Next-Generation Smart Cars:

Towards a More Intelligent Interactive Infotainment System

by

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ABSTRACT

Today, in a world of automation, the impact of Artificial Intelligence can be seen in every aspect of our lives. Starting from smart homes to self-driving cars everything is run using intelligent, adaptive technologies. In this thesis, an attempt is made to analyze the correlation between driving quality and its impact on the use of car infotainment system and vice versa and hence the driver distraction. Various internal and external driving factors have been identified to understand the dependency and seriousness of driver distraction caused due to the car infotainment system. We have seen a number UI/UX changes, speech recognition advancements in cars to reduce distraction. But reducing the number of casualties on road is still a persisting problem in hand as the cognitive load on the driver is considered to be one of the primary reasons for distractions leading to casualties. In this research, a pathway has been provided to move towards building an artificially intelligent, adaptive and interactive infotainment which is trained to behave differently by analyzing the driving quality without the intervention of the driver. The aim is to not only shift focus of the driver from screen to street view, but to also change the inherent behavior of the infotainment system based on the driving statistics at that point in time without the need for driver intervention.

DEDICATION

I would like to dedicate this work to my parents Suresh Mithanthaya and Latha Suresh, my brother Akshay Mithanthaya, my partner Sandeep Kowligi, my colleague and friend Guru Srikar, family and friends for their support.

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

CHAPTER Page

LIST OF FIGURES

FIGURE Page

LIST OF TABLES

TABLE Page

LIST OF ABBREVATIONS

1. NHTSA – National Highway Traffic Safety Administration
2. AAA – American Automobile Association
3. IVI – In-Vehicle Infotainment
4. LRU – Least Recently Used
5. MRU – Most Recently Used
6. LFU – Least Frequently Used
7. AASHTO – American Association of State Highway and Transportation Officials
8. ADAS - Advanced Driver-Assistance Systems
9. SAE – Society of Automotive Engineers
10. GPS – Global Positioning System
11. UI/UX – User Interface/User Experience
12. AC – Air Conditioning
13. ESC - Electronic Stability Control

CHAPTER 1

INTRODUCTION

Driving is the controlled operation and movement of a motorized vehicle with wheels, such as a car, motorcycle, truck, or bus by either a human or computer controller. [1] The streets of today in the US has more than 253 million running cars and trucks. [2] The number itself shows how driving is a part of everyday chores in most people's lives in America and yet driver safety was and is one of the prevailing primary concerns in the society.

We have seen several improvements in the mechanics of the car like the ESC, Forward Collision Systems, Adaptive Headlights, Lane Departure Warning Systems and others. But despite all these advancements, it is estimated that "Collectively, over the next few years, the improvements in technology will allow us to take fatalities down from the mid-30,000s to the lows 20,000s in terms of numbers of deaths." [3] This is one of the primary motivations to this research. No matter how much we are moving ahead with the technology, the fear of accidents leading to fatalities, deaths, damage to property/infrastructure still prevails. As we have seen and known, one of the primary concerns for today's road safety is driver distraction.

The National Highway Traffic Safety Administration (NHTSA) estimates that at least 3,000 [5] deaths per year involve distracted driving, though the true number is likely far higher. The following statistics help put the dangers of distracted driving into context: [26]

1. "Taking your eyes off the road for more than two seconds doubles your risk of a crash.
2. When driving 55 miles per hour, five seconds with eyes off the road is equivalent to driving the length of a football field blindfolded.
3. Distraction is a factor in nearly 6 out of 10 moderate-to-severe teen crashes.
4. About 87 percent of drivers engaged in at least one risky behavior while behind the wheel within the past month, per latest research by the AAA Foundation for Traffic Safety. These unsafe behaviors include driving while distracted, impaired, drowsy, speeding, running red lights or not wearing a seat belt. These disturbing results come as nearly

33,000 Americans died in car crashes in 2014, and preliminary estimates project a nine percent increase in deaths for 2015.

5. 1 out of 4 car accidents in the US are caused by texting while driving.
6. When polled, 77% of adults and 55% of teenage drivers say that they can easily manage texting while driving.
7. When teens text while they drive, they veer off lane 10% of their total drive time.
8. A study at the University of Utah found out that the reaction time for a teen using a cell phone is the same as that of a 70-year-old who isn't using one.
9. 48% of kids in their younger teenage years have been in a car while the driver was texting. Over 1600 children in the same age group are killed each year because of crashes involving texters."

Further, Figure 1 shows the number of kills that were reported due to driver distraction over the years 2010-2014.

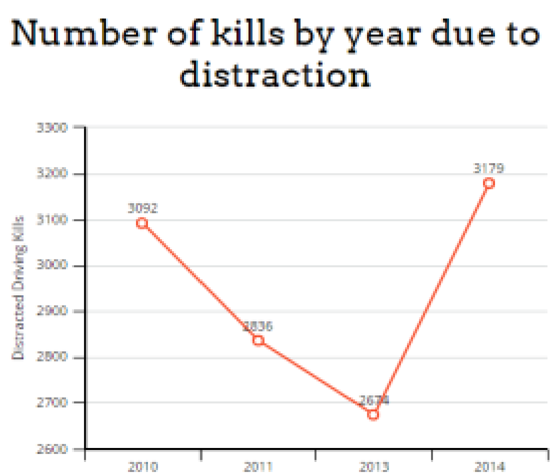

Figure 1 – Number of kills due to driver distraction

The above Figure 1 depicts that the deaths occurred because of driver distraction is a persisting problem and this draws concerns. No matter how advanced we are getting in the age of computers which is also reflected in cars, curbing distraction is now a greater challenge than ever before for the following reasons:

1. With technological advancement number of handheld, portable devices are huge in number and is used by people of all ages.

2. Distraction now involves a mixture of reasons that adds more danger to the life of the person behind the leaves. It now can be a mixture of visual-cognitive distractions

In this research, the variables are classified into two categories to show factors that cause distracted driving and factors that reflect/show distracted driving and co-relation between each is measured using statistical analysis techniques. The hope was to be able to gauge and direct focus to the driving factors that will help in building a car center stack that is trained with data to alter the way it behaves during the various distraction levels.

CHAPTER 2

BACKGROUND

This chapter introduces the user to the technology in car and how it has advanced from computers in cars to infotainment and driverless cars to give an overview of what are the pros and cons of the technologies, the kinds of distraction that can arise because of infotainment system and hands-free devices. This chapter essentially allows the user to understand the technology in cars today.

The remainder of this chapter gives an overall background to this research starting from, section 2.1, the cars and computers, and then talk about ADAS in section 2.2. Next the matter under interest i.e. the Car Infotainment System in section 2.3 and the dangers of Distraction in section 2.4, prior solutions to distraction like Speech Recognition in section 2.5 and then a brief overview of what's there in the near future for technology in car that is the step towards self-driving cars describing the levels of automated cars in the section 2.6.

2.1 Cars and computers as we know today

"Software developers are turning cars into rolling personal computers. Lots of attention is still paid to horsepower, curves in the metal, and giving drivers the ultimate creature comfort behind the wheel: the ability to relax and let the car take over. But even as the industry accelerates toward a self-driving future, it's the touch screen in the dashboard and the slick smartphone app that increasingly sway buyers' decisions in the showroom" [41].

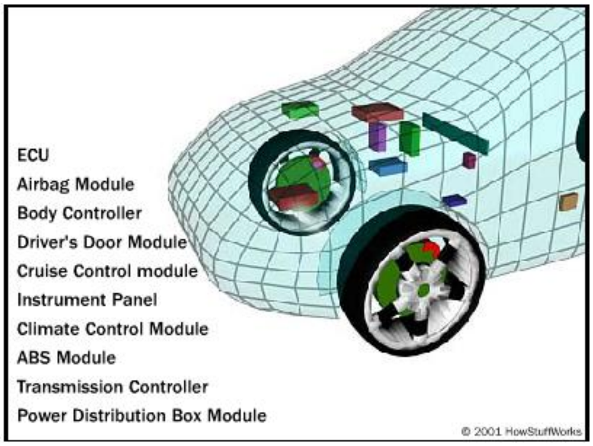

Figure 2. Computers or a car? Depiction of car as computer on wheels

Figure 2 illustrates the extent of computerized modules present just in the front wheels and engine area of a typical vehicle.

"Some of the reasons for this increase in the number of microprocessors are:

- The need for sophisticated engine controls to meet emissions and fuel-economy standards
- Advanced diagnostics
- Simplification of the manufacture and design of cars
- Reduction of the amount of wiring in cars
- New safety features
- New comfort and convenience features" [41]

Figure 3 shows a chip inside a Ford Ranger, which looks like any chip on a regular desktop or PC.

