Final Year Project Report

Half Unit – Final Report

Human Computer Interaction

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A report submitted in part fulfilment of the degree of

BSc (Hons) in Computer Science with Management

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Declaration

This report has been prepared on the basis of my own work. Where other published and unpublished source materials have been used, these have been acknowledged.

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Signature:

Table of Contents

Abstract

Since 2007, with the reveal of the first most successful mobile device “iPhone”, the whole mobile device industry has been changed. Almost everyone is whether using a tablet or phone for everyday communication, business, entertainment and much more. What was the key point of this success? There were many devices with touch screens including stylus but what made iPhone so special and how touch-based interfaces got accepted by everyone? This project will be explaining the importance of User Interfaces (UI), User Experience (UX) and the most popular 2 different design languages brought to people’s lives from successful tech companies as Material Design and Flat Design will be discussed. The project aims to identify the importance of Human-Computer Interaction (HCI) on daily basis with comparing these designs. To support this idea, a car infotainment system which requires paramount importance on safety research will be designed.

Project Specification

Human Computer Interaction (HCI)

This report will provide relevant background theory on Human Communication Interaction (HCI) for understanding how humans perceive their environments. The aim of the project is to compare Material Design, released by Google in 2014 and Flat Design, which gained popularity back in the 1970s. Project will also evaluate their design in terms of usability including Nielsen's heuristics for user interface design. The objective would be to create two car infotainment systems in the same concept but with the following Material and Flat Design guidelines. Following the same concept but different design guidelines will allow us to see which design guideline is most suitable for user's ease of use. The storyboards that will be created is a dashboard for car settings adjustment, a climate control panel, multimedia (entertainment) interface for playing and displaying music, video and photo. Also, a brief navigation system will be added to the design. I'm highly motivated to do this project because, in the last couple of years, car manufacturers yet started to realise how important the car software will be in near future. Majority of reputational car brands are now hiring qualified, industry specialised software engineers to improve their systems. **[5]** I believe that at the end of this project I will have a wider understanding of how to use guidelines when designing software. Designing car software will allow me to improve and specialise myself in this industry which is one of my long-term goals. UAT tests will be done at the end of the project will also allow me to enhance user experience on the designs I create. Having this project as my final year course will show my dedication to this industry in employment processes.

This report would also include prototyping tools used to design a car infotainment system.

Literature Survey

In order to provide a better understanding of the importance of HCI in daily basis, I will be using sources from Royal Holloway, University of London's lecture slides. The structure of the sources is in slide format, so it does not contain sufficient information that can be discussed in detail. For this reason, I will also reference a book called "Human Computer Interaction, 3rd Edition" by Pearson which is also incorporated in the lecture slides. Another source that I will be referencing is Interaction Design Foundation which is a 17 years old non-profit community. The aim of the community is to raise the level of global design education to an Ivy league standard. There are credible people within the industry from leading designers to Ivy league professionals that contribute to the foundation. I also be using the encyclopedia of human computer interaction book which contains a lot of topics that is discussed in the final year projects list especially in Chapter 42.

Chapter 1: **The Human**

1.1 Introduction

The central character in any discussion of interactive systems. Human is the one whom computer systems designed to assist. Since the human is the main factor in our systems, everything should be focused on human (user) requirements and needs. Cognitive psychology is one of the key points to determine how people perceive the environment around them, how they store, process information and solve problems. If the designer has sufficient information about human perception, the designer will also have the ability to manipulate them. There is a correlation between perception and user experience (UX). If a user perceives the environment around better, it will also enhance the user experience. A person's interaction with the environment occurs through data exchange, similar to computer systems. A computer system is giving output as information by using different types of interaction (display, sound, haptic feedback, etc…) and the user is responding to this output by making inputs to the computer system. In humans, an input is occurring through senses and the output is occurring by motor movements. There are five major senses that a human has; smell, taste, vision, hearing and touch. For now, just three of these senses have major importance in HCI. **[20]**

1.2 Human perception

Perception is the process of collecting various types of sensations and processing them in order to create a meaningful experience for the environment. **[1]**

1.2.1 Vision:

Vision is one of the major senses that a human has. It is the source of information. The human eye is responsible for receiving light and transforming it into electrical energy for the brain to process the image. Visual perception can be divided into two parts; processing and interpretation of stimulus (brain) and physical reception of stimulus (eye). **[20]** The brain processes the visual information alongside with other types of input information from other senses and combining them to create a better perception for the human. Vision by alone allows human to perceive colour, size and depth, shape, brightness, text, font and various other elements that help us to create a better understanding of the environment. This allows designers to manipulate their designs to fit perfect ratios, colour schemes and fonts to appeal user's attention. To understand how this works, the topics need to be deeply discussed.

Perceiving Colour – Colour is made up of hue, intensity, saturation. Saturation is the amount of white in the colour, the intensity is the brightness of the colour and hue is determined by wavelengths. The human can perceive approximately 150 different hues. Combining these elements allows us to create 7 million different colours.

Image 1.1 Colour hue, intensity and saturation **[2P]**

Perceiving Brightness – Brightness of an object begins with a light source and luminance. Luminance can be determined by the amount of light falling on an object and its reflective properties. Perceiving light occurs by photons reflecting from an object to the human eye, more photons means more light emitted by eye. A photometer can be used to measure luminance. Those type of sensors being used in mobile devices to adjust the brightness of the screen automatically matching with the environment.

Perceiving depth and size – Every image appears on the retina as upside down even though the reflected light is straight. Size of that image defined as the visual angle. This is affected by the distance of the object and the size. Visual angle illustrates how much space that an object on the field of view. **[20]** A person with 190cm height can look really tall if the person is close to your visual angle (see the illustration below) but if the same person is further away from your visual angle, they can look really tiny. As in image 1.3 if the sun is much closer to a person's visual angle, the bigger it will appear to a human eye.

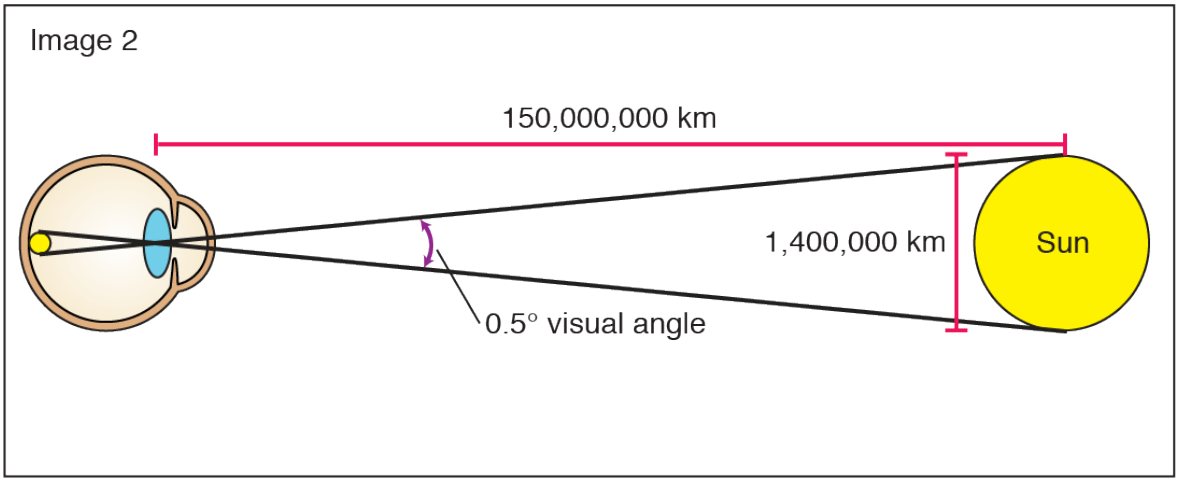


Image 1.2 Visual Angle Illustration with object "Sun" **[3P]**

1.2.2 Hearing:

Hearing is a major sense that human has but it is more likely considered as secondary important sense. Hearing begins with waves and vibrations travelling through the air. Sound is created by changing or vibrations in air pressure. Sound has variety of properties like pitch, amplitude and timbre. **[19]** Pitch represents the frequency, denser the wavelength means high pitch. Amplitude represents the loudness of the sound, more the amplitude more the loudness will be. Timbre represents type of sound. For example, pitch and the amplitude could be the same for a sound but human ear will hear the sound as two different types if the sound is coming from a piano and guitar. Hearing sounds allow a person to understand the location, distance, direction and the intensity of objects. For example, hearing a car passing by from the street can give information about the direction of the car, how fast it is travelling, the approximate size of the car and from which street it is travelling. The information provided as input is not strong as visual perception.

1.2.3 Touch:

Touch is also one of the major senses that the human body has. It is also called haptic perception. This sense is created by the brain and the nerve system via electrical signals. When human makes contact with an object, the relevant receptors immediately transfer data to the brain as electrical signals (pulses) to allow the brain to process this data

alongside with other sensory data to create a better user experience with the outside world. Human has three different receptors in the skin; thermoreceptors, nociceptors and mechanoreceptors. These receptors respond to heat and cold, intense pressure and pain, pressure respectively. HCI studies on mechanoreceptors since humanity don't have any ready software to simulate pain and temperature on the human body. **[2]** There are two types of mechanoreceptors and they are so important for HCI. Rapidly adapting mechanoreceptors respond to immediate pressure. Slowly adapting mechanoreceptors respond to continuously applied pressure. **[2]** Apple has invented "Force Touch" with including Taptic Engine that enables digitisers to distinguish levels of pressure applied to the screen by user while giving feedback.

Image 1.3 Force Touch technology on an iPhone 6S **[4P]**

A regular person can test their haptic perception accuracy by two-point threshold test **[3]**. This can be easily done by taking two pencils and touching them to the thumb. The distance between the two pencils should be around 1cm. Try to increase the distance until you can feel 2 different pencils on your thumb.

1.2.4 Motion:

Human receives information from the environment continuously and reacts according to the information. This action can be auditory or movement. After the human receives information through its sensory receptors and sends the data to the brain for processing. Brain receives the information and gives the order to relevant muscles to make a movement or speech. Total time taken to respond a stimulus defines as "reaction time + movement time" **[20]** Moving the cursor to "Skip Ad" button when a person sees an advertisement on YouTube can be an example for this situation. A person can react to pain in 700ms, to visual signal in 200ms and 150ms for auditory signals. **[20]** Combination of these creates a better and faster response. Also, practise and familiarity can increase the response time. Response time and accuracy are important key elements when designing software for special cases like car infotainment system, medical services, machinery, fire systems, etc… This affects the whole design in terms of usability. Whereas the target buttons should be large and the distance should be the smallest as possible.

Fitt's Law – This describes the distance between the initial position of human and target area are related with the target width. Designers can use this law when they're designing their software. This will increase usability in the entire system. Commonly used items, buttons can be placed near the cursor area and their size could be increased in order to have easy access.

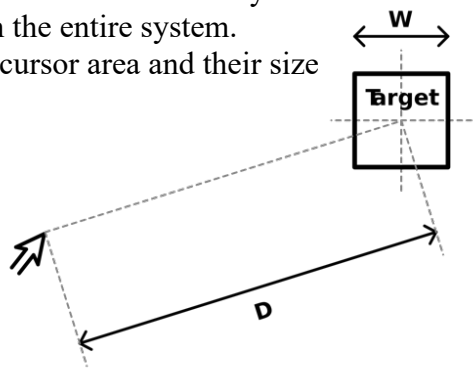


Image 1.4 Fitt's Law Illustration **[1P]**

1.3 Human Memory

While receiving dozens of information continuously from the environment, human also stores this information in the memory to learn and retrieve information when needed. Information stored in memory could be an image, sound, text, smell, taste, movements of a person… etc. There are many variations of information. Memories give human the sense of identity, relationships, language. Every process is associated with memory. What HCI studies with human memory are sensory memory, short-term memory and long-term memory.

Sensory Memory – It is out of cognitive control and it is fully automatic. Continuously overwritten and it has three sub-sensory channels as iconic memory for visual stimuli, echoic memory for auditory stimuli, haptic memory for tactile stimuli. It is responsible to understand actions that are happening in a very short amount of time. This type of memory holds sensory information less than 1 second but this time interval is yet enough for recognising an object, movement, speech. **[19]**

Short-term Memory – This is responsible for holding information in the memory for a few seconds to recall without receiving the same information again. It is also called "the working memory". Short term memory can be accessed rapidly approximately 70ms but it also decays rapidly approximately 200ms so the information stays there for very short time intervals. This type of memory also has a limited capacity. To improve the amount of information to remember, a combination of senses could be used and if the information is visual then the information could be grouped instead of seeing it as chunks.

Long-term Memory – This type of memory stores every kind of information we recognise. Unlike short term memory, it has an unlimited storage capacity, has slower access time which is approximately 1/10 second and also decaying occurs much slower compared to short-term memory. Long term memory is maintained by a more stable and strong neural connection in the brain unlike short term memory which is located on the frontal lobe. Two types of sub long-term memory are in charge of these responsibilities; episodic memory and semantic memory. Episodic memory is storing the experiences and events in serial form. Semantic memory is storing skills concepts and keeps record of the things that human had learned during these events. Semantic memory recalls information from episodic memory.

1.4 Reasoning

Human beings are processing any kind of information that they are receiving from the environment at any moment. These received information somehow should be turned into a reasonable knowledge that where reasoning starts to act. Reasoning is the process that received information through different kinds of perceptions turned into conclusions or infer something new about the domain of interest. Reasoning has different kinds; deductive, inductive and abductive reasoning. All of these types of reasoning used in daily basis but each kind have a different structure.

Deductive reasoning – Deductive reasoning, or deduction, starts out with a general statement, or hypothesis, and examines the possibilities to reach a specific, logical conclusion, according to California State University. **[12]** It is essential not to confuse that logical conclusion must not be always have to correspond to human's notions of truth. For example;

> *If it is sunny then the ground is wet*
> *It is sunny*
> *Therefore the ground is wet.*

This looks like a perfectly valid deduction even though it is not representing the notion of truth and it conflicts.

Another example;

> Some people are babies
> Some babies cry

Most of the people will infer that "Some people cry" which is in fact a wrong deduction. There is no information about all babies are people, therefore it is logically possible that the crying babies are those who are not people. Deductive reasoning is usually misapplied. In these types of situations the validity and notion of the truth contradicts each other. Human deduction becomes the poorest. Humans use information that they have from the environment as kind of a statement of truth which makes conversations among humans more informative and efficient. If validity is preferred to truth, all statements would have to be made much more explicit.

Inductive reasoning – This happens by making an assumption from the cases and events that a human being has seen before and infer the cases that human had not seen yet. Claiming that every dog has an ear can be true until the time we see or produce a dog without ears. In inductive reasoning, inferences cannot be proven true, they can be proven to be false. The best way to make inductive reasoning is to have evidences alongside with the inference. Despite of inductive reasoning's unreliability, induction is a very useful process that humans use constantly in learning about the environment. **[20]** There is no possibility for a human being to see entire history of the dogs to prove they all have ears, but the time period that a human being lives in and experiences the environment can be very useful information to learn about surroundings. Humans are better at using positive evidence rather than negative.

Abductive reasoning – Abductive reasoning typically begins with an incomplete set of observations and proceeds to the likeliest possible explanation for the set. **[13]** This is the type of reasoning that humans use to derive explanations from the events they observe.

Unlikely inductive reasoning, abductive reasoning is more like an action reaction process. For example; we suppose that a software is terminating because of an error without seeing an error message. If we see the same software is terminating again, we would assume that an error happened again, even though we don't have any evidence. There is a possibility that the process has been completed successfully and the software terminated itself for the reason that it completed the process without a message of confirmation, but we just assumed that the same error happened again. This can lead to problems in using interactive systems. If multiple actions are followed by the same reaction the user would assume the first knowledge that they observed from the environment.

