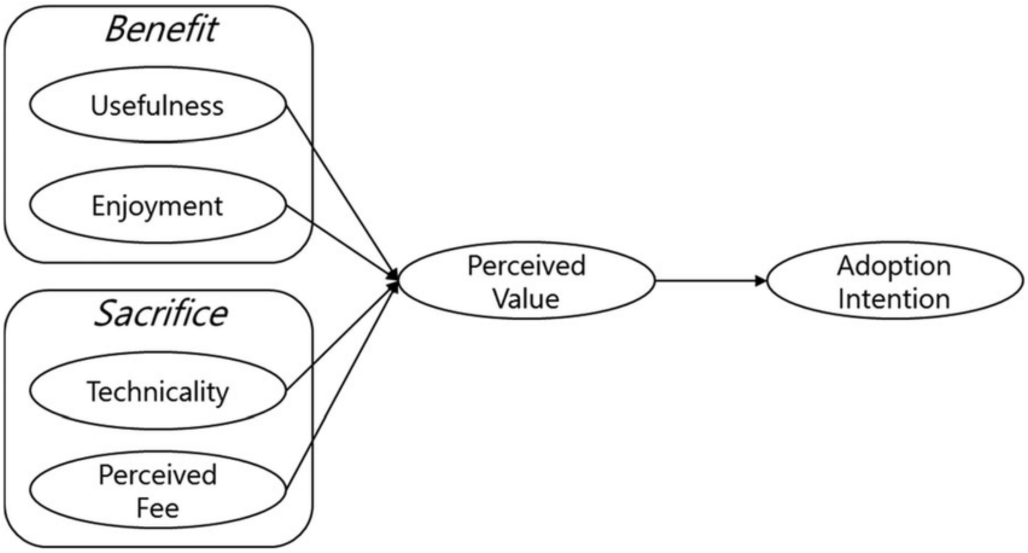

Figure 2.2: Value Based Adoption Model (Kim, Chan & Gupta, 2007)

Perceived Sacrifices

The sacrifice component of VAM consists of two factors - *technicality* and *perceived fee*. This is because Kim et al. (2007) suggest that the perceived value of a product or service depends on both monetary and non monetary factors. Monetary factors include the actual price of the product and the non monetary factors include how much time, effort and other spending the user put in to the product or service. In this context this has been defined as technicality of using the product and draws a close parallel to perceived ease of use from the technology acceptance model. If the users perceive the product to be technically easy to use, is overall user-friendly and does not require physical, mental or learning effort, it has a positive impact on the perceived value of the product. Additionally, the system must also be error-free, secure and consistently available. If this is not the case then technicality has a negative impact on the perceived value and affects user adoption rates. This is an important factor for IoT systems in particular because there are a number of devices that work together to provide a service to the user. Even if one aspect of the service does not behave the way it is expected to, it has a negative impact on the whole experience for the user.

According to the adoption level theory, users generally do not posses perfect information about prices but have internal reference prices and make comparison to those references (Grewal, Monroe & Krishnan, 1998). This comparison is defined here as the customers perception of fee. Kim et al. (2007) report that studies in marketing show that the monetary price that the users perceive negatively impacts the perceived value they place on a product or service. They state that higher the fee perception, lower the value perception which leads to low user adoption.

Kim et al. (2007) therefore define perceived value as a comparison of benefits and sacrifices and that it is positively related to adoption intention as there is strong empirical support for the relationship between perceived value and behavioural intention to use a new technology.

2.3 User Experience (UX) Design

Human computer interaction (HCI) has been one of the earliest proponents of user-oriented perspective to computing (Gaines, 1984). Research and practice of HCI has lead to valuable insights into how to potentially design usable and useful systems. As the context in which people use technology has drastically evolved over the last few years, UX design, which is an integral part of HCI, has risen as a new paradigm for designing and evaluating new technologies (MacDonald, 2012). Norman (2013) defined UX design as “the practice of designing products, processes, services, events and environments with a focus placed on the quality and enjoyment of the total experience.” He states that UX design takes a holistic view of the entire user-system interaction by going beyond the tasks users perform with technology and focuses on the emotional outcomes from using that technology. According to Hassenzahl and Tractinsky (2006) UX design is “designing for pleasure rather than for absence of pain”. As designing a system that is useful, easy to use and provides enjoyment is critical to user adoption, using the principles of UX design could be an efficient way to apply the theoretical factors identified in the previous sections to the actual design and development of an IoT system.