Figure 3. The computer from a Ford Ranger

2.2 Advanced driver-assistance systems (ADAS)

"These are systems developed to automate/adapt/enhance vehicle systems for safety and better driving. Safety features are designed to avoid collisions and accidents by offering technologies that alert the driver to potential problems, or to avoid collisions by implementing safeguards and taking over control of the vehicle. Adaptive features may automate lighting, provide adaptive cruise control, automate braking, incorporate GPS/ traffic warnings, connect to smartphones, alert driver to other cars or dangers, keep the driver in the correct lane, or show what is in blind spots." [26]

A number of researches are being carried out constantly to improve ADAS and its intuitiveness during driving. One of the recent researches with respect to ADAS was to improve road safety with the help of multimodal redundant warnings. The overview of this search is further a motivation to this thesis.

Some of the highlights of this research can be summarized as follows: [26]

- This study investigates the effect of multimodal warnings on drivers' behavior.
- Multimodal warnings produced faster responses than auditory, vibrotactile warnings.
- Multimodal warnings produced higher ratings of perceived urgency but not annoyance.
- Multimodal warnings were beneficial when using a phone or driving in dense traffic.
- Emergency situations are the appropriate conditions to employ multimodal warnings.

With the above results in mind, a further improvement in the behavior of the infotainment system that in turn helps in curbing the driver distraction is proposed in this thesis.

2.3 Car Infotainment System

"In-Vehicle Infotainment (IVI) is an auto industry term that refers to vehicle systems that combine entertainment and information delivery to drivers and passengers. IVI systems use audio/video (A/V) interfaces, touchscreens, keypads and other types of devices to provide these types of services." [10]

Though the earlier intentions of improvising the infotainment system was to enable ease of driving, the current situation is not quite the same. The technology and people have advanced to a level that the infotainment system is now expected to behave more or less like a smartphone. This might seem like an interesting and an innovative idea at first but it has effects that could cost one's life.

So, what are the advantages and disadvantages of the present infotainment system?

Pros:

- All-in-one smartphone like features
- Internet enabled systems
- Advanced, highly responsive User Experience
- Built-in speech recognition modules for hands-free operation

Cons:

- Requires either visual, mental and manual attention or combination of them.
- Voice recognition is not always efficient and the times that it is ineffective, can cost somebody's life.
- Demands shift of attention from street focus to screen focus
- Cognitive load on drivers increase while operating the center stack

So, what is it the main reason why the infotainment system is causing life threatening situations? The answer to this is Driver Distraction.

The American Automobile Association defines driver distraction as occurring "when a driver is delayed in the recognition of information needed to safely accomplish the driving task because some event, activity, object or person within or outside the vehicle compelled or tended to induce the driver's shifting attention away from the driving task" [32]

Figure 4. Causes for distraction

The NHTSA in the United States has attempted to categorize these sources of driver distraction under the following 13 headings:

1.” Eating or drinking;

2. Outside person, object or event;

3. Adjusting radio, cassette, or CD;

4. Other occupants in vehicle;

5. Moving object in vehicle;

6. Smoking related;

7. Talking or listening on mobile phone;

8. Dialing mobile phone;

9. Using device/object brought into vehicle;

10. Using device/controls integral to vehicle;

11. Adjusting climate controls;

12. Other distractions; and

13. Unknown distraction”

Figure 4 depicts some of the causes for distraction such as eating, talking on phone and texting.

Age	Reporting Sending Text or Email While Driving	Reported Sending Text or Email Often / Regularly While Driving
16-18	31 percent	7 percent
19-24	42 percent	11 percent
25-39	45 percent	10 percent
40-59	24 percent	4 percent
60-74	7 percent	2 percent
75+	1 percent	1 percent
Total	26 percent	6 percent

Table 1. Distracted Driving Statistics [4]

According to a research conducted by the National Safety Council estimates "21 percent of all crashes in 2010 involved talking on cell phones – accounting for 1.1 million crashes that year. A minimum of three percent of crashes are estimated to involve texting." [40]

AAA has conducted a research to assess the badness of distraction amongst the teenage drivers. [21]

The cause for teenage distraction during driving according to this research "Distraction and Teen Crashes: Even Worse than We Thought" can be summarized as follows: [22]

- "Interacting with one or more passengers: 15 percent of crashes

- Cell phone use: 12 percent of crashes
- Looking at something in the vehicle: 10 percent of crashes
- Looking at something outside the vehicle: 9 percent of crashes
- Singing/moving to music: 8 percent of crashes
- Grooming: 6 percent of crashes
- Reaching for an object: 6 percent of crashes”

2.4 Types of distraction

According to the National Highway Traffic Safety Administration, distracted driving was a cause of roughly 424,000 accident-related injuries and some 3,154 fatalities in 2013 alone. Because this data comes from police reports, which may not record all driving distractions, the true figure is likely higher. [19]

Distracted driving comes in 3 different forms: [18]

“Visual distraction:

Visual distraction occurs when a driver looks at anything other than the road ahead. Drivers who check the kids' seat belts while driving are visually distracted. Electronic devices for the car, such as GPS devices and portable DVDs/digital entertainment systems, also distract drivers.

Manual distraction:

Manual distraction is when the driver takes one or both hands off the wheel for any reason. Some common examples include eating and drinking in the car, adjusting the GPS, or trying to get something from a purse, wallet, or briefcase.

Texting and driving is particularly dangerous because it involves all 3 forms.

Cognitive distraction:

Cognitive or mental distraction is when a driver's mind isn't focused on driving. Talking to another passenger or being preoccupied with personal, family, or work-related issues are some examples.

Even drivers listening to their favorite podcast or radio station are at risk; the audio can take drivers' focus away from their driving and overall surroundings."

Figure 5 gives an overview of the types of distraction.

Figure 5. Types of distractions

Further, a research by AAA with researchers at University of Utah made a study on the cognitive distraction and its load on drivers. This will be discussed in the upcoming chapters.

A common approach used to curb distraction which has proven to have not worked as expected in the past is to use the hands-free devices. The main idea as mentioned in the research [40] is that the hands-free device helps in eliminating the two obvious risks – visual and hands off the wheel. But the hands-free device doesn't help to mitigate the third kind of distraction or rather increases it, that is the cognitive distraction.

Now, that we have established that distraction is the causal effect, we can define the problem statement as follows.

Distraction is hard to measure - Audio, video, physical and mental and come in groups. Making it difficult to deal with distraction.

Prior researches have shown that both conversation and texting impair the event perceiving abilities of drivers, which leads to unsafe driving conditions [23]

A recent study on understanding the effects of mobile phone use while reaction time during driving deduced that "In preliminary analysis of reaction time data the 90th percentile value of reaction times found to be more than 2.5 s (standard value set by AASHTO and adopted by IRC) in all distracted driving conditions (except for simple conversation task).” [23]

The above research indicates that the usage of smartphones is proven to be hazardous and increases cognitive load on drivers while leading.

2.5 Speech recognition and why it is not the most sought after solution

Speech Recognition is “the inter-disciplinary sub-field of computational linguistics that develops methodologies and technologies that enables the recognition and translation of spoken language into text by computers.” [25]

Further speech recognition’s main motto is to enable hands-free operations on the infotainment without having to touch or look at the screen while driving. This has the benefit of helping users to complete their work more efficiently while doing multiple tasks simultaneously [15].

We have seen a lot of technological advancements in making speech recognition the main means to operate on car system while driving. However, despite all the latest advancements, speech recognition is still looked down upon due to various reasons.

Researchers at the University of Utah led by Prof. David Strayer hooked up test drivers to heart-rate monitors and other equipment to measure their stress levels while driving and using speech recognition technology to perform tasks such as composing text messages or emails, dictating phone numbers and changing stations on the radio [16].

This research shows “that hands-free technologies in the car can dangerously divert driver attention, even at seemingly safe moments. Potentially unsafe mental distractions can persist for as long as 27 seconds after dialing, changing music or sending a text using voice commands, according to surprising new research by the AAA Foundation for Traffic Safety. The results raise new and unexpected concerns regarding the use of phones and vehicle information systems while driving. This research represents the third phase of the Foundation’s comprehensive investigation into cognitive distraction, which shows that new hands-free technologies can mentally distract drivers even if their eyes are on the road and their hands are on the wheel.

The researchers discovered the residual effects of mental distraction while comparing new hands-free technologies in ten 2015 vehicles and three types of smart phones. The analysis found that all systems studied increased mental distraction to potentially unsafe levels. The systems that performed best generally had fewer errors, required less time on task and were relatively easy to use." [17]

The Figure 6 shows how much impact do speech recognition systems have in various cars.