1.5 Problem Solving

Human cognition and perception are complicated and refined but they are not without their limitations. Problem solving starts with using the information they have already in the memory with concluding a reasoning behind it. **[13]** Problem solving is the process where a human being tries to find a solution for a problem that they never encountered before by using their existing knowledge from past experiences. Problem solving is highly related with having the ability to adapt the existing information to the new environment, so it differs from person to person. There are vast amount of research and information about how problem solving works in the brain but we will evaluate the HCI perspective of this information.

Since most of the people are familiar with mobile devices and operating systems nowadays, the guidelines given to developers for their applications can be an example to reduce problem solving process. Universal guidelines allow users to understand the work mechanism of a program even though they are using different multiple apps. Using guidelines are eliminating problem solving process as vast amounts in navigation and interaction. Giving the user interface and navigation styles that users are used to is a good design element for making a user to understand the infrastructure with no need of a user manual. This will be discussed more in the usability chapter.

1.6 Conclusion

In this chapter, human perceptions, memory and reasoning are explained in detail in order to have understanding of what aspects of this information correspond in HCI. We have considered that human is an information processor which gets inputs from the environment through the perceptions every human being has and responds correspondently with creating an output. This process happens by storing this information received through receptors and organs in either temporary, sensory, working memory or permanently in long-term memory. This information then used in reasoning and problem solving. Having all of this information about the central character in any discussion of interactive systems allows designers to understand how they implement this valuable knowledge into their systems. Since human is the one whom computer systems designed to assist, understanding of how interaction mechanism works also allows designers to manipulate these processes without letting the users know about it.

Chapter 2: **Interaction and Usability**

2.1 What is usability?

Usability in general, refers to ease of access and/or use for a product. Usability can be evaluated by doing tests in real environments with users that never used the product that has being tested. Even tough usability seems to be an easy study, when it's studied in HCI everything starts to get complex. HCI and usability standards have been developed over the past 15 years with the beginning of personal computing. Researches have shown that there are many factors that affect usability directly. Consistency, memorability, ease of learning, efficiency of use are some types of factors that affect usability over a product. **[19]** Usability highly related with human perception for the fact that giving an information clearly allows human being to rapidly adapt and understand the context and generate a response accordingly. Giving only the relevant information by not including the climate controls on the screen at every time by reducing confusion and giving the right information clearly in this case could be an example to this.

2.2 Why usability is important?

Over the last 15 years, a comprehensive range of international standards has been developed to define the general principles of user-centred design and good practice in user interface design. **[14]** After the big market of enterprise computing, individuals had started to interact with computer and this resulted in vast amount of researches in this topic. Having a standard of usability in cross-platforms allowed regular user to easily adapt their existing knowledge to newer systems in enormously growing computer industry. One of the biggest innovations made in personal computer industry was switching from old terminal interfaces to WIMP (windows, icons, menus, pointer) style interaction. Switching from terminal to WIMP style allowed every user not to be computer specialists but regular users that have no common sense about computers to use computer systems without requiring any kind of information. Since we are making a car infotainment system, we will be using touch interfaces for the best result and that's why usability is very important for this case.

2.3 Factors of usability

A usable interface should consist on three main elements; the software should be easy to understand and navigate for a user when they firstly encounter with the product. The user should achieve their goals within the application without having any problems and difficulties. Lastly, the software should be easy to recall in terms of design and structure to make it memorable at any time. Combination of these elements creates good usability. Following factors should be examined to achieve great HCI.

2.3.1 Visual Factors

Font Size and Colour – Font texture can differ in many ways depending on what operating system they work on, what kind of displaying device used to display fonts and the environments that users look at the fonts. Using uppercase, lowercase fonts with font pairing can help user to understand the context more easily. Including paragraphs with distinguishable titles and sub headings are often good for clear understanding of the context. Using sans-serif fonts on car infotainment system for example, is much better

because it is often better to read on the screen whereas serif fonts can be much better at paper. **[21]** Even though yourself did not realise that all of these factors are applied to this research paper, you can clearly distinguish the importance levels of information just with brief look.

Image 2.1 Sans Serif "Akzidenz-Grotesk" font **[5P]**

Layout Colours – Colour schemes used in software can distinguish elements, buttons to appeal user's attention whereas wrong colour schemes can result in difficulty of reading, not distinguishable elements and bad usability. For this reason, this is also one of the crucial factors that must considered before making a design. **[22]**

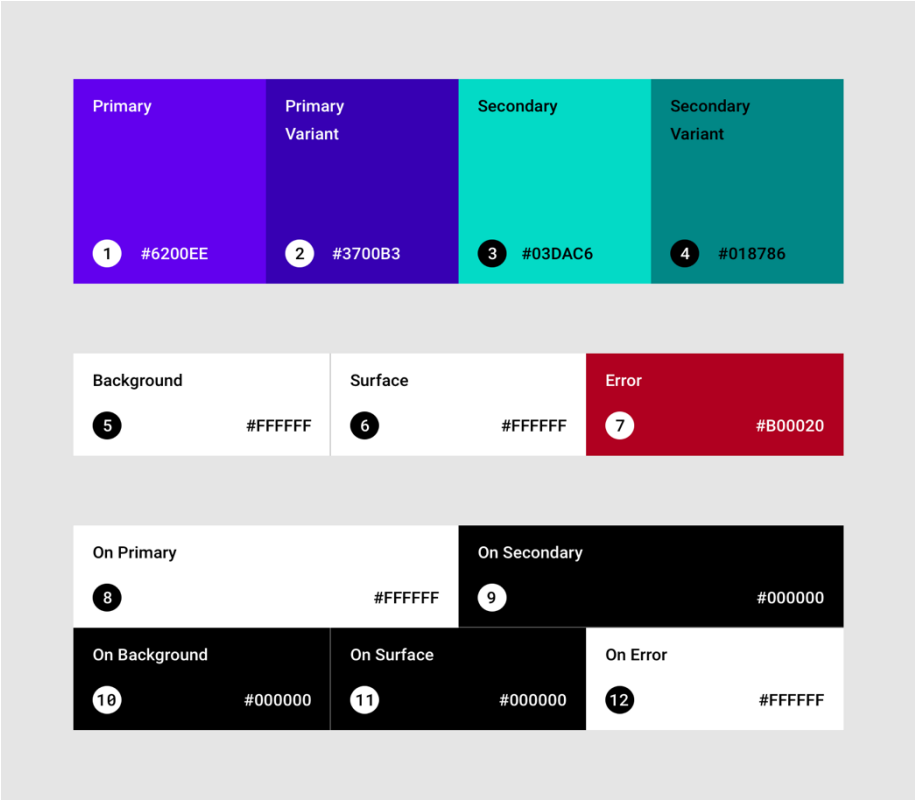


Image 2.2 The baseline Material Design colour theme **[6P]**

Navigation – For users to get the most from a software, they need to get from point A (the entry point) to point B (where they want to be) as quickly and easily as possible. That means providing useful navigation systems, including voice recognition, to facilitate that transition. **[15]** This factor is holding a very crucial importance in car infotainment system because navigating through functions should be easiest as possible not to distract driver from the road. Navigation types can be examined as three different groups;

Linear – This type of navigation only allows user to navigate in only one direction. A software designed by this type of navigation usually does not contain much interaction and it is not suitable for multifunctional software.

Hierarchical – Hierarchical navigation systems are kind of AVL trees. Every page has an ancestor and user can easily navigate back by touching a return button. The structure of this navigation type is good for keeping the system consistency but it is not useful if the system has many sub-pages for completing a function. This can lead forcing user to remember which pages they travelled through in order to go back to the previous function or page.

Webbed – A webbed topology allows the user to navigated in a more fluid fashion. The range of webbed topologies is quite broad, ranging from almost hierarchical with additional links, to where each page will link to others of similar or related topic but where there is no underlying categorisation by topic.**[16]**

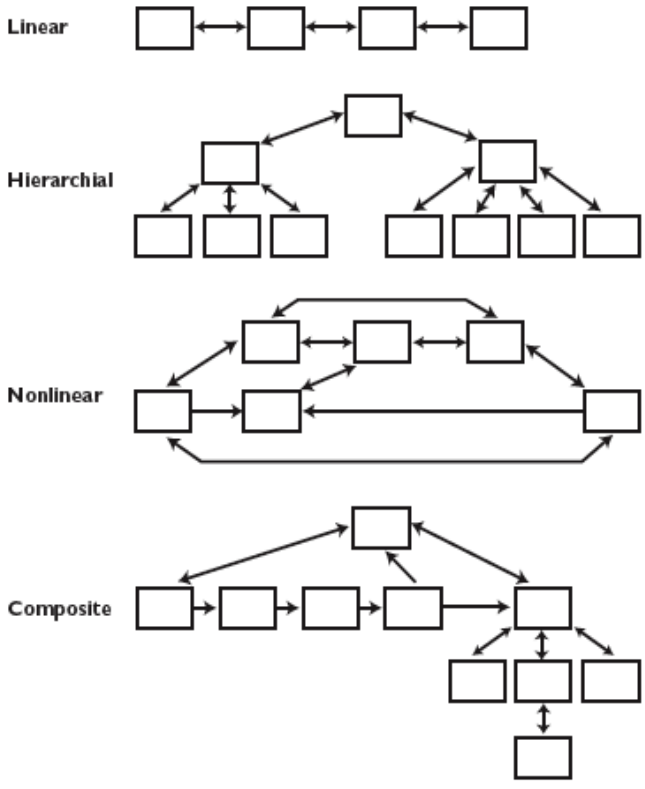


Image 2.3 Navigation types used in modern software **[7P]**

Satisfaction – An interface that satisfies the user is often considered having a good usability. In order to test whether a system have good usability or not UAT could be done. These tests would be based on the user stories. Participants (users) can be audio, video recorded during the testing and a survey can be asked to fill out. User acceptance testing

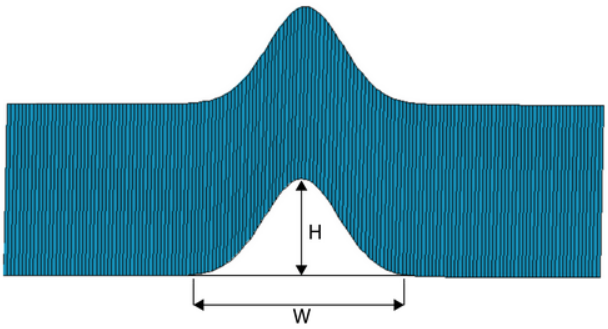
(UAT) is the last phase of the software testing process. During UAT, actual software users test the software to make sure it can handle required tasks in real-world scenarios, according to specifications. UAT is one of the final and most critical software project procedures that must occur before newly developed software is rolled out to the market. UAT is also known as beta testing, application testing or end user testing.

2.4 Interaction and usability in car infotainment systems

Nowadays, every car manufacturer is implementing their own design languages which they believe is the best for their user's experience. Designing process also includes types of interaction that will be used with the system. There are 2 types of interaction used commonly as the most significant part; hard interaction and soft interaction. Hard interaction can be defined as using physical objects, buttons to communicate with the system. The deliberate manipulative actions are performed by the driver for changing the status of a setting such as drive mode. Whereas soft interaction is the action performed by the system itself as non-deliberative actions made by the driver. Auto climate control, voice assistance can be an example for this. Lately produced cars have automatic brightness setting for the backlighting in the dashboard which creates seamless experience and it is a perfect example for soft interaction. It is certain that soft interaction decreases distraction of the driver from the road for the reason that less input is required from the driver itself to make a change. One study examined how often 17 drivers with access to advanced infotainment systems for four weeks were involved in collisions and near misses. **[17]**

2.4.1 The interaction techniques implemented by car manufacturers in modern systems

Touch enabled screen with haptic feedback – This system is usually straight forward for user to interact with the system easily with getting haptic feedback as confirmation. In early systems, feedback was given to the user as a clicking sound to confirm an action has been made but nowadays it's been changing to physical haptic feedback. Although these systems are safe to use on the road, they lack some certain safety measures when it comes to seamless interaction. Humans can develop muscle memory when they are clicking or using a physical button that they can feel with their senses. In touch screens, haptic feedback is just trying to mimic this feeling in order to achieve some certain level of feel but it is not developed enough. Interesting experiments made in Disney research labs is trying to achieve the best feel and feedback experience by carrying haptic feedback technology to every aspect of the software that when a user is touching to the screen to feel the places of the buttons, the system will give feedback accordingly to the location that the user is touching to. Without looking at the buttons or icons, they can feel with their fingers that where they are located. This creates muscle memory to enhance the user experience while decreasing the road distraction significantly. **[18]**



A 1D Gaussian bump: a basic unit for tactile content generation. The height "H" and width "W" are variable and defined by designers.

An array of 1D Gaussian bumps are rendered to create DVDs, books and other stack of things.

Image 2.4 Visualization of haptic feedback **[8P]**

Hybrid interfaces – This system is commonly used on BMW, Mercedes-Benz and Audi brands since early 2000. Hybrid interfaces combines touch enabled screens with physical control unit (button) which they can even include haptic feedback as well. The arise of this system was due to the lack of the technology that touch screens have in the past. In early 2000, touch screens were based on pressure points which even does not enable multi finger touch, which makes gestures like zooming a map or swiping a song very hard. Some manufacturers embedded physical buttons in order to interact with the software parts that requires gestures in order to have much less distraction. Instead of putting one "-" button to the screen for zooming out, they preferred to include a button to turn for zooming in and out. This type of interaction has worked for many years, but it was also creating a confusion on the users because it violates the fundamental rules of human computer interaction. Having 2 and even in some cases 3 different interaction choices is not good for consistency and causes more distraction. The current technology we have enables us to replace old systems like this to just one glass panel that has all of the functionality that these systems have and sometimes even more.

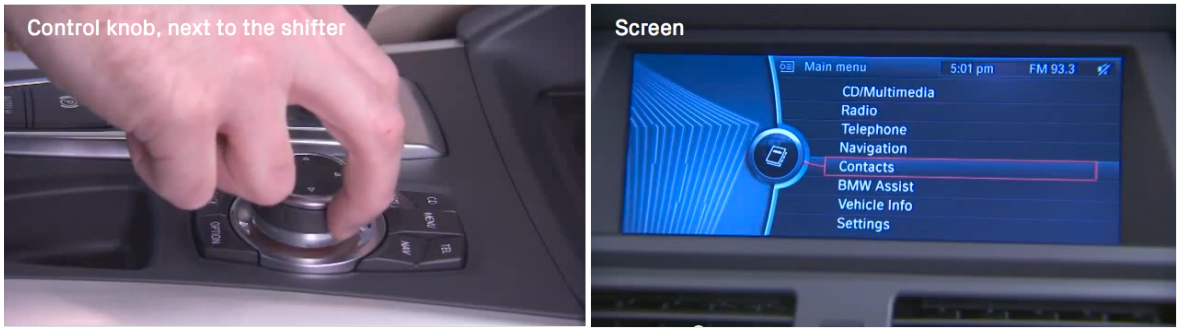


Image 2.5 Hybrid system used in a BMW, late 2000's **[9P]**

Gesture Control – This is one of the latest systems that BMW revealed on 2015 with the flagship model 7 series. This interaction type is trying to avoid driver distraction by enabling gesture control over the air for basic tasks like changing the song, increasing and decreasing the volume, etc… The sensing of 3D visual data is getting progressively easier with the reduced costs on the sensors and increased number in algorithms that helps the process significantly. It is a good step forward for the current interaction styles we have already but more investment and research needs to be done in order to achieve optimal conditions. Again in Disney research lab, some experiments has been done about interactive tactile experience in the air. This allows user to feel the buttons and the gestures they made by getting feedback as an air burst that is created by a mechanism. The device

emits a ring of air called a vortex towards a user's hand. The vortex can impart a force on the user's hand, enabling a range of dynamic free air sensations. **[18]**

Image 2.6 Gesture control system on 2015 model BMW **[10P]**

Eye tracking with supportive secondary displays – This is the interaction type that does not include any hard interaction. Everything is automated and done by the system itself. The first implementation of secondary displays to show information on or near the driver's line of sight have been in use since 1980's. Car manufacturers are packing more technology in the cars to increase safety and reduce human mistakes. Some of these systems are supported by visual feedback from head up display and sensors that tracks face and eye movement to make sure the driver is always in the focus. The contextual information given in the secondary displays as HUD (Head up display) reduces driver distraction because necessary information is always displayed on the windshield. For instance, navigation information, speed, gear, autopilot information, etc… can be crucial information to be shown. The eye tracking system can also be used in application where turns off the screens that the driver is not looking at which minimizes distraction.