Challenges

One of the biggest challenge facing user experience design is that emotions are highly subjective and research in this area to understand if using UX design leads to a positive increase in user adoption is still in early stages. In the context of IoT systems it becomes even more difficult as predicting use contexts beforehand and designing to accommodate them becomes very challenging as the technology involved can get very complex. To overcome these challenges the design and development of the system has to be an iterative process that involves user testing to assess and improve the product to ensure that all aspects of user experience and usability are covered.

Human-Centered Design

Human-centered design (HCD) is an approach that puts human needs, capabilities and behaviour first, then designs to accommodate those needs, capabilities and ways of behaving (Norman, 2013). It is a cornerstone of UX design. An important aspect of HCD is “emotional design” that each correspond to different levels of emotional processing the user does while using a product. The visceral level corresponds to appearances and aesthetics and is closely connected to what appeal the product has for the user. The behavioural level is a critical aspect that is associated with expectation. It is determined by how well a product functions and if it does what it’s supposed to do. The reflective level is closely associated with emotion and how users look back on the products they use. According to Norman (2013), the reflective level is the most important aspect of emotional design as it is the factor that drives the user to continue using a product and recommend the product to others. Although he says that the memories and emotions that the user feels while using the technology is more dominant than the immediate experience or period of use, he states that all three levels are critical to determining if a user likes or dislikes a product or service. To successfully incorporate emotional design into the actual design of a product, the following fundamental principles of UX design need to be addressed.

Fundamental Principles of UX Design

1. *Discoverability:* When a user interacts with a product they need to understand how to use it. If the user can easily figure out what actions are possible and where and how to perform them, the discoverability of the system is considered to be high. This directly correlates to the user getting an enjoyable experience from using the system. Discoverability results from the use of the following five concepts.

- *Affordances*: Norman (2013) coined the term affordance to describe the relationship between an object and the person interacting with it. It is determined by the properties of an object and the capability of the person to understand and use the object as it's meant to be used. As it describes a relationship, affordances are variable depending on the abilities of the user.
- *Signifiers*: Signifiers are signs or symbols that communicate what actions are possible and where these actions should take place within the system. They are indicators that communicate a behaviour to the user.
- *Constraints*: Constraints are powerful clues that tells the user what actions can and cannot be performed on the device. According to Norman (2013), using good constraints within a system allows users to determine the proper course of action while using a new technology.
- *Mapping*: Norman (2013) reports that mapping is way to lead the user to immediate understanding of what an object can do by designing it in such a way the user recognises how to use it. Controls and displays on a device should use natural mapping to make the set of possible actions on them visible to the user.
- *Feedback*: Communicating the results of an action within a system to the user is an important aspect of discoverability. It must be immediate and informative but it shouldn't be distracting or anxiety-provoking for the user. Norman (2013) says that too much feedback will result in the user ignoring all of them and that good feedback should not interfere with usage of the system.

2. *Understandability*: To explain the importance of understandability in providing a good user experience, Norman (2013) uses *conceptual models*. He states that this is the most important aspect compared to the rest as it provides true understanding of what the product or service is. Simply put it is an explanation of how something works. Usually the conceptual model derives from the system or product being used. This can be done by providing understanding of how things will behave within the system and also giving the user information about what to do when things don't go as planned. All of the discoverability factors discussed above have a positive impact on the user understanding the conceptual model. If the device does not provide a good conceptual model to the user then they end up operating it blindly without knowing what to expect or what to do if things go wrong. This leads to a negative user experience.

Chapter 4

Implementation

4.1 The LUCID Respite Chair

The existing IoT product to which the identified adoption factors are going to be applied to is the Lucid Respite chair. The Respite chair was created as a collaboration between Lucid Inc., a tech startup in Toronto, and Steelcase, a United States based furniture company. It utilises auditory, visual and tactile stimuli to compliment the music experience to lower anxiety, increase focus and unlock human potential. This curated wellness experience delivers rejuvenation in as little as 4 minutes (LUCID, 2019). The chairs use sound, light and vibration to relax users and encourage a state of calm or focus depending on the user's choice. The music is personalised to each individual and their unique wellness needs by using biometrics and machine learning. In collaboration with Lucid, this project aims to develop a front-end system that effectively and efficiently work with their IoT ecosystem to enhance the user experience and result in user adoption.

As IoT devices consists of three layers architecturally (Bandyopadhyay, Balamuralidhar & Pal, 2013), the Respite chair's architecture can also be divided into the three layers namely the device layer, the connection layer and the application layer. The device layer for the chair consists of the chair itself that is embedded with tactile vibration, light panels which provide the visual stimuli and sensors which collect biometric data throughout the experience. The connection layer consists of the core internet network through which data is being passed back and forth from the device layer and the application layer. The application layer consists of an iPad that contains a native application through which the user can control various aspects of the entire experience. This application also contains all the music which provides the audio stimuli.