Figure 6. AAA Distraction due to speech recognition

NHTSA gives the analogy that the cognitive load on a driver whilst using speech recognition is equivalent to solving math problems. This clearly is not a good sign for driver safety and the following research helps to draw a better perspective of the above statement.

Another research [20], measures the cognitive load on the driver when he's involved in performing single task versus performing multiple tasks involving speech recognition as one the tasks shows evidence of increased cognitive load in IVIS (In-Vehicle Information System) interactions showing that the average response time and hence the cognitive load is significantly higher when the driver is involved in working with speech and other multi-modal interactions. Here's the list of conclusions drawn using this research [20].

“The momentary cognitive workload ratings associated with IVIS interaction averaged 3.34 on our 5-point scale and ranged from 2.37 to 4.57. These findings reflect a moderate to high level of cognitive workload. The workload ratings were associated with the intuitiveness and complexity of the IVIS and the time it took participants to complete the interaction.

The momentary cognitive workload experienced by older drivers performing the IVIS interactions was significantly greater than that experienced by younger drivers. In fact, the age-related differences that were observed in the single-task condition doubled when participants interacted with the IVIS. Practice does not eliminate the interference caused by IVIS interactions. IVIS interactions that were easy on the first day were also easy after 5 days of practice and those interactions that were difficult on the first day were still relatively difficult to perform after 5 days of practice.

There were differences in the cognitive workload of the different IVIS systems over and above any differences associated with simply driving the vehicles. We found that robust, intuitive systems with lower levels of complexity and shorter task durations tend to have lower cognitive workload than more rigid, error-prone, time-consuming systems.”

2.6 Autonomous Cars to Self-Driving Cars

An autonomous car (also known as a driverless car, auto, self-driving car, robotic car) is a vehicle that is capable of sensing its environment and navigating without human input.[4] Many such vehicles are being developed, but as of February 2017 automated cars permitted on public roads are not yet fully autonomous. They all require a human driver at the wheel who is ready at a moment's notice to take control of the vehicle. [15]

Another definition for automated driving system is that “it is a complex combinations of various components that can be defined as systems where perception, decision making, and operation of the automobile are performed by electronics and machinery instead of a human driver, and as introduction of automation into road traffic. This includes handling of the vehicle, destination, as well as awareness of surroundings. While the automated system has control over the vehicle, it allows the human operator to leave all responsibilities to the system”

Risks and liabilities:

The research study [37] boldly claims that, “When considering the risks of cutting-edge automotive technology, the first thing that usually comes to mind is autonomous vehicles. But focusing too much on self-driving technology risks ignoring a critical reality: Today's cars and trucks are already connected to the internet, and like any other internet-connected device, they can be hacked.”

Another study [38] discusses about the liabilities that entails the self-driving cars and how the manufacturers of the car will be held totally responsible for failed and unsafe autonomous cars on street. It states that [38], "Self-driving vehicles potentially offer major benefits regarding road safety, social inclusion, reduction of emissions, and avoidance of congestion.54 The admittance of self-driving cars will inevitably raise questions of liability. In terms of product liability, manufacturers of safety critical automated vehicles will need to fulfil high safety standards to avoid liability. In fact, manufacturers might soon be facing damage claims for a higher proportion of accidents than today, as accidents might be traced back to a product defect in a large number of cases. This article discussed the resulting shift in liability from the vehicle holder to the vehicle manufacturer."

So, with these studies and researches on self-driving cars it is safe to assume that though the automation is bound to happen in the field of automobiles, the driverless vehicles are far from replacing the traditional cars. With that in mind, this research is proceeded to provide safety solutions for the current cars with drivers.

CHAPTER 3

RESEARCH APPROACH

In this chapter, the sections are divided to explain in detail the User Interfaces in Experiment 1 and Experiment 2. The reasons behind design choices such as the number and size of icons for Experiment 1 and 2 are explained in section 3.1. The technical specifications and description about the Driving Simulator used to conduct the experiments is in section 3.2.

3.1 User Interface

User Interface is the intuitive, textual/graphical pages that enables ease of operation for the users. It is intuitive in the sense, that the user must require minimal amount of effort/training to get used to the interface or the GUI. The experiments were designed in such a way that they are either numbered or have symbols that are in alignment with the real-world car infotainment system. The UI, in the experiment 2, had to be more intuitive as the user was required to get acquainted with the system before taking the experiment.

3.1.1 Experiment 1

An important aspect of this research was to make an android application that not only mimics the real-car infotainment system UI but also to have tasks that vary in number of steps needed for completion, training needed to get acquainted and reduce the learner's biasing and to be intuitive with respect to a car center stack. User Interface design is one of the most significant factors of this device. It not only needed to have the right set of apps that can match most regular car infotainment systems, but the second experiment, which required prior training and getting used to before taking up the experiment, had to be easy to follow and represent infotainment systems in real cars. This was the primary challenge in building the user interface.

Further, as we have established that the cognitive load increases distraction, the applications used in our experiments was designed in a way to not involve any hands-free/speech recognition based design.

Experiment 1 consisted of 2 screens and 2 phases of experiment. The main intention behind this design is to avoid training on using the center stack which is in this case, a 10” Samsung Galaxy tablet. To accomplish this, the icons were numbered and placed in random order. This way, the real-world scenario in cases like rental cars or borrowed cars and others are mimicked to gauge the levels of distraction in an untrained infotainment.

Further, the screen 1 of the phase 1 consisted of 6 icons that are randomly placed. This is an experiment that is a future work of Minimalist Design Experiment [23] in which the elements were placed in sequential order.

3.1.1a Why Random?

The numbered icons were placed in random order to mimic the real-world scenario of an infotainment system. As we know, it’s not always certain or clear where every icon is located. This can happen either because

1. As the navigation into the system gets deep, people will have more icons to look for and this is not something we can memorize given that the driver is expected to focus on driving and this adds a cognitive load on the driver.
2. We cannot always say that a driver is on his own car, many a times the driver is driving some other car be it rental or borrowed. So, there is no time to get acquainted with the infotainment system.
3. Perpetual users/ perpetual experts - Used to everything and download new application or there is an update and UI changes

To obtain realistic, real-world based results the icons are numbered in random order. This gives us an unbiased result and it mirrors the real-world driving condition.

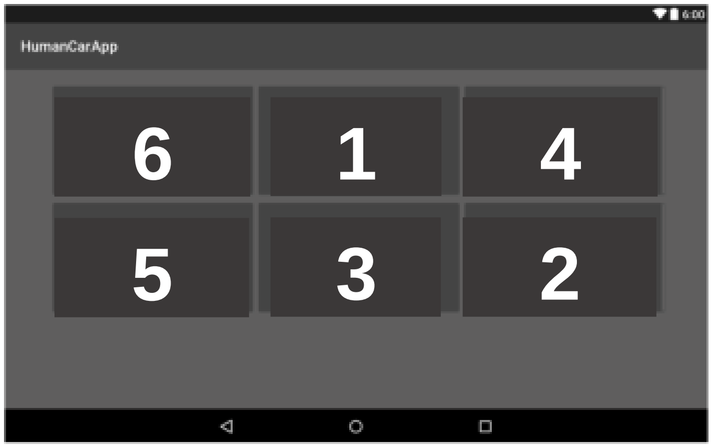

Figure 7. 6 icon screen

Next, Figure 8 illustrates the screen 2 of the phase 2 consisted of 30 randomly numbered icons.

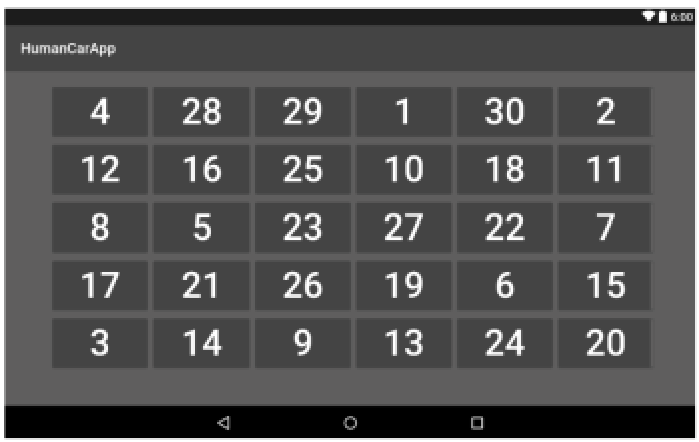

Figure 8. 30 icon screen

The icons designed are large enough to have distinguished touch effect. In order to confirm the right icon was clicked by the driver, the icon changed to black color for a duration of 50 milliseconds. This avoided the noting of erroneous response time when wrong icon is clicked.