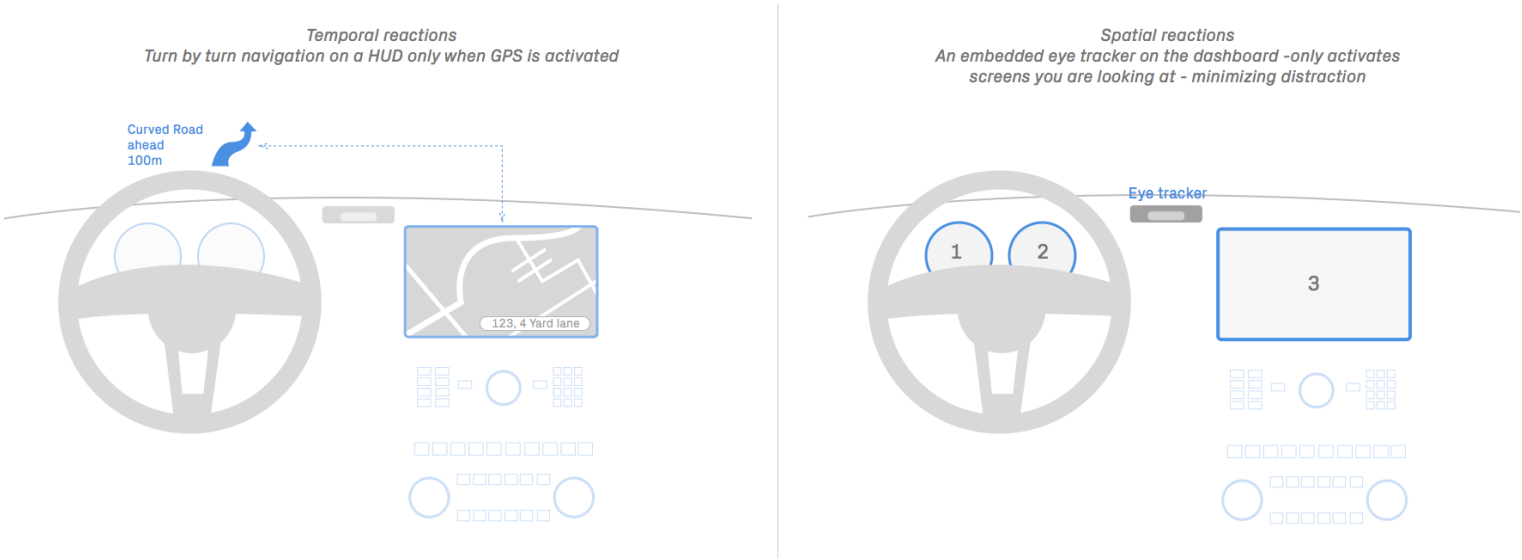


Image 2.7 Embedded eye tracking system with HUD

2.5 Conclusion

Even though usability started to be taken as a significant measure after the era of personal computing began, it is very crucial for every system designed to help humans. Usability highly related with human perception for the fact that giving an information clearly allows human being to rapidly adapt and understand the context and generate a response accordingly. There are examples show that wrong designs can even result in fatal accidents especially when it comes to designing a car infotainment system. Studying human perception and cognition allows us to understand how we perceive the environment around us and makes designers to design products that is most suitable for humans to use. Every information included in this chapter is highly linked with each other. Good usability cannot exist without an optimal interaction and safety will not exist if combination of these are not present. In order to achieve the best conditions as possible, vast amount of research and testing is required. In terms of designing a car infotainment system, we evaluated many interaction styles that supports unique software that car manufacturers designed by themselves. It is clearly shown that not the quantity of interaction choices is good but the quality is important. The right interaction choice should be implemented with the software itself. Researches also shows that every improvement made on interaction and the design of the software reduces driver distraction where most of the fatal accidents avoided. In my system, touch screen with haptic feedback will be used because that is the most suitable choice for the software I'm designing. Eye tracking with supportive secondary displays can be also added to my system but it will require a capital to invest in order to achieve a product that can be easily used by every single user. I believe this technology is not ready for commercialising and making research on this just includes human computer interaction which shows it's importance in every day basis.

Chapter 3: **Design Guidelines**

To achieve good design, some standards should be identified and set to developers. Human interface guidelines are designed to help designers and developers create a beautifully consistent experience on whatever operating system (OS) or software they are working with.**[11]** These type of guideline targets to improve user experience and consistency. They can have limited definitions on design language but it also needs to be considered that not every application is working on the same environment and system. Following these guidelines as a developer are a must for most of the big companies when working on SDK's but for some companies or open-source systems, it is not that applicable. Policies are sometimes based on studies of human–computer interaction, but most are based on conventions chosen by the platform developers preferences.

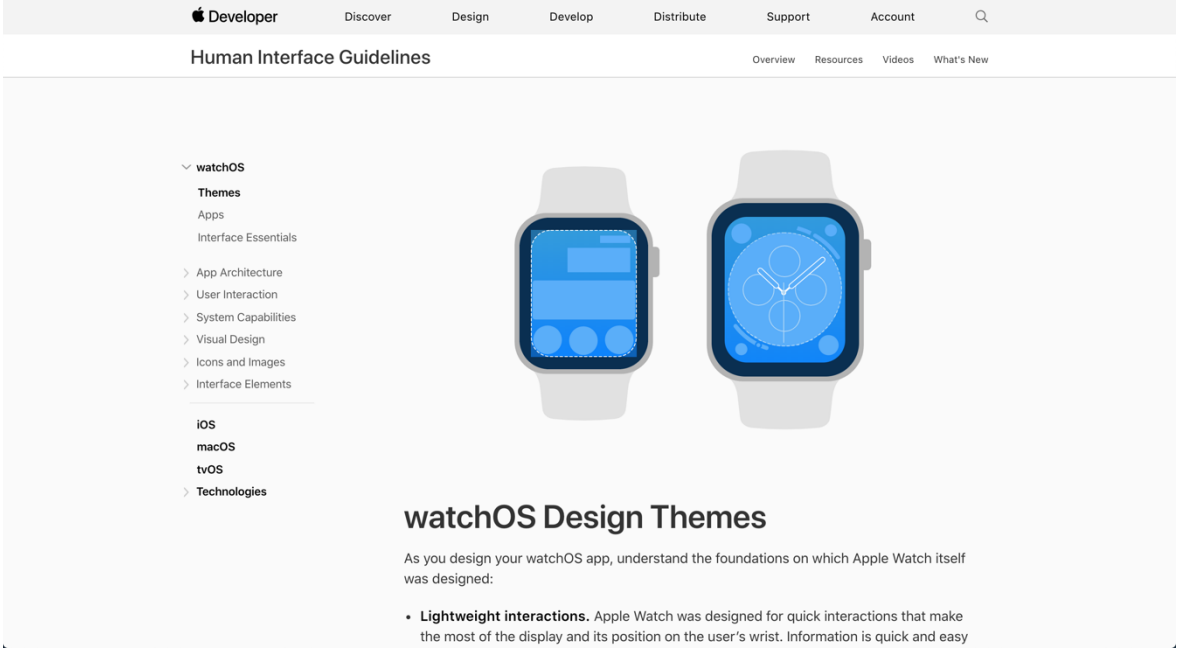


Image 3.1 Example of Human Interface Guidelines for a mobile device

3.1 What is Flat Design?

Flat design is a user interface design concept that is based on minimalistic design. **[19]** The design concept was primarily developed to achieve easier understanding of the context and enhancing the user experience. Flat design is also holding the most convenient, responsive design because it enables to resize icons and texts to the according resolution very smoothly. By using minimalistic shapes, texts and structure (ex. No shadows) the loading times are faster and smoother. It usually uses 2D objects with vivid colours. Using crisp, bright, shiny and clean UI elements makes flat design appealing rather than boring. Flat design is primarily influenced by the font "International Typographic Style" and modernism. This type of user interfaces first started to appear in a German design school called Bauhaus. Even though the font would not making any appearance on nowadays systems, it was considered as the most substantial influence on flat design. This design concept gained it's popularity after Microsoft had released their own design language called "Metro" based on flat design. Windows Media Player, Windows 8, Apple's iOS 7 and even Google's material design is based on flat design. It is mostly contrasted by skeuomorphic style which mimics three dimensional design by copying real world properties. Instead of bringing aspects from real life to the interface, it illustrates a clean separation between technology and tactile

objects. Although, flat design achieved a high reputation because of it's responsive, modern, sleek design it also has drawbacks.

Image 3.2 Apple iOS 7 as example for Flat Design **[11P]**

3.1.1 Issues with the Flat Design

However, despite its popularity, flat design also has drawbacks regarding the user experience. Lack of shadows, three dimensional objects and effects takes away the cues that indicates to a user that how to interact with the interface. Buttons, icons are less distinctive than the other visual elements that appear on the screen compared to other design concepts. Vast majority of users were having difficulties of using the interfaces because displaying of elements were not straight forward. To overcome with this problem, designers introduced new ways to implement the flat design. New interface implementations were often referred as "Flat design 2.0" or "almost flat design". These updated design concepts are adding depth and dimension by using subtle skeuomorphic qualities such as colour variations and shadows.**[10]** For instance, Apple and Google are trying to achieve the best user experience by combining all the elements which creates blurs, shadows, 3D distinctive buttons and texts to appeal attention of the user.

In the image 1.6 it is clearly shown that a user that is not familiar with Apple's icon texture would not understand the context on the control centre. There is also no distinction between controls which does not prioritise the importance of the functions they are controlling. The user can change volume instead of changing the brightness because there is not enough distinction between them.

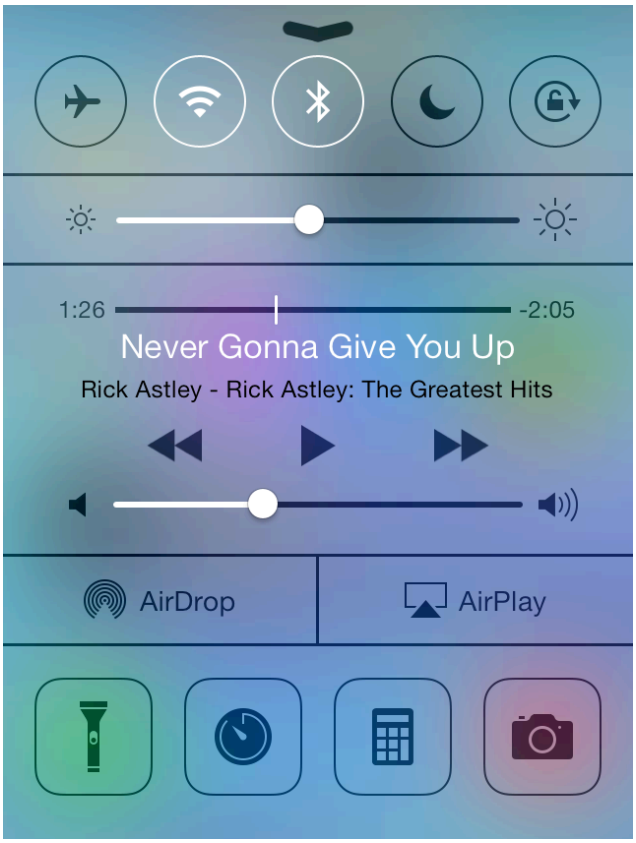


Image 3.3 iOS 7 Control Centre with Flat Design **[12P]**

3.2 What is Material Design?

Designed and released by Google in 2014 to be used firstly in Google internal applications. After internal development, Google allowed 3rd party users to implement the same design language by releasing guidelines to public. **[23]** Material design uses shadows, depth effects, padding and it is mostly based on grid layouts. Although material design is based on flat design, it arise from the problems that popular design language flat design has. It focuses on every individual item to set their level of priority. Most commonly used buttons, texts or items will be placed on top of a layer with different tone of the same colour with a touch of shadow, allowing to distinguish items from unnecessary ones. Material Design is based on paper and ink, Google says. The implementation of the design takes place in an advanced manner. Unlikely as flat design, this interface uses real world objects to match and create seamless experience for the users. It does not try to distinguish technology and the real life itself, it tries to achieve the best match with the real world to enhance recognisability.

Image 3.4 Comparison of three different design concepts **[13P]**

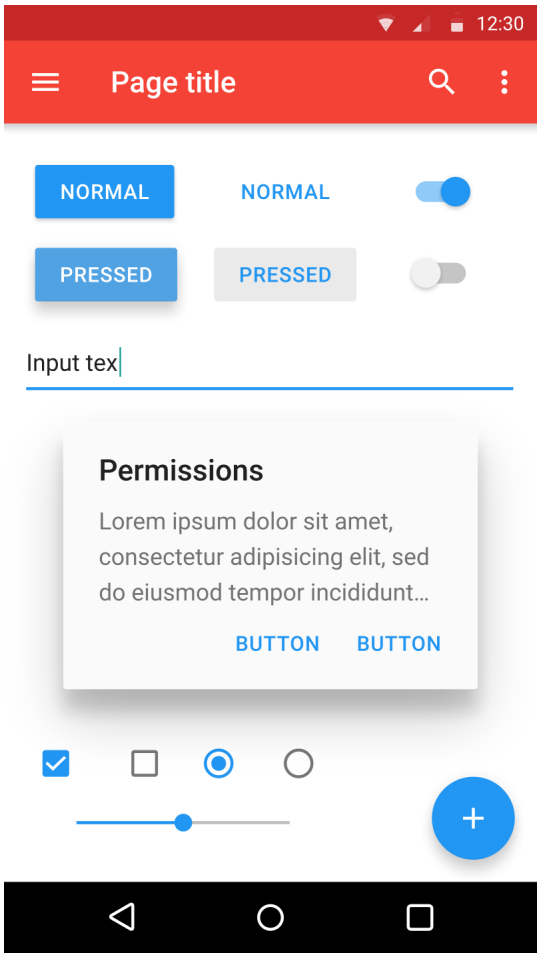


Image 3.5 Material Design, founded by Google Inc. **[14P]**

3.2.1 Issues with Material Design

Despite the fact that material design released to eliminate the problems that flat design have, it created newer problems for users. Google released this interface with very strict guidelines that emphasizes functionality over design. **[23]** Since, design is the most important part of human computer interaction, most of the app developers did not like the material design because of this. To increase recognisability for users in recently released design guidelines, Google was forcing developers to choose themes from a small number of colour palette and small range of button and icon layout. Result of this was monotone, similar application that look alike each other. To resolve this problem, Google introduced new version of material design guidelines in 2018 which also included a "Material Theme Editor" and new icon packs. **[22]** This allowed designers to customise the structure of the layout and colours for their preference. Huge range of new colours were the most significant difference that can be seen with naked eye easily by everyone. Google calls the new material design, version 2.