Figure 4.1: Lucid Respite chair prototypes (Lucid, 2019)

4.2 The Application Layer

The application layer is the layer that is the closest to the end user as it is the layer through which the user interacts with the IoT ecosystem (Chin-Lung & Chuan-Chuan Lin, 2018). Since the application layer for the Respite chair is the iPad application, designing for a coherent and engaging user experience which is easy to use while providing an enjoyable experience for the user will greatly contribute to the successful adoption of the chair by the users. Ease of use and enjoyment are two factors that have a positive influence on behavioural intention of a user to adopt a system as previously examined in the value based adoption model. These two factors can be incorporated into the design and development of the app by using the fundamental principles of human-centered design discussed in chapter 3. Ultimately the goal of the app is to provide the user with a simple and efficient platform that allows them to immerse themselves in the auditory and visual experience. Additionally, the entire platform has to be consistent and should be designed in a way which prevents any problems and errors from occurring throughout the experience. These factors will also contribute to a positive increase in the perceived value the user places on the system.

Since the front-end application is being developed for an iPad running on iOS mobile operating system, Xcode will be used to create the software. Xcode is an integrated development environment containing a suite of software development tools for creating iPhone and iPad apps (Apple Inc, 2019). Xcode runs on Swift programming language therefore working with Swift within the Xcode interface is an integral part of successfully developing this software. The graphic elements for the application was designed using Adobe Illustrator and Adobe XD was used to create and understand the user flow for the app.

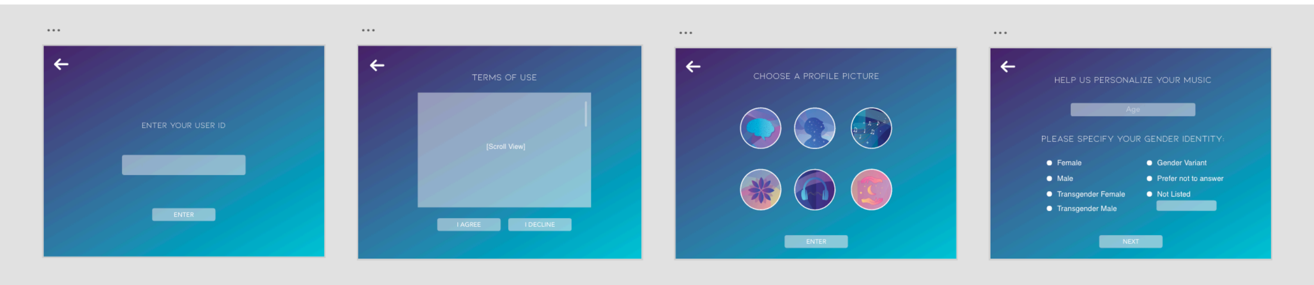

Figure 4.2: App design for the Lucid Respite chair iOS application

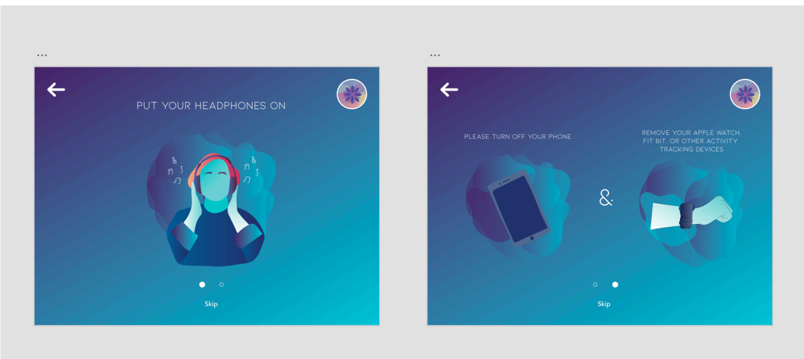

Figure 4.3: Initial on-boarding screens

4.3 Applying UX Principles

Discoverability: The application interface was designed to make sure that the user gets a good understanding of what the experience entails and what aspects of the experience are in their control. This was done by providing the user with a prompt and simple on-boarding process. Not only does the on-boarding process make sure that the users are aware of all the various aspects of the wellness chair, it also lets them know what parts of the experience are in their control. As one of the major components of the experience is to have the user use the sensors correctly, on-boarding them on how to use it at the right moment was important. The on-boarding process also includes a simple message about how the users can control the intensity of the tactile and visual stimuli provided by the chair.