3.1.2 Experiment 2:

In this research, we first tried to identify all the variables that would lead to understanding the level of distraction. Then the variables were categorized into 2 groups i.e. cockpit activities and driving activities.

Cockpit activities include activities like answering the phone, texting, operating on center stack, errors while doing it, response time. The driving activities are car based factors like operating on the dashboard and driving related variables like braking, lane position, braking, steering, headway distance.

The hypothesis is that these factors collectively or individually have a direct/indirect impact on the level of driver distraction. The Figure 9 depicts the research approach for experiment 2.

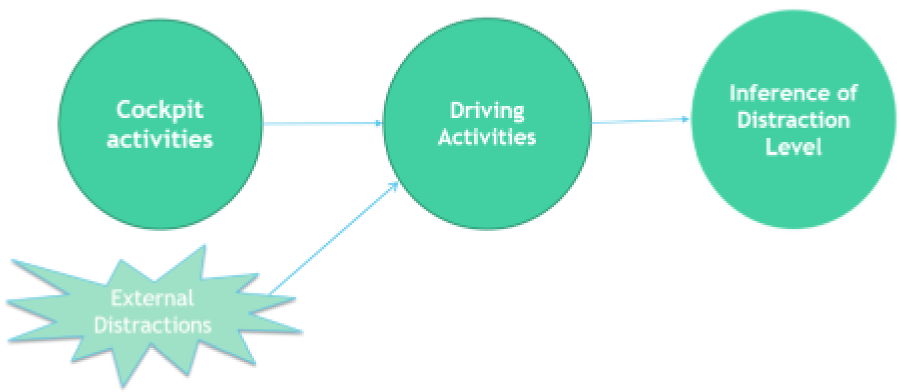

Figure 9. Research Approach High-level Overview

Before diving into creating the android application and conducting the experiment, the initial high-level flowchart for the navigation in the infotainment system. The tasks on the center stack were defined and further categorized based on the number of steps required to complete one full activity such as playing a song on the center stack. Based on the minimalistic design and multimodal design experiments from the prior experiments, the navigation model's prototype was first created.

The icons in the application for Experiment 2 are presented with images rather than words, as prior researches [39] have proven that the visual memory for a human is much higher than reading just plain text on a screen. The main idea was to design user interface that had all car-related applications/navigations such as Media, GPS, Wiper and Windshield controls, AC controls, Contact List, Play list and Radio. As established by minimalist design [23], the main screen has 6 icons and each of the 6 icons had subpages for diving deeper into navigation.

Main Screen Icons: Figure 10 shows the main page of the car infotainment app

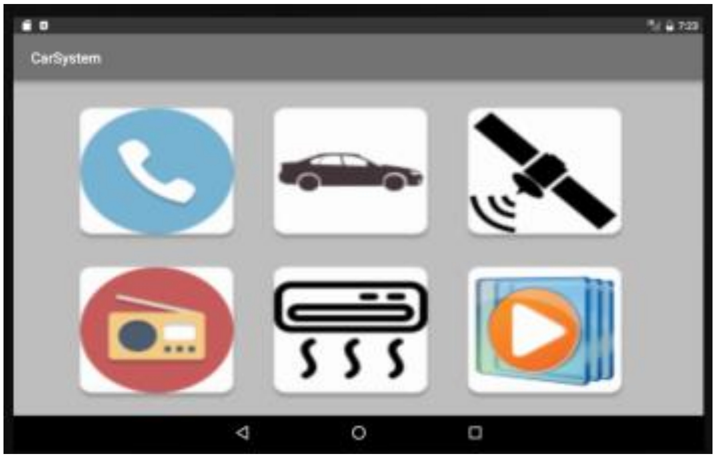

Figure 10 Car App Home Page View

3.1.2a Navigation Model:

A Navigation Model provides a high- level overview of a system. It helps in visualizing how the different parts form a hierarchy within themselves and connection with each other. At a simple level, a navigation model helps users understand how one page of an application links to another and how one can navigate through the app. They help system designers understand and structure the application better based on the project requirements and give clarity to developers who implement the system.

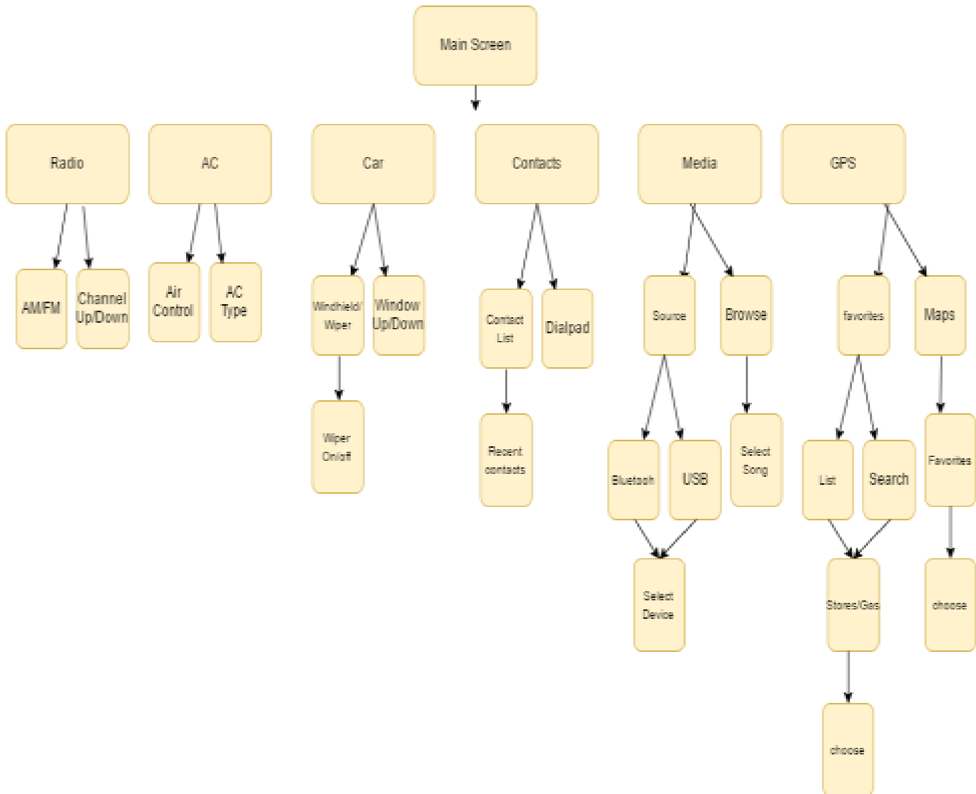

Figure 11. High-Level Flowchart for Center Stack Application – Level 1

The Figure 11 depicts an overview of the navigation model built for this research and it shows a high-level overview of the system that was built for this research. This helps user visualize the overall structure of the app and high level connection between them. The other levels (2 & 3) are not shown here because, for our experiments the steps to complete tasks that users are familiar with is rather more important than having to show the link between different parts in the system. The level 2 and level 3 will be useful once a basic customizable navigation model is built from the data of this experiment.

3.1.2b. 2-Step:

Radio & AC Controls:

These are the two parts of the navigation model which only takes 2 steps to complete one whole operation such as choose AM or FM from Radio or to change AC heat level. The design, Figure 12 and 13, is intuitive in a way in which the tasks are carried out. The user is not required to navigate back and forth between apps as he is asked to complete one whole task at a given instance.

Figure 12. Radio Operations

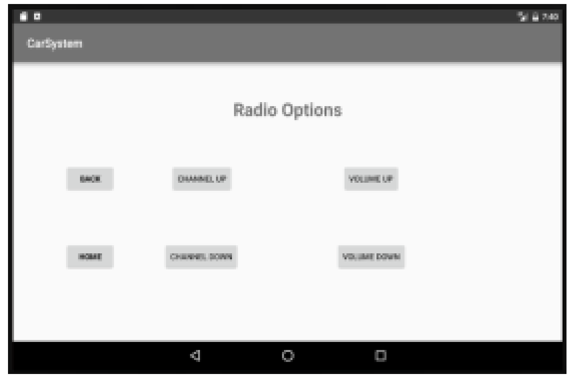

Figure 13. Radio Operations - Level 2

3.1.2c. 3-Step:

Contacts and Car Window Controls:

These two tasks are designed to be completed in three levels of hierarchy from the high-level navigation overview model explained earlier. The phone options such as getting to dial pad or to get recent contacts list is depicted in the Figures 14-19 below

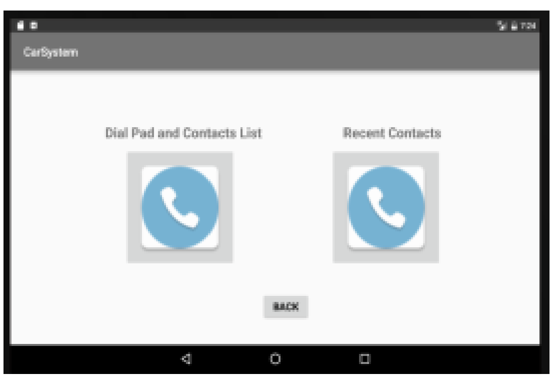

Figure 14. Contacts

Figure 15. Dial-pad and phonebook

3.1.2d. 4-Step:

GPS and Music Player:

These two parts take 4 steps each to complete a task. The individual landing pages of the maps is depicted in the figures below.