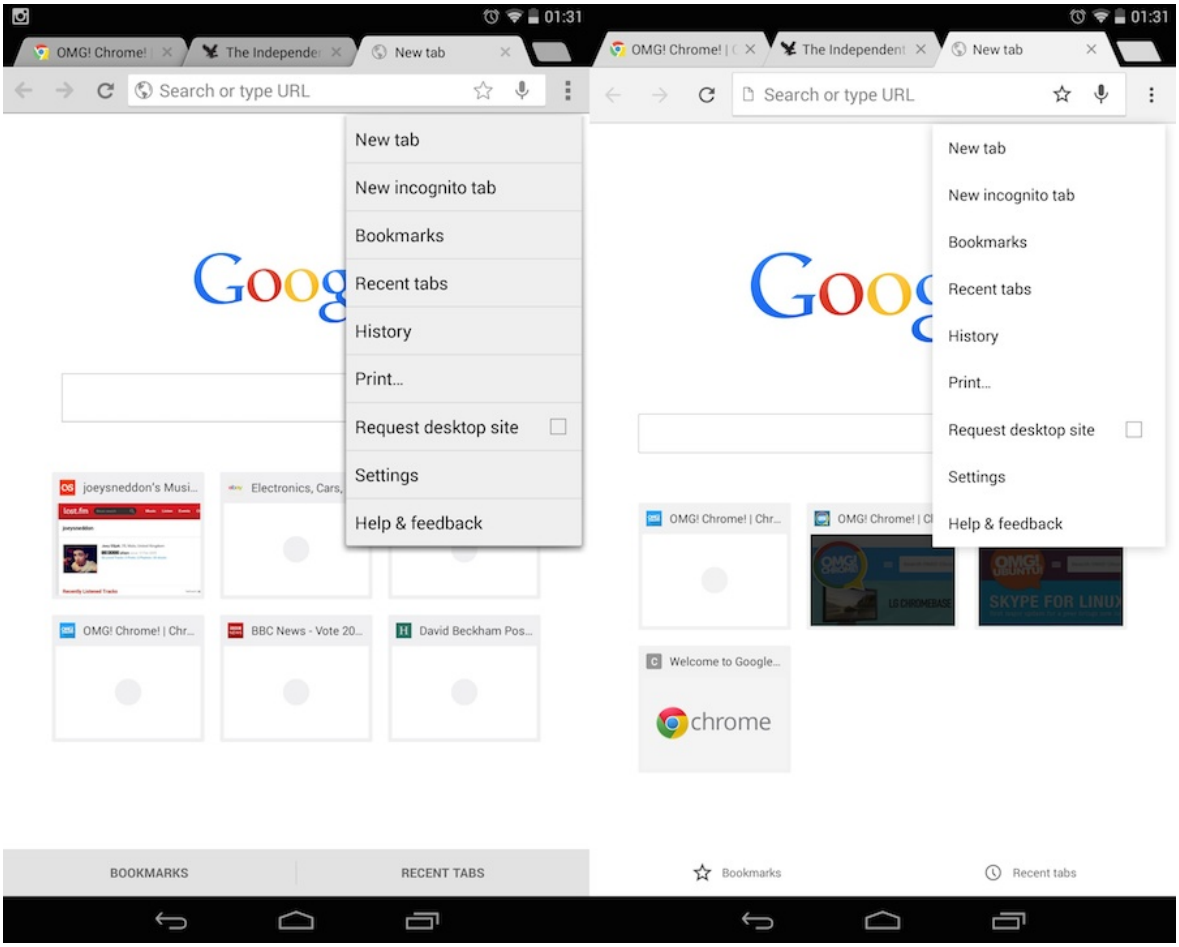


Image 3.6 Left – Material Design version 1 and Right – Material Design version 2 **[15P]**

Chapter 4: **Software Sketch**

All files for the software can be accessed here:
https://github.com/Cemonex/finalyearproject

4.1 Why Designing a Car Infotainment System?

Vastly growing technologies allowed on-board computers to be implemented in vehicles. Since 2007, there has been a huge increase in car infotainment system production as 3rd party corporations allowing motorists to benefit from them. One of the biggest developments on this time period was software used in these type of car systems. Nowadays, biggest car production companies are hiring people who are specialised in this industry to achieve the optimal solutions. Lack of having good systems in car industry is a good opportunity to make it as benefit.

4.2 User Stories

A user story is a high-level, detailed definition of requirements just containing enough information to inform developers about user needs.

• As the driver, I would like to have a simple, minimalistic design, so I can easily adapt to design.

• As the driver, I would like to see control the air conditioner, so I can easily change temperature.

• As the driver, I would like to see travel information, so I can know when to fuel up.

• As the driver, I would like to play music, so I can entertain everyone in the car.

• As the driver, I would like to access my contacts, so I can have phone conversations.

• As the driver, I would like to have voice recognition, so I can command with voice.

• As the driver, I would like to have machine learning, so the car learns my habits and settings.

• As the driver, I would like to have NFC pairing system, so I can easily transfer data, profile.

• As the driver, I would like to have Apple CarPlay and Android Auto, so I can integrate with the mobile device.

• As the driver, I would like to link my phone with the navigation system, so I can see live traffic information and various details over the touch screen.

• As the driver, I would like to see the album, title and artist of the song, so I can easily access information.

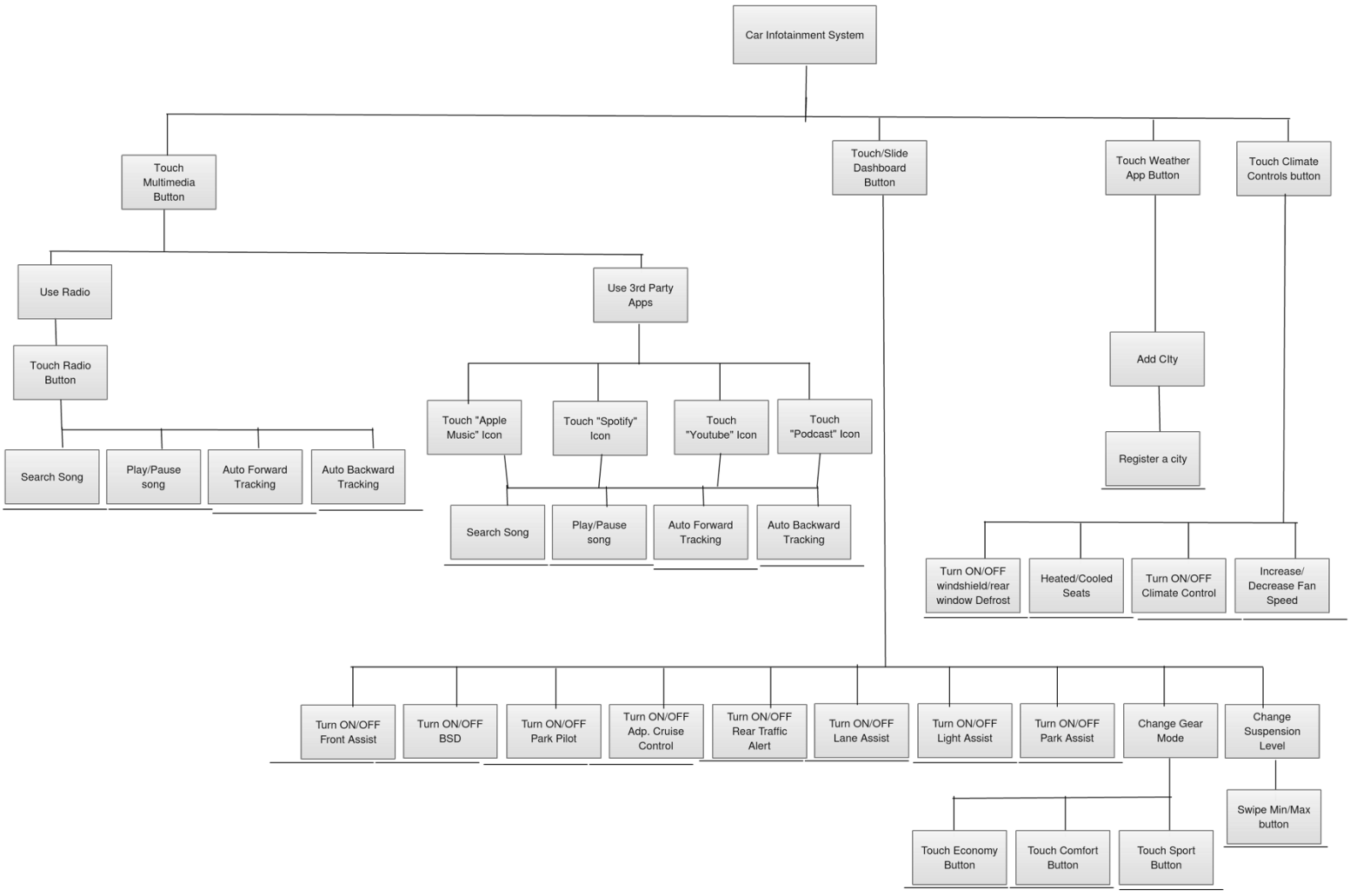
• As the driver, I would like to have a multi-destination trip entry, so I can be less distracted along travel.

• As the driver, I would like to have a tire-pressure management system, so I can increase security and get notified.

• As the driver, I would like to have a hotspot system, so I can get a wi-fi connection for my devices.

• As the driver, I would like to use multiple apps at once, so I can get informed without distracting myself with switching over pages.

4.3 HTA Diagram



4.4 User Acceptance Testing

User acceptance testing (UAT) is the last phase of the software testing process. During UAT, regular users who will be interacting with the infotainment system called as "drivers" are the test participants. The reason for selecting drivers as testing participant is their experience about the driving and distraction from the road. In the design process of a software, every type of user should be considered for the target audience. For example, passengers who would like to be more engaged with multimedia part of the system will require different functionalities. When it comes to user acceptance testing, our project mission is to reduce road distraction while enhancing functionality and user experience so that we will be using main drivers mostly instead of passengers.

Participants;

1. **Gurur Yigit, 21 – Driver for 3 years**
2. **Batuhan Toprak, 21 – Driver for 3 years**
3. **Can Bankeroglu, 21 – Driver for 3 years**
4. **Alp Bankeroglu, 21 – Driver for 1 year**
5. **Omar Alharbi, 22 – Driver for 4 years**
6. **Tariq Alshlash, 22 – Driver for 4 years**
7. **Jesus Gallegos, 19 – Driver for 2 years**
8. **Jake Purcell, 19 – Driver for 1 year**
9. **Reuben Hoyte, 20 – Have no driving licence**
10. **Enes Kaya , 20 – Driver for 2 years**

All participants have signed a consent form for taking place in this testing process.

4.4.1 Script for UAT

- Go to dashboard which is located on the main page
- Navigate to the previous page
- Go to climate control for changing temperature
- From this screen please navigate to Spotify app
- Navigate to radio app
- Find the detailed weather app
- Navigate to the multimedia app selection screen
- Navigate to "Apple Music" app
- Change the input for media
- See the error message

4.4.2 Feedbacks and comments

This section contains feedback and comments we have received from user's that have tested our system.

TEST 1 (Flat Design)

Every participant except 10 – All of them confused the weather app widget on the main "Home" screen with climate controls. Everyone suggested it should be somewhere else, preferably in the status bar

Participant 4 – I did not understand what are the logos used in the "Dashboard" screen are representing. Also the fuel economy button in the main screen was so confusing to read.

Participant 5 – Everything was smooth and working as intended.

Participant 6 – Everything was smooth and working as intended. Improvements could be done on colour theme.

Participant 8 – Map on the main "Home" screen was not functional. Point of interests could be shown on the small map for more information. Having a UK house inside the button "Take me Home" and other pictures as UK culture is a nice touch.

Participant 10 – System looks outdated, colours can be changed to light blue to give more appealing look. I did not like the Radio app being the same as Apple Music and Spotify.

- Other participants had no comments for the test. Everything was OK for them. -

TEST 2 (Flat Design) – with some improvements were made

All participants agreed on – Changing the location of the weather widget more closer to status bar made everything much clearer and this time they did not confuse with the "Climate Control" button. Also, we tested this feature on some new people that never user the system before. Again, no mistakes has been made.

Participant 2 – Radio and multimedia applications are still looking the same and I'm having trouble to understand how they work. Play/pause button should be larger than "Repeat, Mix" buttons.

Participant 7 – This time I had problems with multimedia apps, did you change anything? (No we did not but some users have confused using the multimedia apps in the second time because they were more focused on 3rd party apps rather than main "Home" screen which they tested and saw improvements)

- I decided to redesign the multimedia apps with Material Design to see any changes-

TEST 3 (Material Design) – with new multimedia app layout

Participant 1, 4, 6, 7, 10 – They definitely did not like the Material Design Theme Colours. They said the colour scheme does not affect anything to the usability, but previous colour choices were much better and futuristic then this one.

Participant 4 – This design looks much cleaner and simple than the previous one even though the bad colour scheme. Shadows underneath the logo and buttons are making everything much easier to read.

Participant 6 – It looks more like Android. Other design was much sleeker and clean but this one allows me to understand the context more easily and the new multimedia applications are much convenient than the previous ones. I liked the fact that the controls are coming up after I touch to the screen.

Participant 8 – Multimedia applications are much better now. Design is bad, it doesn't fit to a car infotainment system. It more looks like an Android phone, otherwise everything is great and functional.

At the end of the tests I concluded that, having a user feedback is very useful and should be always considered as a part of the development process. It allows developer and the designer to notice very absurd mistakes that has been discarded because they are expert enough to understand how the system works. Users are usually noticing very different aspects of mistakes that the developer might not even think about. For example, climate control button and weather widget were totally different things for me and I never thought people might have problems with confusing these both. On the other hand, developers also should not listen everything that a user suggests because they don't have the expert knowledge enough to evaluate the system's usability and sometimes the recommendations from them is making the system much worse. So, it is the best to stay between both.

4.5 Interaction and Usability

Before discussing the interaction styles that will be used in our software, safety measures must be evaluated. In 2017, there were 2,823 road crashes in Britain in which distraction in the vehicle was deemed a contributory factor, making up 3% of all road accidents. This included 79 fatal accidents and 469 accidents in which someone was seriously injured. **[20]** Tasks done in the infotainment system such as listening to radio and changing songs are often accepted socially. But nowadays car infotainments are containing complex function and screens that even makes changing a radio station very hard and sometimes distracts the user from the road. This is where human computer interaction professionals make a difference in the software that they are designing. Distraction arises with the combination of three resources; cognition, visual and interference. Cognitive distraction happens when the driver's attention is carried over the infotainment system rather than the road. Visual distraction happens when driver takes their eyes from the road. Lastly, interference is caused by the driver pulling their hands of from the wheel to interact with the system. When all of these taken to consideration, a balanced design must be created to avoid any distraction. In our system, touch interface with haptic feedback will be used. Although hard (button) interaction can be used, haptic feedback combined with gesture enabled touch screen reduces distraction more compared to hard interaction.

4.6 Professional Issues

As a computer scientist, being ethical is one of the most important duties that everyone should have. Also stated in British Computing Society website as "Code of Conduct", some certain rules must be followed in order to approach production in the most ethical way. The first issue can happen in every research related work is plagiarism. Any type of information or design should not be copied directly from other people's work and also there should be no excess influencing from other people's work than can also count as plagiarism.