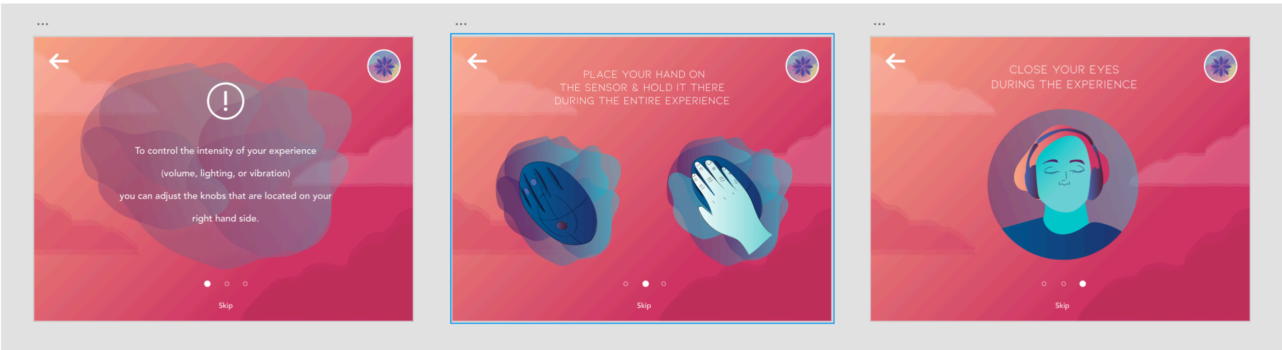

Figure 4.4: Onboarding process

Affordances and Signifiers: By keeping the design of the application consistent and making sure that it conforms to platform conventions, users will never have to wonder what a particular action will do. Throughout the design, signifiers have been incorporated in a way that at no point during the experience the user is unsure about what actions to perform. This affords the users to use the application as it's meant to be used and prevents confusion. This can be seen in the design of the home screen shown below. Instructions for using the application is also easily visible to the user and the entire system is designed so that it promotes recognition rather than recall.

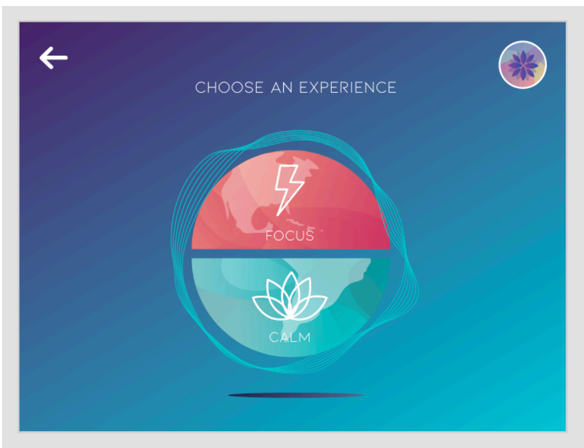

Figure 4.5: Homescreen

Constraints: The app was carefully designed such that it prevents a problem from occurring when the user is in the middle of the experience. If a user chooses an option by mistake, then they are given the choice to navigate back to the previous screen to change their selection. Therefore undoing an action is very easy and the user can leave an unwanted state without putting too much effort. One of the major constraints designed in the app is that once the music experience begins the user is not allowed to go back and change their selection as resending an experience request will lead to the visual and tactile experience not keeping up. To avoid the unpleasantness of a misaligned experience if the user wants to change their experience choices they will have to end the experience and start again.

Mapping: The entire application was designed with words, phrases and actions that are familiar to the general public. The various icons used in the design follow standard design norms so that the user is not confused about what it does. Therefore, the system caters to the novice as well as the experienced users. The entire app uses clear headlines and gives simple instructions on what actions the users need to perform. The UI elements used reflect objects that the users are familiar with in the real world. This is very evident in the Environment selection page where the users choose an environment which provides ambient music through the experience.