Figure 16. GPS overview

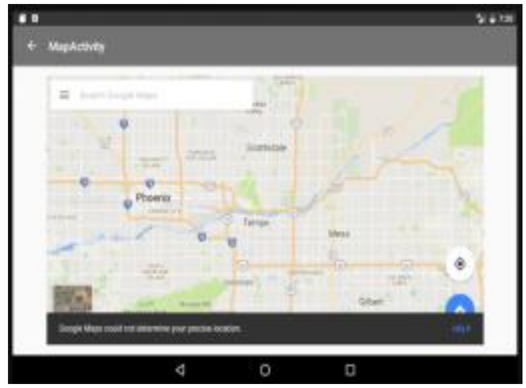

Figure 17. Maps Search Window with Current Location

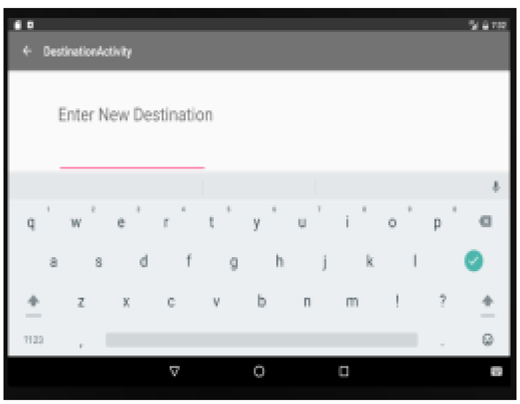

Figure 18. Search Bar - Maps

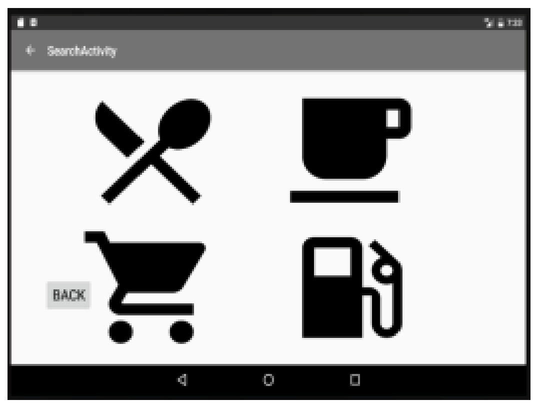

Figure 19. Search Categories

Track Modes:

In the Simulator building's hyper drive simulator, 3 tracks were setup with a city-like setting on a day, night on a freeway street, city on a foggy morning. The tracks were designed using the Hyper Drive Simulator in which the speed limit, intersections, street type, traffic and environmental conditions were programmed based on the experiment needs.

City Morning:

Sunny: This had 4 intersections, moderate traffic, pedestrians crossing, curved roads and traffic signals.

Foggy: This too had same track with4 intersections, moderate traffic, pedestrians crossing, curved roads and traffic signals but had fog up to 10 meters.

Freeway Night:

This was a freeway track with minimum traffic, no streetlight, curved roads and night mode with rainy weather.

3.2 Driving Simulator

The experiment was conducted in a DriveSafety research simulator DS-600s (Figure 20). The DS-600c is a fully integrated, high performance, high fidelity driving simulation system which includes multi-channel audio/visual systems, a minimum 180° wraparound display, full-width automobile cab (Ford Focus) including windshield, driver and passenger seats, center console, dash and instrumentation, and real-time vehicle motion simulation. It renders visual imagery at 60 frames per second on a sophisticated out-the-window visual display with horizontal field-of-view. It also includes three independently configurable rear view mirrors.

Figure 20. HyperDrive Simulator

Figure 21 shows the driving simulator computer used for designing and executing the simulation. All driving scenarios were created using DriveSafety HyperDrive Authoring Suite version 1.9.39. HyperDrive is an integrated, Windows-based software package that lets you develop driving simulation content for your simulator. “With HyperDrive's point-and-click, drag-and-drop interface, even non-technical users can design, build, execute, and analyze driving scenarios. These vehicles obey traffic laws, signs and signal devices, and interact realistically with other vehicles based on human behavior and real-time physics-based vehicle dynamics. If specific behavior is desired, vehicles can be given script commands through the use of triggers, timers, paths, routes and other tools. We can control traffic signals, ambient traffic, scripted traffic, roadway friction, weather conditions, etc. Using triggers, virtually any scenario can be designed. The rear-view mirrors also have small tablets displaying the rear end of car to keep track of blind spot and lane.” [23]

Figure 21. Computer with Hyper Drive Simulator’s Software

CHAPTER 4

EXPERIMENT DESIGN

This chapter is organized in a way that it introduces the reader to the prior experiments that formed the base for my research experiments in section 4.1 where 2 experiments and the output obtained from each of them is described. This is followed by this research's experiments description about the independent and dependent variables that are being considered in the respective experiments and followed by the experiment hypothesis and the methodology in section 4.2

4.1 Prior Experiments

Experiment 1:

This experiment was conducted as part of Master's Thesis study by Tanvi Jahagirdar [23].

Goal:

To evaluate the effect of minimalist design on driver distraction and the effects of icon size, screen size and orientation.

Setup:

The Hyper Drive Simulator was used for this experiment [Figure 22]. The volunteers were asked to drive on a previously programmed route, with tasks like left turns at an intersection, pedestrians crossing, curved road and following a car. Then the 2 drives – with smaller screen size and larger screen size were monitored closely. The response time was also noted for both.

Figure 22. Driver's View of the Simulator with 10" Tablet

Results:

Driver Response Time:

In general, all response times were below 2 seconds. Actual readings ranged from 0.71 seconds to 0.98 seconds for all the 8 settings. This gave us a strong indication that we can safely design the UI with 6 icons on a screen of 10-inch. In the experiment, we interviewed the volunteers to seek their feedback about the screen orientation. Most people preferred landscape over Portrait orientation. One reasonable explanation is that it is more common as most screen orientations of technology are landscape. For example, computers, television, radio and media players are predominantly horizontal. However, more research is needed to test the boundaries of both orientations.

Experiment 2

An Applied Project report submitted by EcoCar3 Team [24]

Goal: To determine if the delay between operations with UI of the car reduces driver distraction.

Setup:

The experiment was conducted in a Drive Safety research simulator DS-600s (Figure 23).

Figure 23. Hyper Drive Simulator

An android application was developed to display the user interface with numbers from 1-9.

Results:

With the experiment, having delayed and regular response on user touch, it was observed that the user distraction is less with delayed multi-level navigation user interface.

The obtained results showed that a slight delay in infotainment response will help the driver to get his focus on street quickly as he would not spend more than 2 seconds looking away from the street. This will help in maintaining the driver's focus on driving and helps to mitigate the distraction to some extent.

4.2 Experiments

Experiment 1

6 vs 30 – Minimalist and Random numbered icons:

Independent Variable:

Response time: The response time is the time taken by the driver (in seconds) to click on the numbered icon on the screen whilst driving. This is calculated to estimate the difference or increase in time when the number of icons on the screen significantly increases.

It is used to estimate what constitutes to be a safe number of icons on the screen in order to decrease cognitive load on the driver

Dependent Variable:

Distraction/Possible Distraction Estimate: According to NHTSA, if driver's eyes are off the road for more than 2 seconds, it could lead to distraction and in turn a fatality. The response time directly helps to estimate the possible distraction with this experiment.

Null Hypothesis:

The number of icons in the center-stack will not cause any distraction/effect on the response time of the driver.

Alternative Hypothesis:

The number of icons on the center-stack will increase the distraction and increases the response time of the driver.

Setup 1:

On a 10”, Samsung Galaxy Note iii, tablet that mimics the infotainment system, landscape mode, randomly numbered icons are placed. The icons are clickable and turn red when clicked on them.

Setup 2:

On the same tablet, 30 randomly numbered icons are placed. The icons are clickable and turn red when clicked on them.

People:

42 licensed drivers were given time slots and were asked to take the experiment. Before conducting the experiment, the students were allowed to get acquainted with the simulator setup and driving in the simulated condition. Once they were confident with the driving process with any number of trial runs, the experiment was carried out.