Another aspect for being ethical which is very important for this type of work is using HCI fundamentals in a good way. Agreements or marketing plans made with 3rd party corporations should not be confidential from the user. A designer can use their knowledge in Human Computer Interaction to make a button in the car infotainment software more appealing or selective for example like "Spotify". This can be used in order to manipulate

user's attention in a subliminal way forcing them to use the specific application maybe because there are marketing contracts that has been signed with the infotainment producer. While designing the infotainment system, although the design is unique, there will be licencing issues with Material Design that has been used to achieve universal recognisability. Since Google corporation is the owner of this design concept, they will not allow a 3rd party to create a whole different system that is not using Google's internal software and operating system to run. Licencing issues will be not applicable for Flat Design because it is open source and can be used by everyone. Flat Design has no owner patent whereas Material Design does.

One of the most important issues that can be encountered with is safety. Designing a car infotainment system requires vast amount of research on road safety and driver distraction to minimize confusion and usage time while the driver (user) is using the system. Making a wrong design without following the fundamentals of HCI can lead to serious problems like accidents and can harm properties and people. I believe this is one of the most crucial issues because it involves other people's lives and materialistic value. Also, every country has their own road legislation rules that requires all the systems should have a certain standard because of the different types of road structures used. Importance of information security and intellectual property is also very crucial when it comes to privacy and safety. New car infotainment systems are holding valuable information about the drivers such as their preferred configuration that can include seat controls, climate settings, car settings, radio presets, contacts, phone conversations, messages, navigation info, etc… Breach into the infotainment system can cause very serious problems with integrity and intellectual property so it should be considered very carefully. This critical approach to the ever-emerging understanding of Intellectual Property and the value of preserving its integrity also gave me a solid basis of knowledge for oncoming professional experiences as well.

Providing wrong information to user about the system status is also one of the issues that can be encountered. The software should be always providing live, up-to date information to the driver in order to avoid any kind of misunderstanding. This is one of the rules in Nielsen's Heuristics for user interface design as "Visibility of system status". Giving the user wrong information can lead to diagnose wrong solutions for maintenance or for the breakdowns that the car itself caused. In result of this, someone can be injured, can lead to an accident or can end up with damage to property. For example, providing wrong information in TPMS (Tyre Pressure Monitoring System) can result in tyre blow and can cause serious accidents with injuring others as well.

In one of the experiments that my supervisor provided myself which is called "Case of the killer robot", importance of professional issues can be seen very clearly. The case includes a story about a production plant robot which has only keyboard input and it's far away from the place where engineers read about the user manual about the robot to make inputs on the system. Alongside with having just a keyboard for input, drop down menu based interaction used which is very irrelevant with the input device they used. There was a malfunction on the robot arm which started to shake itself very violently thus there was no emergency stop functions in the software and it was taking time to stop the machine, during that time the operator was killed by the robot arm. Both environmental design issues and bad software design played role in the result. This case study is a very good and sad example to understand the importance of HCI fundamentals.

4.7 Storyboards (Flat and Material Design)

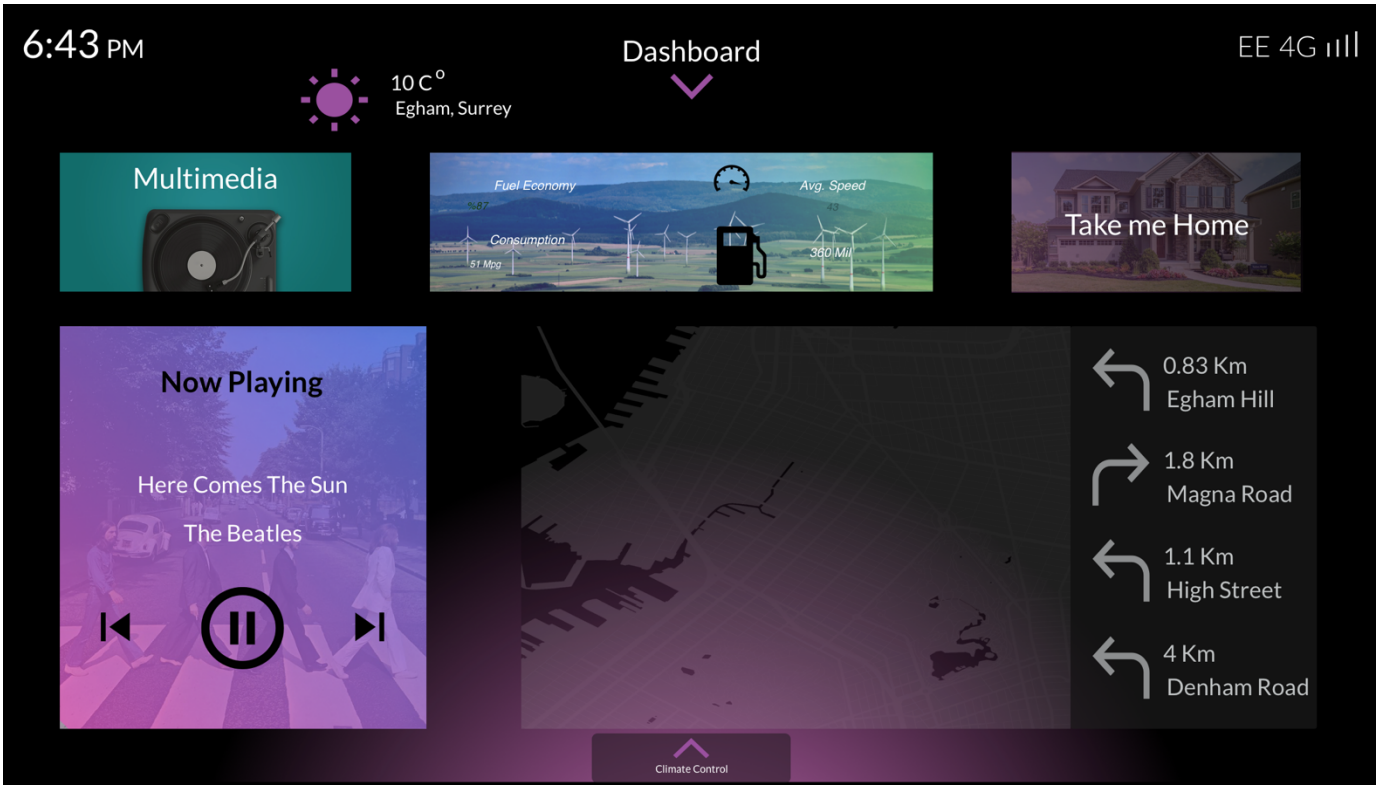


Image 4.1 Main "Home" Screen in Flat Design

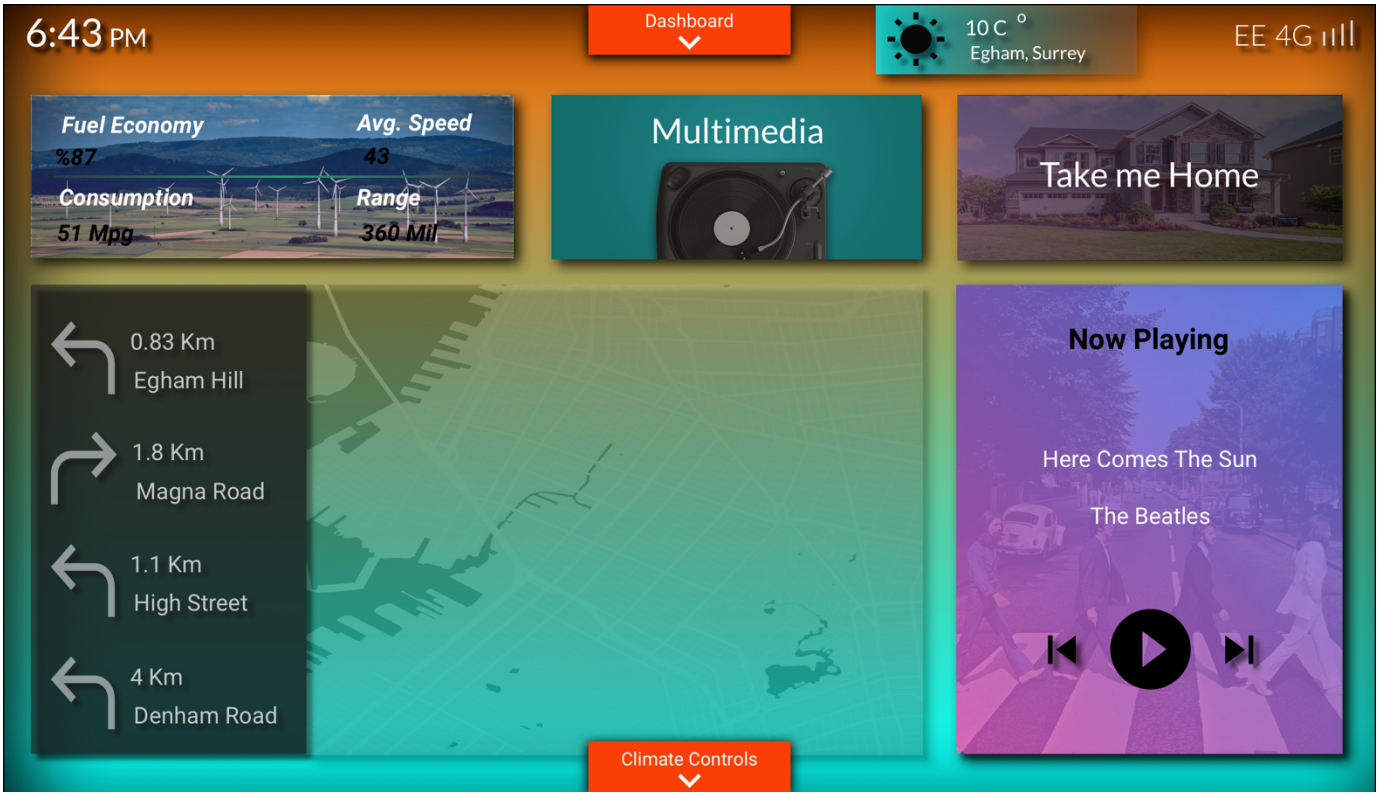


Image 4.1.1 Main "Home" Screen in Material Design

UI Element	HCI Concept	Description
Background colour	Colour Theory	Blue background with orange gradient has been applied to manipulate user's mood to uplift. (Relaxing mood with Purple background in Flat Design)
Multimedia button colour	Colour Theory	Creating a contrast between background colour with a pleasing colour creates a cue for user to distinguish a button. Shadow and 3D bezels helps it more. (In Flat this is not so achievable)
UI element colour	Navigation and Visual Perception	Orange buttons added on top of bright background for giving a cue to user where to interact (In Flat, purple buttons)
System Font	Font	"Roboto" font is used to enhance recognition of text from a LCD screen. (In Flat, "Lato" is used)
UI elements organisation	Minimalistic	Following a minimalistic design language by just providing the relevant information
Button click feedback sound	Auditory Perception	Auditory feedback given to user when they click a button.
Images used in buttons	System match with real world	Enhancing the recognisability of functions throughout the system

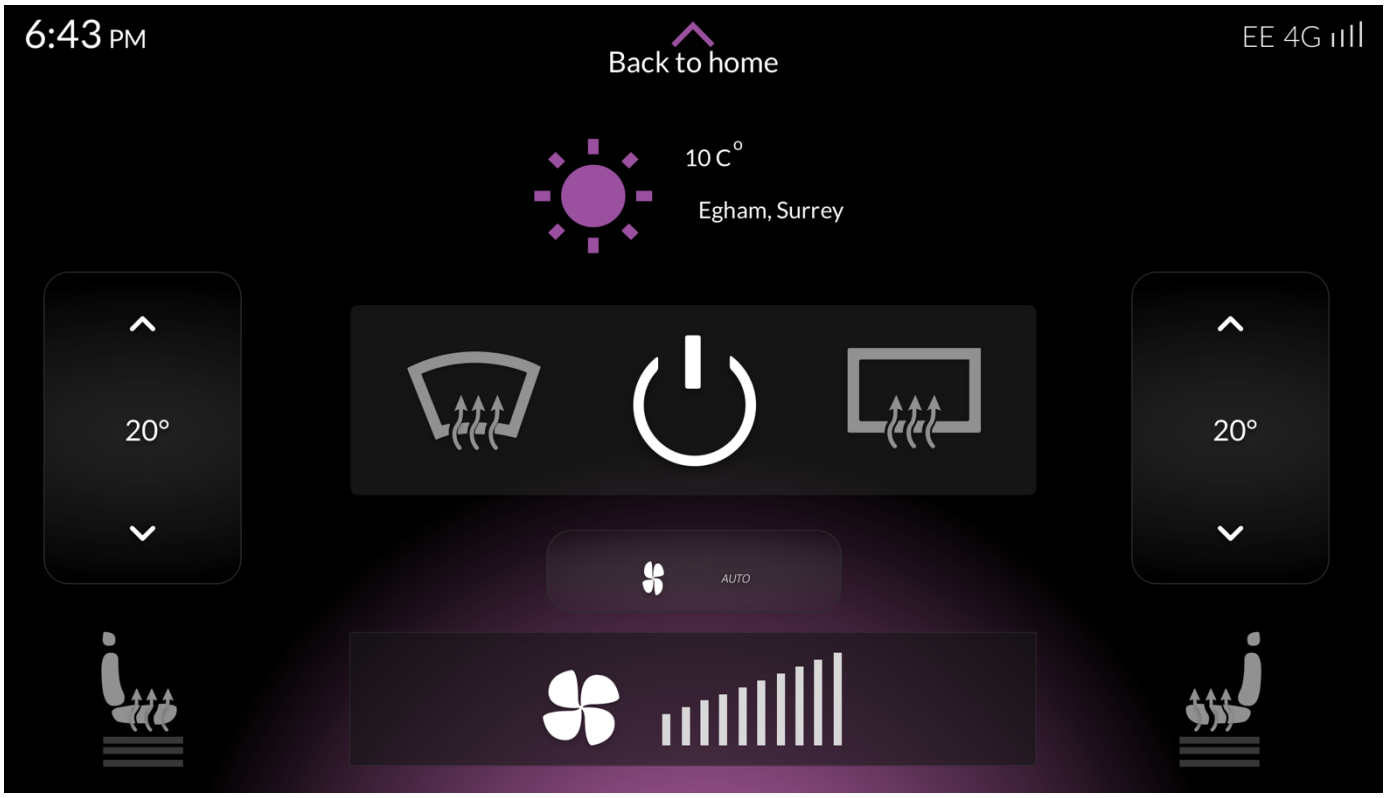


Image 4.2 Climate Controls Screen in Flat Design

Image 4.2.1 Climate Controls Screen in Material Design

UI Element	HCI Concept	Description
UI element colour	Navigation and Visual Perception	Purple buttons added on top of black background for giving a cue to user where to interact
Vectoral icons for climate control	Usability	Big, high resolution icons are making interaction more easy on a touch screen
Size of the buttons	Recognition rather than recall	Large buttons are enhancing the recognisability while vehicle in motion
Change in colour of a button after input has been made	Visibility of system status	User can easily understand if a function is on or off