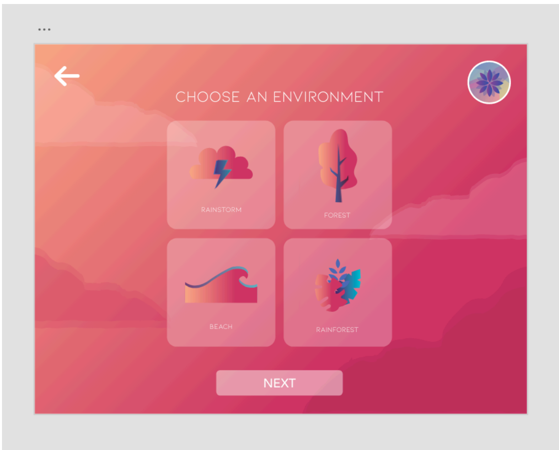

Figure 4.6: Environment selection screen

Feedback: The user is given continuous feedback about the results of their actions and the current state of the device. Error messages were incorporated to precisely indicate the problem so that users can recognise and recover from them. Additionally, the app constantly keeps the user informed about what is going on through appropriate feedback. This is evident when the experience request is sent due to the incorporation of a loading spinner. As the chair ecosystem takes a few seconds to load the experience, having the loading spinner instead of a blank screen will avoid frustration for the user and makes it clear that the experience is loading. At the end of the experience the user is presented with an evaluation of how the experience has affected them. They are presented with a results screen that displays biometric data that was collected using the sensor. As the science behind analysing the biometric data is complex, the user is provided with a simplified explanation of what the results mean. The results screen also has information buttons that gives the user information about the various aspects of the evaluation.

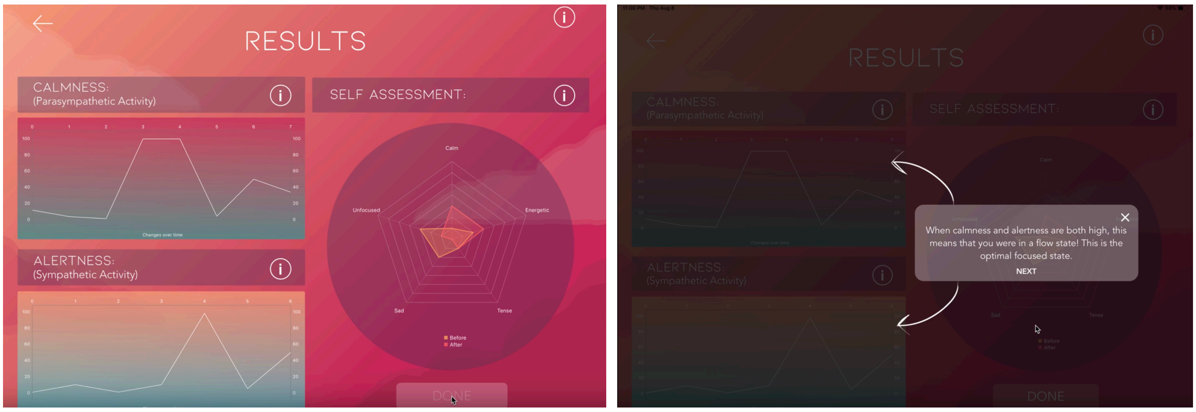

Figure 4.7: Results screen with feedback

Understandability: The app design provides the user with a complete understanding of how the Respite experience works. Not only does this give the user a feeling of control, it also results in making it a more enjoyable experience. The simple on-boarding sequence gives the user all the information they need to understand how the chair works and what actions they can perform to enhance their experience. The navigation of the app is very straightforward and each screen consists of signifiers and instructions on what actions the users can perform. Not only does the system provide appropriate feedback when the user does something wrong, it also provides them with cues to recover from those errors.

Chapter 5

Limitations & Conclusion

Limitations

The technology acceptance model and the value based adoption model both rank perceived usefulness as being one of the major factors that affect user adoption. Since this study focused on creating a front end system for an existing IoT system, incorporating “usefulness” within the system was considered out of scope. Usefulness is a factor that needs to be fulfilled at the ideation or inception stage of a product or service and therefore only easy of use (technicality) and enjoyment were considered in the development of the app. The perceived fee component was also overlooked in the implementation as it pertains to the overall cost the user perceives for the IoT system and not specifically to the application. As mentioned in chapter 2 - section 2.3, one of the major challenges of using the principles of user experience design is that the evaluation factors are very subjective and user testing is required to validate the effectiveness of using UX design to implement the adoption factors. Therefore, without conducting user testing, there is no concrete way of knowing if incorporating the adoption factors were successful in increasing user adoption. Consequently, future work on this project largely rely on user testing and evaluation.

Conclusion

Although a large emphasis has always been placed on the technical aspects of IoT, very little importance has been given to researching factors that could have a significant effect on a user’s intention to use and adopt these services. Since the ultimate goal of any technology is to provide value to the user, understanding why users accept or reject new technology becomes paramount to creating successful products or services. This paper identified factors that positively and negatively impact the user’s intention to adopt a new technology by analysing the technology acceptance model and the value based adoption model. Investigation was also done to see if the principles of user experience design can be used to implement these adoption factors. The challenges of using UX design were highlighted and a proposal was made on how to overcome them. The identified factors were then applied to the actual design and development of the front end of an existing IoT device, the Respite chair. To summarise, this paper examined two adoption models to provide insight into determining factors that directly affect IoT service adoption by users and applied it to developing a coherent and engaging user interface for an existing IoT system.

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