Steps:

1. Driver is asked to drive in city daylight, moderate traffic conditions
2. Driver is asked to select a number between 1 – 30 at pre-decided points of the track. (Screen 1)
3. Driver is asked to select number between 1 – 6 at the same points as step 2 (Screen 2)
4. The response time is noted using a timer for each of the button clicks

The errors are noted to correlate and understand the consequences and direct impact the number of icons on the screen will have on the driver’s response time in completing an action.

Experiment 2

Modal driving to capture response time, errors, driving related details with the help of a simulator:

Independent Variables:

We define the independent variables for this experiment as the metrics that can be measured using the hyperdrive simulator that's been described in the following section. These variables are what we call the driving metrics. By doing this, the driver's change in quality of driving can be compared to that of the ideal mode and this helps in better understanding the effect of changing external conditions on driving and in turn on driver distraction.

Driving Metrics:

Lane Position:

The number of lane departures per unit of time or trial is a very common safety statistic. The lane change frequency is one of the indications of driver distraction. However, what is most critical is that this measure was rarely defined and when it was, the definition was imprecise. [32]

Headway:

The more closely the driver follows a vehicle ahead, the more likely a crash [41]. Of the various types of crashes, rear-end collisions are much more likely when drivers are distracted. In the Highway Capacity Manual., headway refers to the time difference between when two successive vehicles pass by the same point on a road. Generally, it is the front bumper to front bumper difference.

Distractions that are of "mind/eye-off-road" nature show significantly larger headway than the other 2 (visual, manual).

Acceleration, Velocity, Brake:

As previous studies indicate, "if the driver is distracted, then there is an abrupt change in brake, acceleration and velocity. The driver compensates by reducing his speed and after completing the distractive tasks, aligns back to the speed achieved prior to the distraction. This can also indicate the duration of distraction." [32]

Steering Angle:

As stated previously, if the driver is distracted, the occurrence of lane departure is prominent. And after the distractive task is over, the driver will adjust his position in the lane again. In case of no distractions, except for turns, drivers have been observed to maintaining their lane position and requiring minimum steering wheel adjustment. [32]

Response Time:

We measure this metric manually. The driver is asked to do some operations on the center-stack such as picking a number or completing a task of playing a song from USB device or to call a person from the favorite contacts list, etc., For each of these operations, the response time is noted down manually by 2 people and the average of the 2 values is calculated. By doing this, the manual errors in calculation is greatly reduced and it showed more accurate results than doing it automatically as thee automated response time calculator had a delayed response leading to error in data collection.

Dependent Variables:

Level of Distraction: To understand the level of distraction across different driving conditions and with varying the number of steps to complete one full task on the infotainment system by keeping driving metrics and response times as benchmark. It helps to make an estimate about the level of distraction/driving difficulty and its effect on response time with respect to operating on the infotainment system or vice versa and hence the level of distraction.

Null Hypothesis:

External conditions have no effect on driver distraction

Alternative Hypothesis:

External conditions have an effect on driver distraction.

Secondary Hypothesis:

1. There is no effect on driving due to adverse and double adverse conditions
2. The external factors do not have any impact on lane position, braking, speed, steer and headway distance of cars.

3. The average response time and number of errors remains constant across all 3 driving conditions (modes) and the number of steps to complete one full task.

Setup:

- 3 tracks:
  - Daylight in a city street
  - Night in a freeway
  - Foggy morning on a city street
- Infotainment System:

  Samsung Galaxy 3, 11', was used to mimic a car based Infotainment System with 2,3 and 4 step navigations.
  - 2 Step: Radio on off, AC
  - 3 Step: Car, Phone

4 Step: GPS, Media

People:

17 licensed drivers took these tests on 3 different modes. Wherein the lights were turned off and simulated a night-like condition for the night mode of testing. The users were given the tablet and asked to get acquainted with the navigation system and doing various operations on the tablet such as Turn on the Wiper, Go to Media -> Select Browse -> Click on "Name of a song", Go to Media -> Select Bluetooth -> Click on Bluetooth Device -> Select Song, Go to Maps -> Go to Favorites -> Select "Location name". This prior training was given in order to avoid the "learning effect" due to lack of training for the first track and hence the obtained result is unbiased.

Steps:

Every driver was asked to ride in 3 different modes and was asked to navigate into various icons (2, 3 and 4 steps). For each response from the user, the response time, the number of errors were noted down manually. The automated response time on the tablet had a lag after the user reacted to the command and this was giving us erroneous results. To avoid this delay and errored response time from automation, the response time was noted down manually using a timer and 2 people calculated response time for the same users. By doing this, the margin of manual errors was reduced and was negligible giving us accurate data for statistical analysis.

Simulator Dashboard was used to save the driving results of each user with names in the format <StudentNumber><ModeNumber><TrackNumber>. This helped in categorizing the results according to students/mode. Further from the obtained result sheet, we mainly considered factors like Lane Position, Steering Angle, Headway Distance, Brake, Acceleration and Speed. These variables are recognized and categorized as internal factors that determine the driving condition. By doing this, we could obtain data for special cases/extreme cases of driving that could lead to distraction and road hazards. The values obtained for these variables for every driver in all 3 modes, will be used as the data input to train the neural network project in the future.

The standard deviation obtained for each of these internal variables, for each driver in each mode was calculated. By doing this, it was easy to gauge the best and worst driving conditions and the conditions that showed sleek abnormality in driving. This helped in determining the level of distraction in drivers with varying conditions. This will be discussed in future chapters.

CHAPTER 5

ANALYSIS AND RESULTS

In this chapter, each subsection describes the results obtained and what they imply in terms of statistical deductions and the overall results for both Experiment 1 and Experiment 2 in section 5.1 and section 5.2 respectively. Each of the sections tabulate the experiment results to summarize the takeaway from the experiments and whether or not it adheres to the hypothesis made in the prior chapters.

5.1 Experiment 1

Data Analysis:

The obtained two-tailed p value of 0.0029, Table 4 signifies there is a probability of 0.2% that there is no real difference in the result for a larger set of users. This proves our alternative hypothesis that the number of icons on the screen will indeed have a negative/adverse effect on driving as it leads to distraction.

	P-Value	Statistical Significance
6 vs 30 icons	0.0029	Significant

Table 2. Statistical Data

Further, the mean response time of Screen 1 with 6 icons is 1.74021825 seconds that is less than the NHTSA defined standards of 2 seconds and is still in the safe mode of driving. While the mean response time of Screen 2 with 30 icons is 4.23535714 seconds. This is summarized in the Table 5. This is way above the defined threshold and needless to say that the drivers are at a greater risk of a road mishap in this case proving the alternative hypothesis.

	6 icons	30 icons
Average response time in seconds	1.74021825	4.23535714

Table 3. Average response time comparison 6-icon vs 30-icons

Results:

With this experiment, it is established that the reduced number of icons, reduces the cognitive load and distraction on the driver but it doesn't mean that the reduced number will totally remove the possibility of a fatality. Meaning that, the varied pattern in response time made it evident that the UX of the infotainment system not only needs an intelligent design in addition to minimalist design, but it also needs an intelligent, interactive design. Now the reason for this anomaly can be any of the following:

1. The driver was stopping at the intersection.
2. Or the probability factor of seeing the icon as soon as the driver looks at the screen
3. Or the training factor

With this experiment, it has been established that the training effect on the center screen is nullified as the users are not allowed to familiarize themselves with the center stack operations prior to taking the experiment. Hence, we have narrowed down the possible reason for the above anomaly to be either 1 or 2. The study of actual cause for this anomaly can be one of the future works.

5.2 Experiment 2

In this experiment, it was assumed that the level of distraction is a dependent variable that can be calculated using a set of independent variables called the driving metrics defined earlier.

Say that the variable Y is the level of distraction and x is a set of external and internal variables,

With the above defined variables, we can measure the level of distraction as the function of x.

Y = f(x)

Where,

Y = Level of distraction

x = Set (Internal Variables) + Set (External Variables)

Internal Variables = Response Time, Errors in operating the infotainment system.

External Variables = Steer, Brake, Lane Position and Headway Distance

x is a vector (x1 – x6 is a vector set)

The above sets of independent variables are one entity where the data for each of the above variables is used to calculate the average, standard deviation and T-analysis.

To further refine the results obtained, additional environmental factors where designed in the experiment.

The environmental factors were categorized as

1. Controlled (Ideal) mode for driving
2. Adverse mode
3. Double adverse mode

Controlled (Ideal) mode in a city street with daylight and minimal traffic.