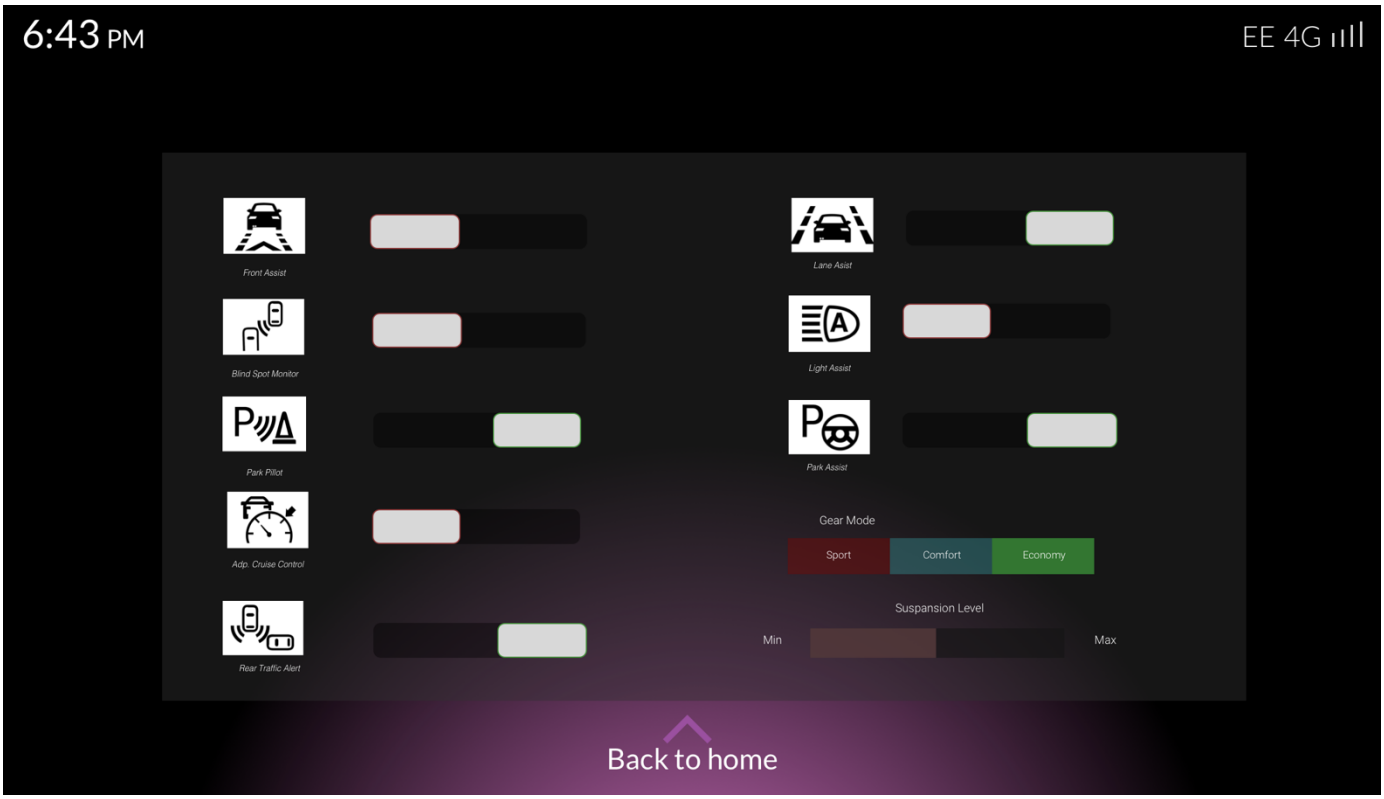


Image 4.3 "Dashboard" Screen in Flat Design

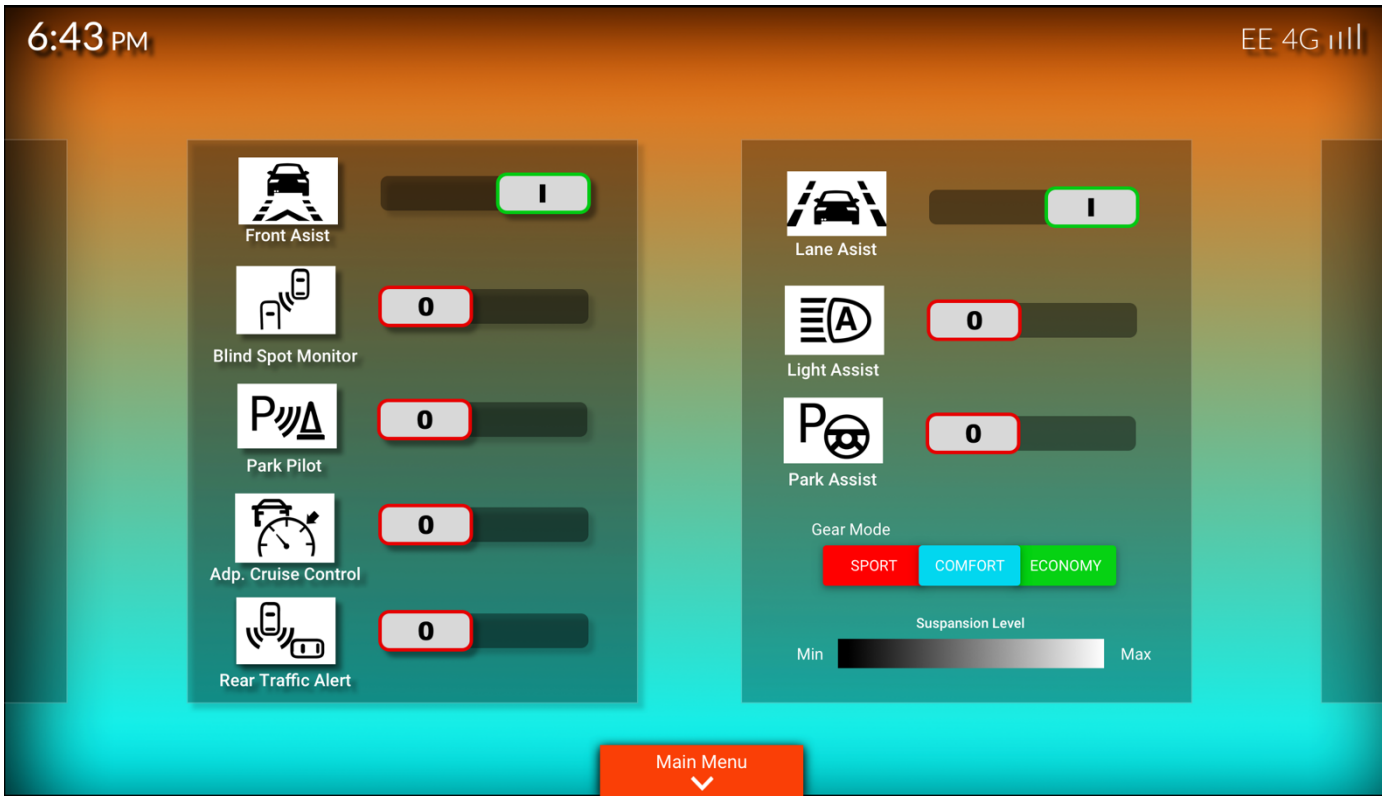


Image 4.3.1 "Dashboard" Screen in Material Design

UI Element	HCI Concept	Description
Icons used for car system functions	System match with real world	Using universal icons for functions are enhancing the recognisability
UI element colour	Navigation and Visual Perception	Purple buttons added on top of black background for giving a cue to user where to interact
ON/OFF buttons	Visibility of system status	Sliding buttons allowing users to understand whether a function is on of off
Shown specific functions	Aesthetic and minimalistic design	Including essential car functions with no other not necessary information is good for ease of use and context understanding

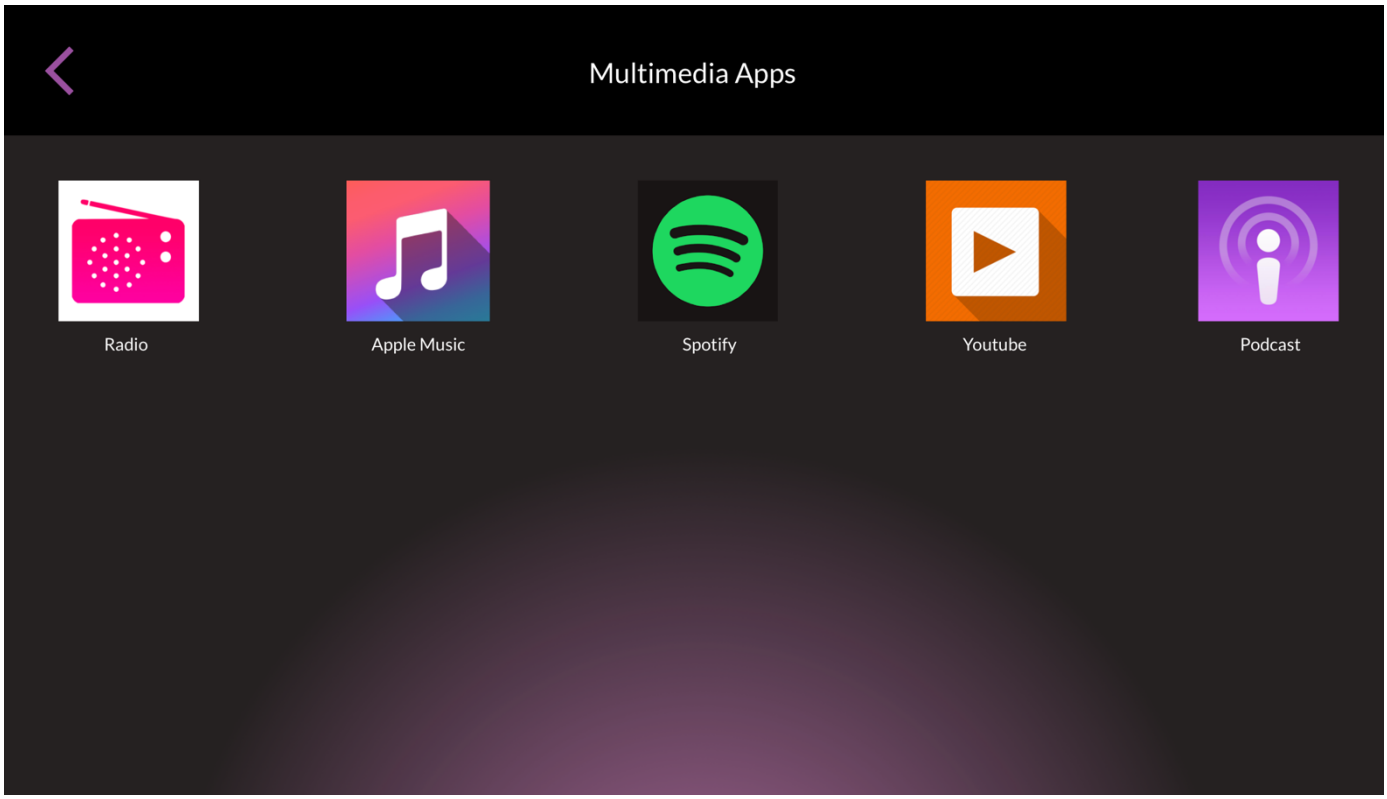


Image 4.4 App selection Screen in Flat Design

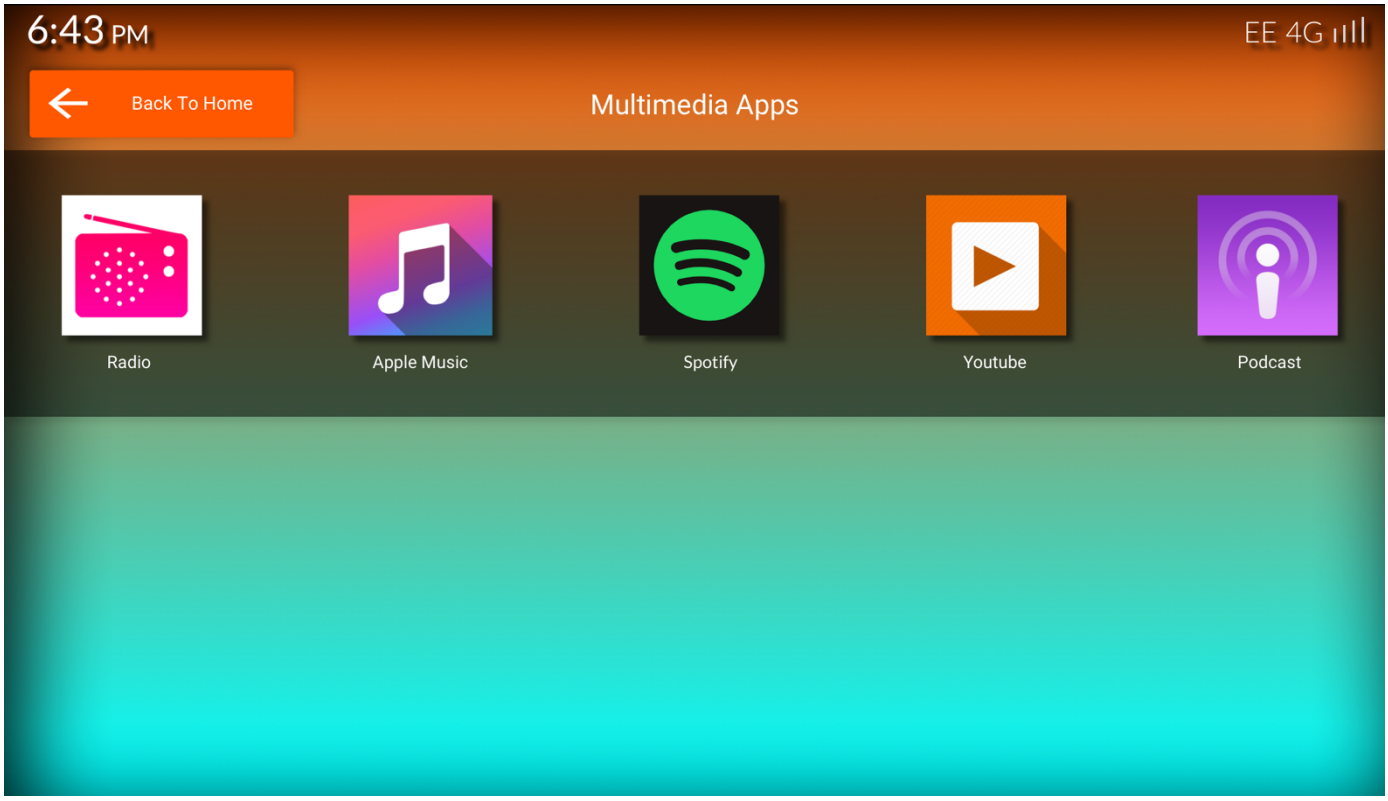


Image 4.4.1 App selection Screen in Material Design

UI Element	HCI Concept	Description
Real logos for applications	Consistency and standards	Using real logos for specific applications result in easier recognition of the context
Using logos over text	Aesthetic and minimalistic design	Maintaining security by decreasing distraction time from the road