Adverse mode in track 2 is in a city street with foggy morning and minimal traffic.

Double adverse mode in track 3 is a night setting on a freeway with no streetlights.

The environmental condition is the variable Z in the experiment.

1. y = f(x) @ Z

   Where y = level of distraction in controlled mode

   X = set of external and internal variables

   Z = Controlled Modes

2. y' = f'(x) @ Z'

   Where y' = level of distraction in track 3

   X' = set of external and internal variables

Z’ = Adverse Foggy Mode

2. y” = f” (x) @ Z”

Where y” = level of distraction in track 2

X” = set of external and internal variables

Z” = Double Adverse Night Mode

Further, the infotainment system has 3 levels of difficulty to navigate and complete a task on the infotainment system.

1. 2-step (Radio, AC Control)
2. 3-step (Dial number)
3. 4-step

The efficiency of the driving is defined to be the average time taken by the user to complete a given task without errors.

$$\eta = \text{Time to complete tasks}$$

$$= T_{\text{response time}}$$

Vectors:

Further in the formulation, there are 5 vectors or the cockpit variables that are independent of each other. The 5 defined vectors (V1 to V5) are Speed, Headway Distance, Lane Position, Brake, Steer Angle respectively. The values are calculated at various points in the track for each user (17) at every mode.

It can be tabulated as follows:

User(N)Mode(K)	V1 = Speed – Speed Limit	V2 = Headway Distance	V3 = Lane Position	V4 = Brake	V5 = Steer Angle
User(i)Mode1	250	250	250	250	250
User(i)Mode3	12500	12500	12500	12500	12500
User(i)Mode2	250	250	250	250	250

Table 4. Vector Matrix

1 User, 1 trip, Mode 1= 250 vector points

= 250*5

= 1250 data points per trip in mode 1

Number of Drivers = 17

Total data points = 17 * 1250

= 21,250 data points

Similarly, data points for 1 user in mode 2 = 1250

Total data points = 21,250

Data points for 1 user in mode 3 = 17*12500

= 212,500

The vector points are collected at every instance of driving right from when the engine is start to shut off. The vector points for mode 1 and mode 2 are equal as the track on both the modes are same except for the weather condition and the vector points for mode 3 is exponentially higher than mode 1 and mode 2 as it is meant to be double adverse mode and hence the driving is difficult and the tasks took a longer time to complete in the center stack.

Observed and obtained results:

After calculating the average response time in each mode for each driver in different environmental conditions, and with varying in number of steps required in the infotainment system to complete the tasks we can state the following results on the driving efficiency.

In all modes (1,2,3) the response time to navigate on a two-step task did not take more than the minimum average defined by NHTSA that is 2 seconds and hence the efficiency of the driver's response time is high and hence the cognitive load Y (distraction) is estimated to be less in 2-step tasks and this is independent of the external driving conditions. Proving the Null Hypothesis right.

But the 3-step and 4-step tasks did have a significant variation in terms of response time and driving metrics values between normal and Adverse conditions. The average response time in adverse and double adverse modes varied by 2 seconds for 3-step task and over 3.1 seconds for 4-step tasks as compared to the response time in normal/ideal mode. Table 3 shows the overview of the response times across all modes.

This shows that the response time and the efficiency is sensitive to the number of steps required to complete one task proving the alternative hypothesis right.

Mode/Response Time	2-Step	3-step	4-step
Ideal Mode	1.5 seconds	2.133 seconds	3.18 seconds
Adverse Mode	1.72 seconds	3.543 seconds	3.96 seconds
Double Adverse Mod	1.79 seconds	3.712 seconds	4.612 seconds

Table 5. Comparison of average response times across all modes

Further, t-stat analysis was carried out for each of the defined vectors/driving metrics above for the modes and the results obtained showed that there is no statistically significant variation in the confidence interval of the t-analysis across all 3 modes for the steering angle. The two paired p value averaged to be greater than 5% for the steering angle when calculated against the ideal mode as the benchmark. This, in other words means that, the steering angle does not change across the mode proving the null hypothesis right.

But, the two-paired p values for other driving metrics averaged to be less than 5% indicating that there is significant variation and changes in the metrics with the change in external modes. This is depicted in the Table 4.

	Steering Angle	Speed	Brakes	Headway Distance	Lane Position
Statistical Significance	Insignificant	Significant	Significant	Significant	Significant

Table 6. Depiction of overall statistical significance for driving metrics

This again proves our alternative hypothesis that the external conditions (Z) and the difficulty level in completing operations on center stack has a direct impact on the quality of driving and hence acts as the significant cause for driver distraction (Y).

CHAPTER 6

CONCLUSION AND FUTURE WORK

This chapter contains the overall conclusion from the research study in section 6.1 and discusses the meaning of the data obtained. Further the section 6.2 gives a pathway to the future research that can be based off from this research and discusses possible solutions to move towards building a smart infotainment system.

6.1 Conclusion

1. With experiment 1, it was proved that the alternative hypothesis that the driver distraction/response time increases with the increase in the number of icons on the screen. The average response time of 1.72s in case of 6 icons is considered to ideal and helps in mitigating the distraction and in turn a possible fatality according to NHTSA's 2 seconds' rule.

2. The experiment 2 contained results that are of two-fold. First one is that the response time remains nearly constant across all driving modes or external conditions when the number of steps to complete one full task on the infotainment system is 2. And the steering angle while driving across all conditions didn't have a significant variation as compared with the ideal mode and hence this proves the Null Hypothesis that the external conditions have no effect on driving distraction. However, the second conclusion is that the increase in number of steps to complete a task takes a longer overall response time in adverse and double-adverse driving conditions. And the statistical pair values of the driving metrics (Brake, Lane Position, Speed, Headway Distance) showed values less than 5% meaning that the alternative hypothesis holds for these conditions.

3. The shorter tasks i.e. the 2-step tasks can be considered as safe across all modes and will especially be helpful in adverse driving conditions.

6.2 Future Work

1. Experiment 1 with minimalist design and random icons showed some anomaly in response times and it was noted that 5% of the response times in case of 30 random icons was less than 2 seconds i.e. adheres to the NHTSA standards and the reason for this can be three-fold. (i) Learner's effect (ii) Accidental effect (iii) The driver has stopped at a signal. The 1st cause is eliminated as there was no room for training in the experiment. But further research needs to be conducted to determine the exact cause for this anomaly.

2. Experiment 2 was mainly conducted to determine the factors of driving and the quality of driving determination and its correlation with the level of distraction using the data obtained from the simulator. With this data, further research can be conducted to customize and change the intrinsic behavior of the center stack. This should be designed in a way that it can change the behavior in such a way that it curbs the driver distraction without the intervention of the driver and rolls back the status to original behavior when the driving condition is restored and back to being normal. This can be done with the design of a neural network around the infotainment system which can be trained using the datasets obtained through the above experiments.

3. Further, an immediate solution to the above problem can be obtained through the technique of profiling. The icons can be de-facto arranged based on various algorithms like Most Recently Used, Least Frequently Used, Least Recently Used, and so on and so forth. By doing this, the infotainment system can change its behavior that is accustomed to the user of that car. This way the infotainment system is trained to adjust to the user behavior rather than the user adjusting to the infotainment system behavior. This will help reduce the cognitive load on the user and in turn reduce the distraction level and guarantee driver safety on road.

4. In Experiment 2, the data for all drivers in every mode was considered as one entity and the analysis was carried out for the entire data set as one unit, in future, the data for individual drivers can be treated as one unit to understand that driver and make the customizing more user specific.

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APPENDIX A

STATISTICAL HYPOTHESIS TESTING

Statistics is the study of the collection, analysis, interpretation, presentation, and organization of data. Statistics deals with all aspects of data including the planning of data collection in terms of the design of surveys and experiments. Two main statistical methodologies are used in data analysis:

- Descriptive statistics, which summarizes data from a sample using indexes such as the mean or standard deviation, and inferential statistics, which draws conclusions from data that are subject to random variation (e.g., observational errors, sampling variation).
- Standard statistical procedure involves the development of a null hypothesis, a general statement or default position that there is no relationship between two quantities.

Rejecting or disproving the null hypothesis is a central task in the modern practice of science, and gives a precise sense in which a claim is capable of being proven false. What statisticians call an alternative hypothesis is simply a hypothesis that contradicts the null hypothesis. Statistical analysis is a component of data analytics. In the context of business intelligence (BI), statistical analysis involves collecting and scrutinizing every single data sample in a set of items from which samples can be drawn. Statistical analysis is fundamental to all experiments that use statistics as a research methodology. Most experiments in social sciences and many important experiments in natural science and engineering need statistical analysis. Statistical analysis is also a very useful tool to get approximate solutions when the actual process is highly complex or unknown in its true form. Example: The study of turbulence relies heavily on statistical analysis derived from experiments. Turbulence is highly complex and almost impossible to study at a purely theoretical level. Scientists therefore need to rely on a statistical analysis of turbulence through experiments to confirm theories they propound. In social sciences, statistical analysis is at the heart of most experiments. It is very hard to obtain general theories in these areas that are universally valid. In addition, it is through experiments and surveys that a social scientist can confirm his theory.