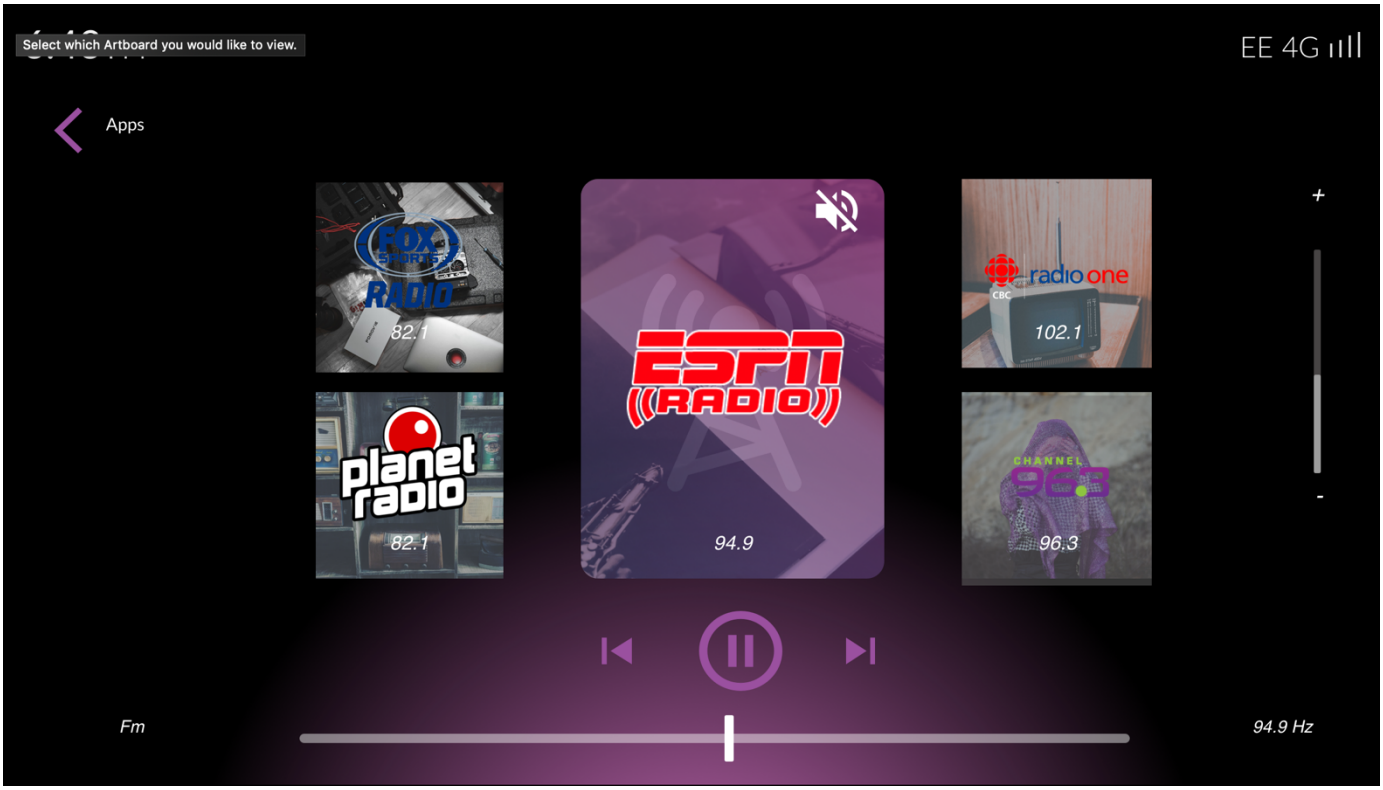


Image 4.5 Radio App Screen in Flat Design

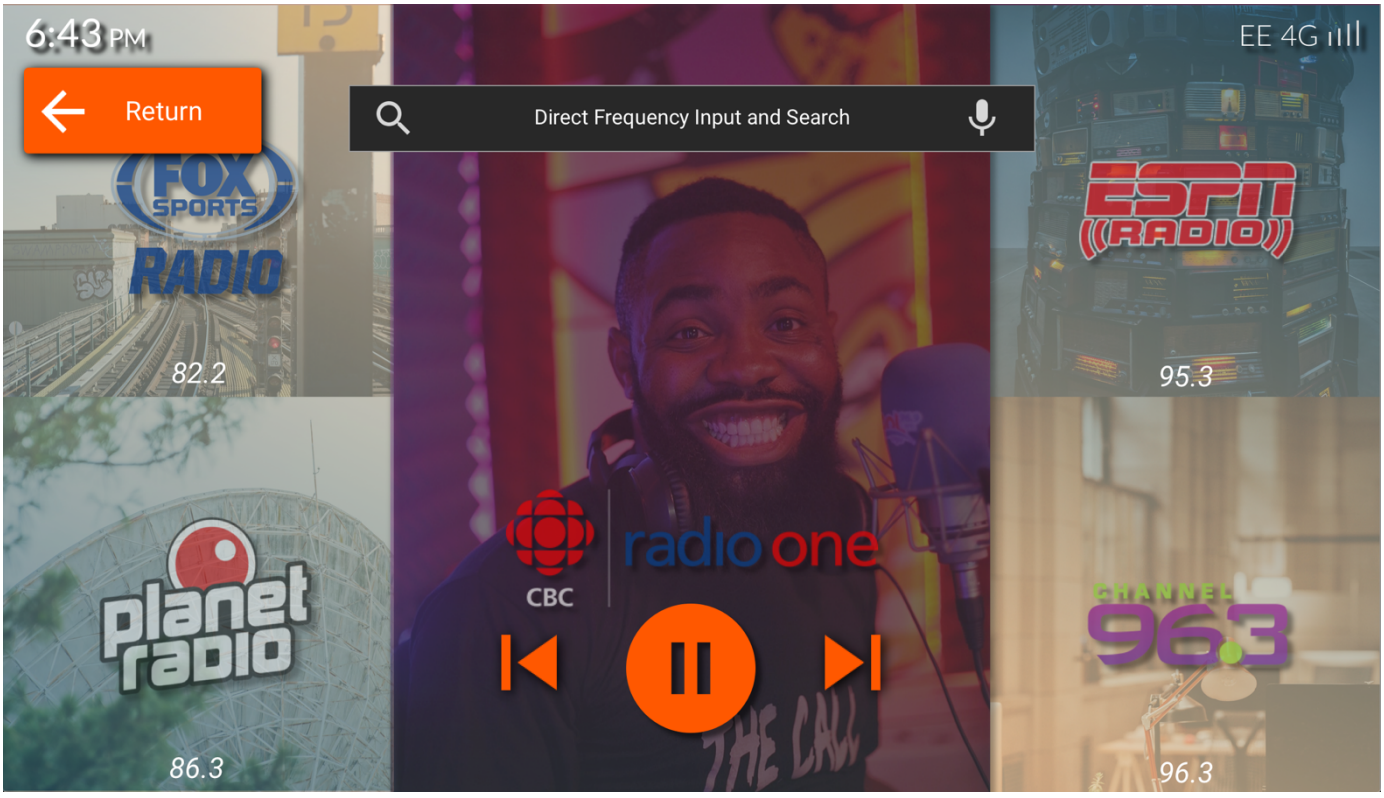


Image 4.5.1 Radio App Screen in Material Design

UI Element	HCI Concept	Description
Status bar visibility	Consistency and standards	Having the status bar fixed but changing it's functionality though pages is maintaining consistency
FM destination bar	Visibility of system status	User can always see which channel are they listening to
Using big logos	Recognition rather than recall	Better recognition (Big logo over text) Also maintaining safety

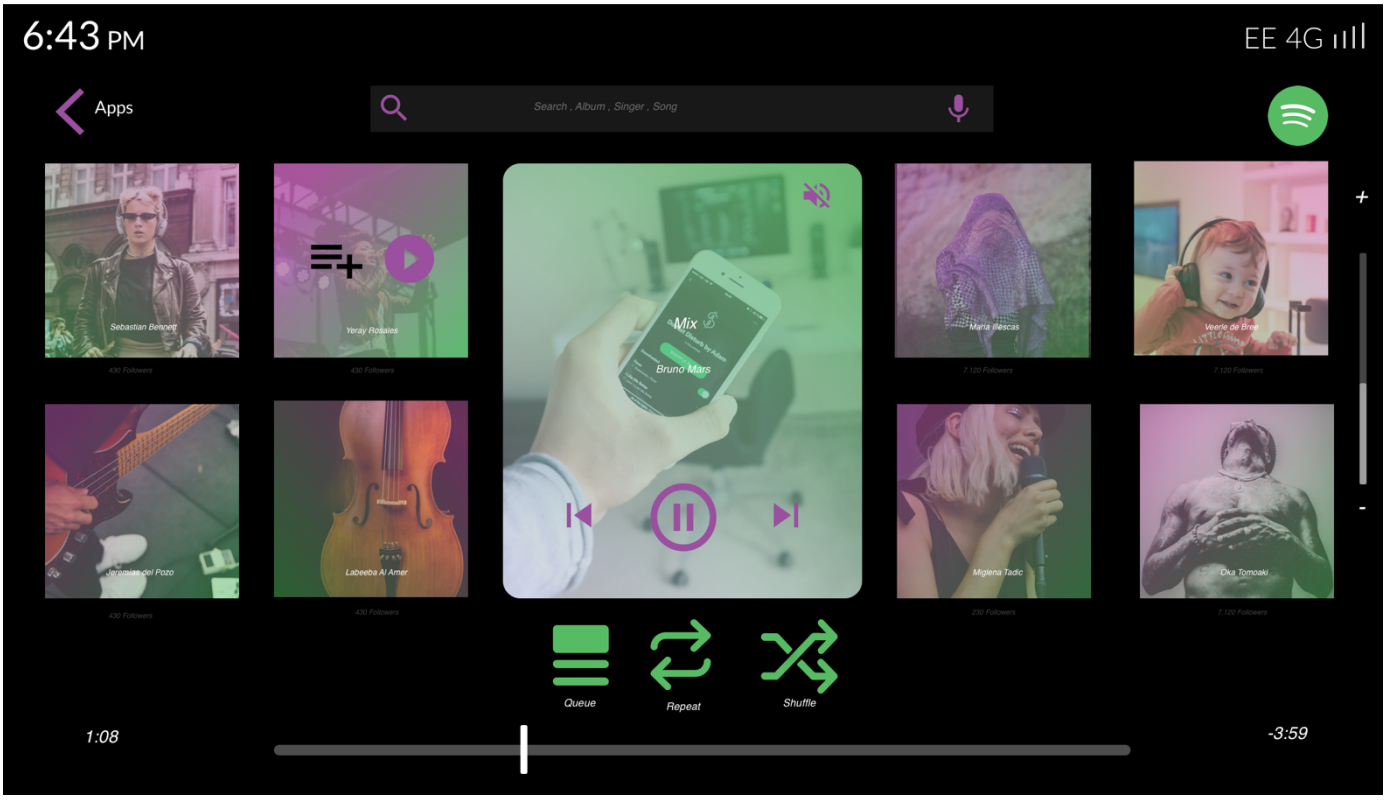


Image 4.6 Spotify App Screen in Flat Design

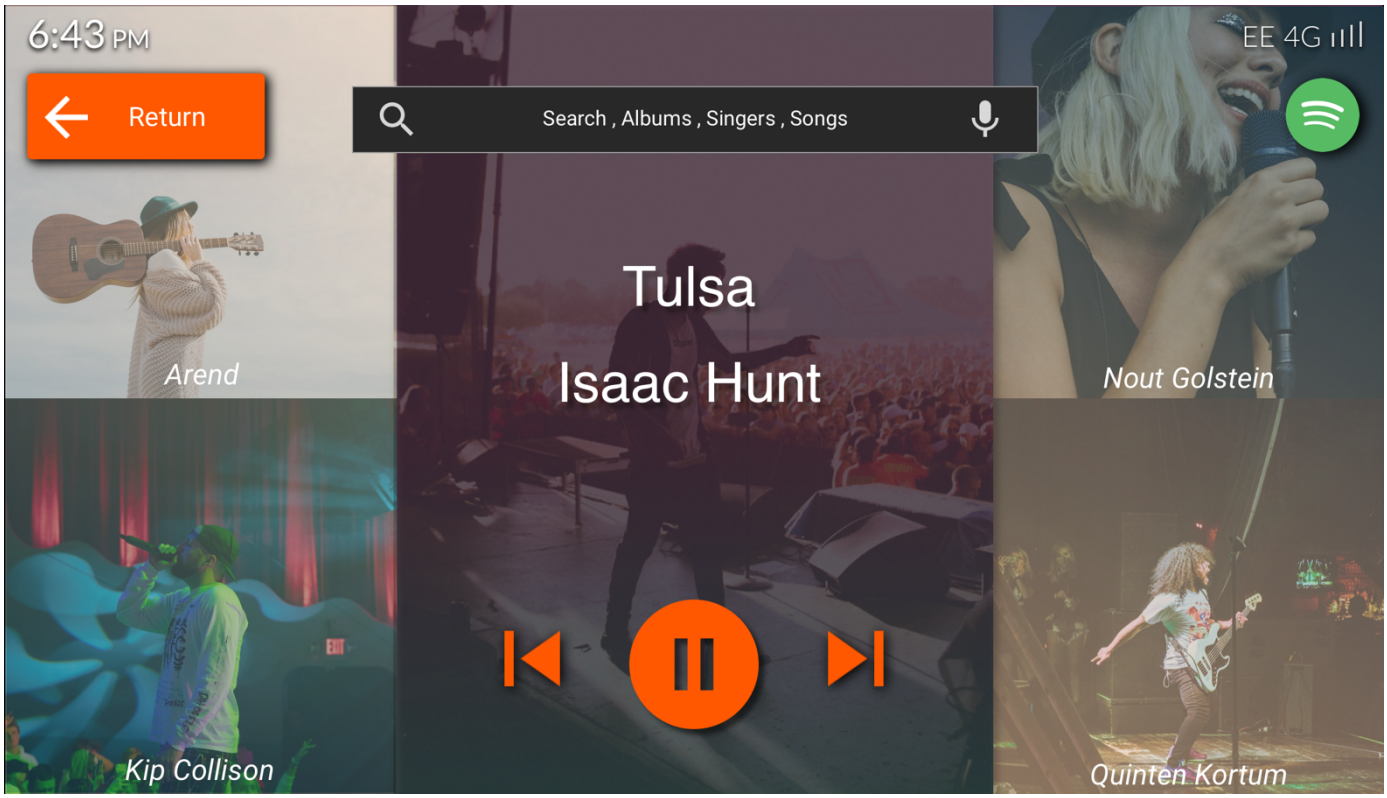


Image 4.6.1 Spotify App Screen in Material Design

UI Element	HCI Concepts	Description
Using similar design throughout the media apps	Consistency and standards	Improving ease of use by reducing complexity of the context
Having a time bar	Visibility of system status	System is always providing current status of the music, context
Gradient colour of the specific application applied throughout the media app	Recognition rather than recall	Giving cues to the user for understanding which application they are using

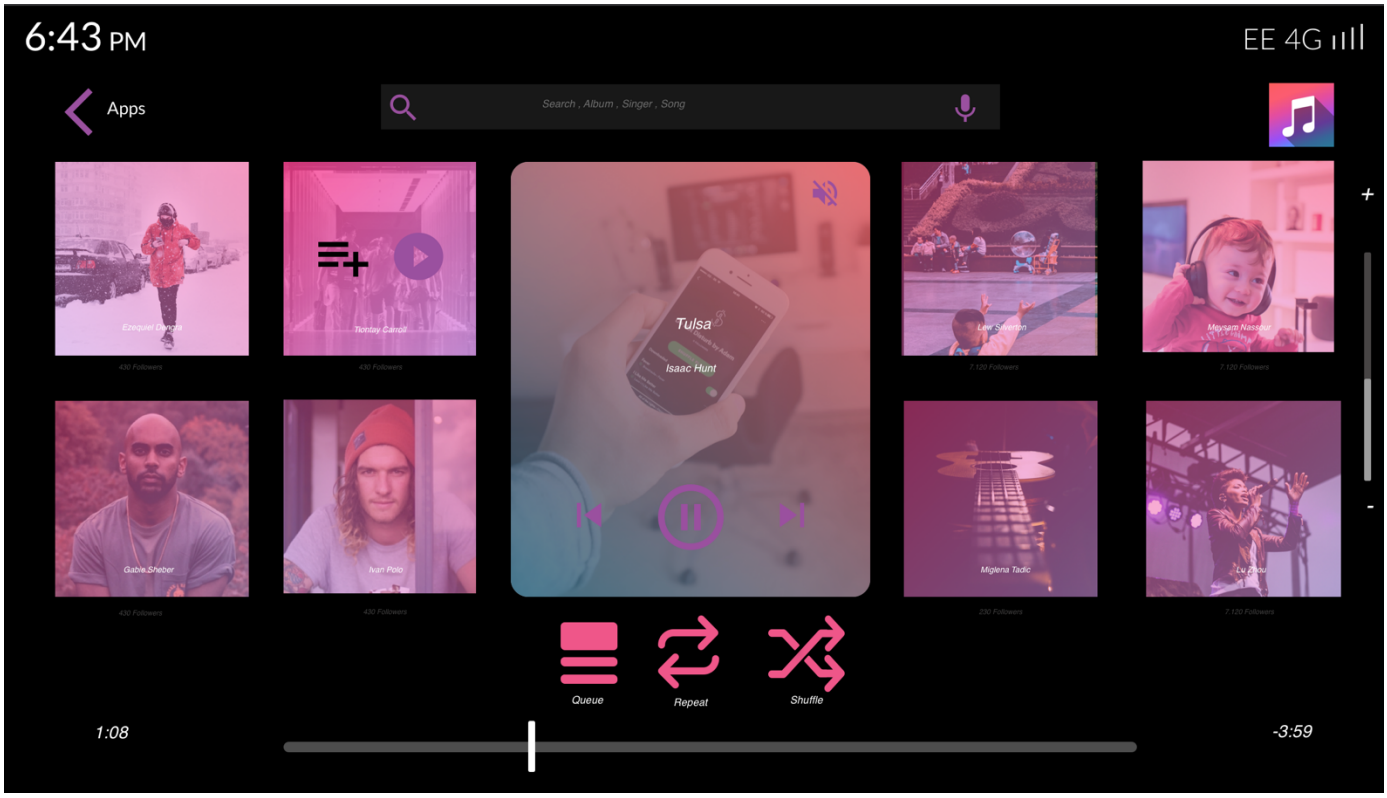


Image 4.7 Apple Music App Screen in Flat Design

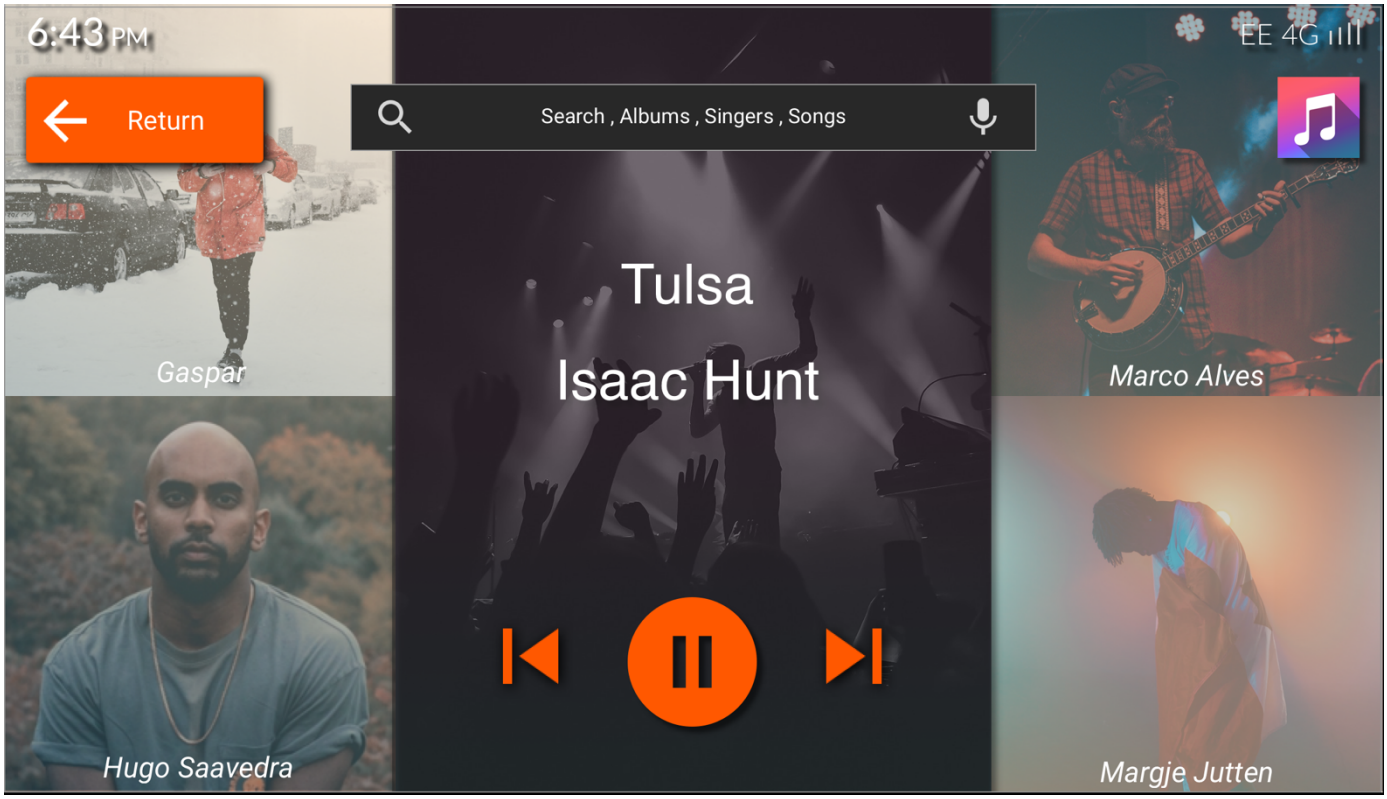


Image 4.7.1 Apple Music App Screen in Material Design

UI Element	HCI Concept	Description
Using similar design throughout the media apps	Consistency and standards	Improving ease of use by reducing complexity of the context
Having a time bar	Visibility of system status	System is always providing current status of the music, context
Having the correspondent app logo on the top right corner	Recognition rather than recall	Easily understandable context by the user
Having a search bar	Flexibility and efficiency of use	Accelerating the interaction with the system for expert users

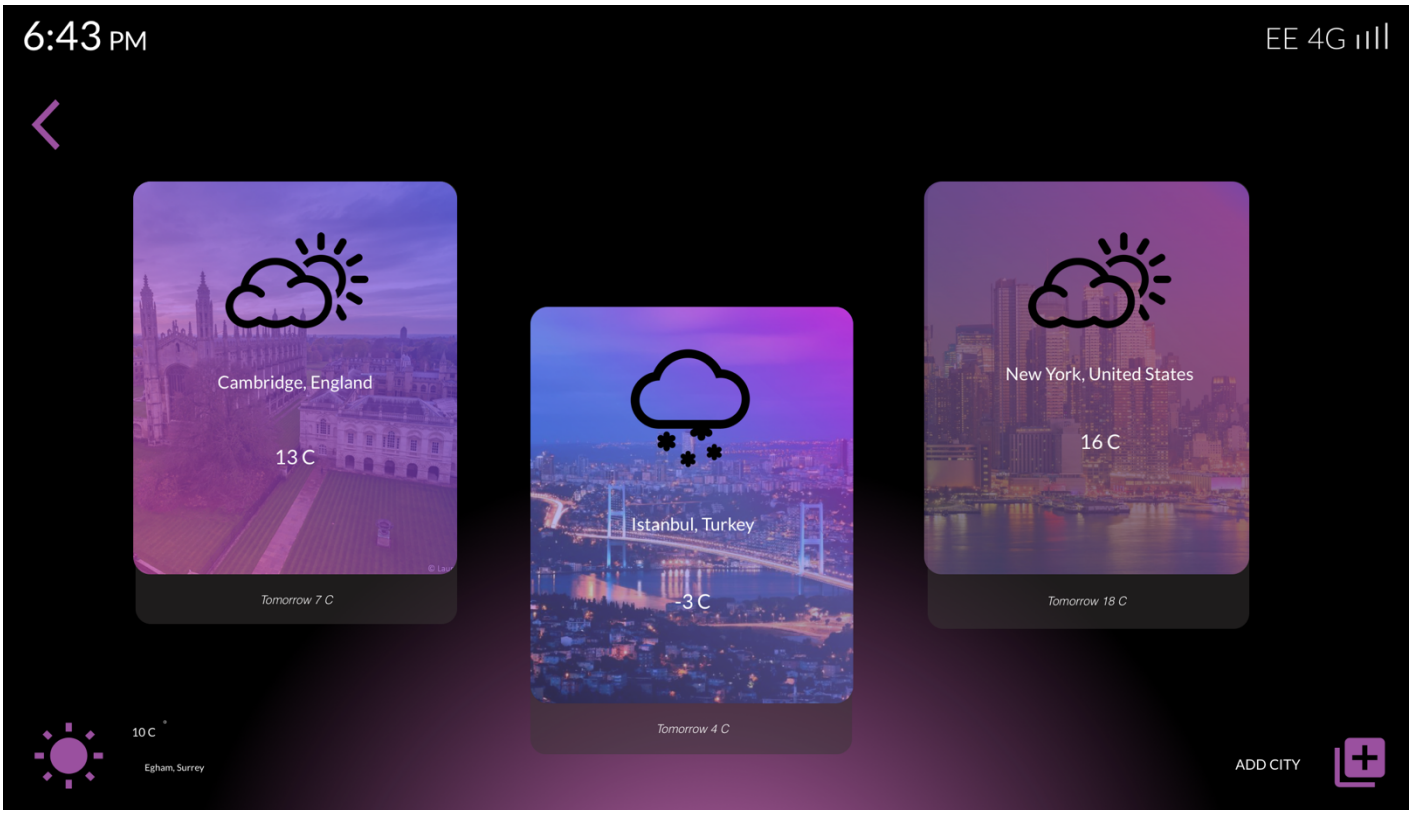


Image 4.8 Weather App Screen in Flat Design

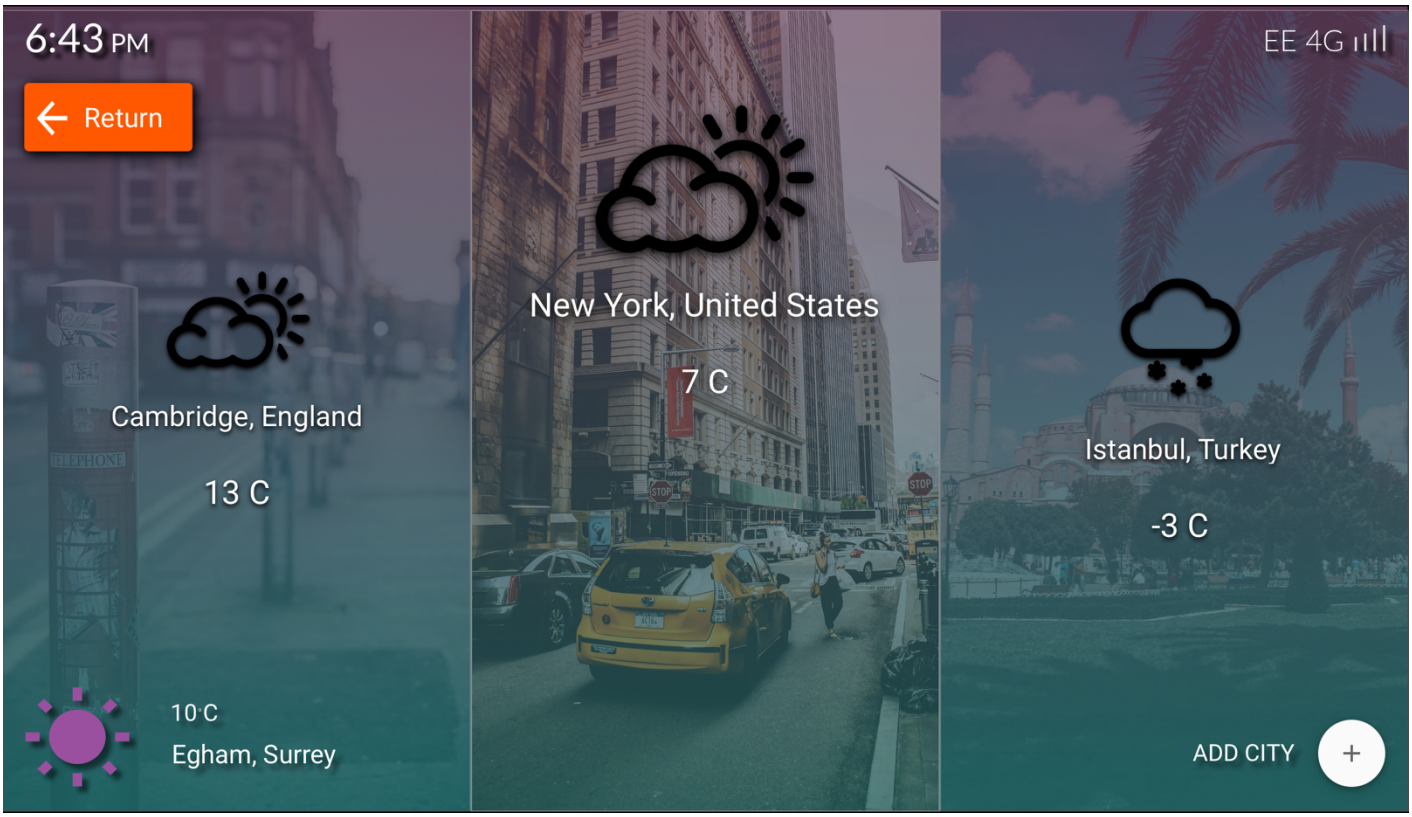


Image 4.8.1 Weather App Screen in Material Design

Project Diary

October 14, 2018

I made the first report for my project explaining the general concept and what to do in the project in brief explanation. I submitted it. Waiting for feedback.

February 11, 2019

For the past 2 weeks, I was reading the book called “Human-Computer Interaction” by Pearson to understand the key elements of HCI and how a design should be implemented in software in terms of usability. Learning key concepts like design process, human perception, the interaction methods and task analysis helped me to develop a more structural prototype for my final software.

February 11, 2019

I wrote approx. 4000 words for the draft report by briefly explaining the key concepts I learned from the book I read. In the following days, I will be implementing the prototype as explaining every element and design guidelines used to develop software.

February 14, 2019

Changes made on the first draft of the report. Research has been done to decide whether to design a car infotainment system by using Material and Flat Design Guidelines or c2c website in same design languages. Started to use prototyping tools.

February 17, 2019

Prototyping has started, firstly I designed my software on Microsoft Publisher to see the interaction styles and this design was implemented with the prototyping tool called “Sketch”.

February 19, 2019

Identifying user stories and adding them to the report. This will also help with UAT testing when users will try the software.

February 25, 2019

A vast amount of research has been done on fundamentals of HCI and human perception to increase user experience on the software. Research has been implemented in the report as a whole chapter. 4 pages are created in 2 different design languages in storyboard as “Dashboard”, “Air Con”, “Media”, “Navigation”. User stories and cases are identified.

February 28, 2019

HTA diagram for the “car infotainment” software has been drawn and implemented in the report.

March 04, 2019

An updated version of the report shared with the supervisor. Professional issues are briefly identified based on the article “Killer Robot” which is talking about crucial mistakes happened in touch screens due to bad design. I believe this example will emphasise the importance of HCI in different applications. HTA has been removed due to make more detailed changes.

March 10, 2019

For user acceptance testing, the people who will try the software is identified and already taken them consent. HTA diagram has been implemented and put back into the report again. Also, more information about Flat and Material design given in order to understand what HCI fundamentals used to achieve these design guidelines.

March 15, 2019

A script for user acceptance test is completed. It includes basic functions of a car infotainment system as changing the climate controls, playing music and changing the media input. Also, more information is added to the report about the design guidelines to mention the problems that the existing designs have. This will help to avoid making the same mistakes when designing the software.

March 18, 2019

First user acceptance testing made for evaluating the navigation system used in the design. UAT was done on flat design.

March 25, 2019

Project presentation is prepared, all citations for the references in the report is done. The project report is ready for draft submission.

April 25, 2019

All UAT tests are done, the report is crafted to it’s finest detail and ready for final submission. (Some changes have been made according to the feedback from supervisor) A3 poster has been also done for project demos.

April 29, 2019

User manual completed and added to the report. Last checks are done. Project is ready to submit.

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