Statistical analysis can be broken down into five discrete steps, as follows:

1. Describe the nature of the data to be analyzed.

2. Explore the relation of the data to the underlying population.

3. Create a model to summarize understanding of how the data relates to the underlying population.

4. Prove (or disprove) the validity of the model.

5. Employ predictive analytics to run scenarios that will help guide future actions.

The goal of statistical analysis is to identify trends. A retail business, for example, might use statistical analysis to find patterns in unstructured and semi-structured customer data that can be used to create a more positive customer experience and increase sales.

Calculation of the test statistic requires four components:

- The average of the sample (observed average)
- The population average or other known value (expected average)
- The standard deviation (SD) of the sample average
- The number of observations.

With these four pieces of information, we calculate the following statistic, t:

$$t = \frac{\text{observed} - \text{expected}}{SD_{\text{observed}}\sqrt{(\text{number of observations in sample})/((\text{number of observation}) - 1)}}$$

Figure 24. T-Stat Formula

A single sample t-test (or one sample t-test) is used to compare the mean of a single sample of scores to a known or hypothetical population mean. So, for example, it could be used to determine whether the mean diastolic blood pressure of a particular group differs from 85, a value determined by a previous study.

Requirements

• The data is normally distributed

• Scale of measurement should be interval or ratio

Null Hypothesis

H0: M - μ = 0, where M is the sample mean and μ is the population or hypothesized mean. As above, the null hypothesis is that there is no difference between the sample mean and the known or hypothesized population mean.

Equation:

$$t = (M - \mu) / \sqrt{\frac{\Sigma X^2 - \left(\frac{\Sigma X^2}{N}\right)}{(N-1)(N)}}$$

Figure 25. T-Stat Formula

Suppose that you've collected data from two samples of animals treated with different drugs. You've measured an enzyme in each animal's plasma, and the means are different. You want to know whether that difference is due to an effect of the drug – whether the two populations have different means. Observing different sample means is not enough to persuade you to conclude that the populations have different means. It is possible that the populations have the same mean (i.e., that the drugs have no effect on the enzyme you are measuring) and that the difference you observed between sample means occurred only by chance. There is no way you can ever be sure if the difference you observed reflects a true difference or if it simply occurred in the course of random sampling. All you can do is calculate probabilities. The P value is a probability, with a value ranging from zero to one that answers this question (which you probably never thought to ask): In an experiment of this size, if the populations really have the same mean, what is the probability of observing at least as large a difference between sample means as was, in fact, observed?

The confidence interval (CI) of a mean tells you how precisely you have determined the mean. In statistics, the number of degrees of freedom (df) is the number of values in the final calculation of a statistic that are free to vary. The standard deviation (SD) quantifies variability. It is expressed in the same units as the data. The Standard Error of the Mean (SEM) quantifies the precision of the mean. It is a measure of how far your sample mean is likely to be from the true population mean. It is expressed in the same units as the data. For example, you measure weight in a small sample (N=5), and compute the mean. That mean is very unlikely to equal the population mean.

The size of the likely discrepancy depends on the size and variability of the sample. If your sample is small and variable, the sample mean is likely to be quite far from the population mean. If your sample is large and has little scatter, the sample mean will probably be very close to the population mean. Statistical calculations combine sample size and variability (standard deviation) to generate a CI for the population mean. As its name suggests, the CI is a range of values. To interpret the confidence interval of the mean, you must assume that all the values were independently and randomly sampled from a population whose values are distributed according to a Gaussian distribution. If you accept those assumptions, there is a 95% chance that the 95% CI contains the true population mean. In other words, if you generate many 95% CIs from many samples, you can expect the 95% CI to include the true population mean in 95% of the cases, and not to include the population mean value in the other 5%. The unpaired t test compares the means of two unmatched groups, assuming that the values follow a Gaussian distribution. The unpaired t test assumes that the two populations have the same variances (and thus the same standard deviation). The paired t test compares the means of two matched groups, assuming that the distribution of the before-after differences follows a Gaussian distribution. The paired t test assumes that you have sampled your pairs of values from a population of pairs where the difference between pairs follows a Gaussian distribution.

Note that the paired t test, unlike the unpaired t test, does not assume that the two sets of data (before and after, in the typical example) are sampled from populations with equal variances. The pairing should be part of the experimental design and not something you do after collecting data. Prism tests the effectiveness of pairing by calculating the Pearson correlation coefficient, r, and a corresponding P value. If the P value is small, the two groups are significantly correlated. This justifies the use of a paired test. If this P value is large (say larger than 0.05), you should question whether it made sense to use a paired test. Your choice of whether to use a paired test or not should not be based solely on this one P value, but also on the experimental design and the results of other similar experiments. The results of a paired t test only make sense when the pairs are independent – that whatever factor caused a difference (between paired values) to be too high or too low affects only that one pair. Prism cannot test this assumption. You must think about the experimental design. For example, the errors are not independent if you have six pairs of values, but these were obtained from three animals, with duplicate Measurements in each animal. In this case, some factor may cause the after-before differences from one animal to be high or low. This factor would affect two of the pairs, so they are not independent. The values used for paired and upaired tests are absolute values.

Experiment 1:

T-Stat analysis:

T-Value: 3.0746

Two-tailed p value: 0.0029

95% confidence interval: From -4.10952420214 to -0.88075357586

Statistical significance: Significant

Experiment 2

Lane Position:

Results:

1. Mode-1 vs Mode-2

   T-Value: 1.2560

   Two-tailed p value: 0.0182

   95% confidence interval: From -0.34730044066 to 0.08236044066

   Statistical significance: Significant

2. Mode-1 vs Mode-3

   T-Value: 1.1992

Two-tailed p value: 0.0393

95% confidence interval: From -0.09031352771 to 0.34887352771

Statistical significance: Significant

3. Mode-2 vs Mode-3

   T-Value: 2.4586

   Two-tailed p value: 0.0195

   95% confidence interval: From 0.04489304951 to 0.47860695049

   Statistical significance: Significant

Speed Limit:

Results:

1. Mode-1 vs Mode-2

   T-Value: 9.0417

   Two-tailed p value: 0.0001

   95% confidence interval: From -17.73669396085 to -11.21450603915

   Statistical significance: Extremely Significant

2. Mode-1 vs Mode-3

   T-Value: 1.8418

   Two-tailed p value: 0.617

   95% confidence interval: From -6.27290508120 to 0.31556508120

   Statistical significance: Insignificant

3. Mode-2 vs Mode-3

   T-Value: 50.2432

   Two-tailed p value: 0.0001

   95% confidence interval: From 11.03082717686 to 11.96303282314

   Statistical significance: Extremely Significant

Braking:

Results:

1. Mode-1 vs Mode-2

   T-Value: 1.3448

   Two-tailed p value: 0.660

   95% confidence interval: From -2.23102784260 to 0.45664784260

   Statistical significance: Insignificant

2. Mode-1 vs Mode-3

   T-Value: 1.4015

   Two-tailed p value: 0.1707

   95% confidence interval: From -2.26850098367 to 0.41922098367

   Statistical significance: Insignificant

3. Mode-2 vs Mode-3

   T-Value: 4.8475

   Two-tailed p value: 0.0001

   95% confidence interval: From -0.05318644930 to -0.02171355070

   Statistical significance: Extremely Significant

Headway Distance:

Results:

1. Mode-1 vs Mode-2

   T-Value: 12.2411

   Two-tailed p value: 0.0001

   95% confidence interval: From -100.9404445416 to -72.1396954584

   Statistical significance: Extremely Significant

2. Mode-1 vs Mode-3

   T-Value: 4.9193

Two-tailed p value: 0.0001

95% confidence interval: From -42.5054659524 to -17.6123140476

Statistical significance: Extremely Significant

3. Mode-2 vs Mode-3

   T-Value: 6.9996

   Two-tailed p value: 0.0001

   95% confidence interval: From 40.0446842646 to 72.9176757354

   Statistical significance: Extremely Significant

Steering:

Results:

1. Mode-1 vs Mode-2

   T-Value: 1.3518

   Two-tailed p value: 0.1859

   95% confidence interval: From -19.41735921420 to 3.92553921420

   Statistical significance: Insignificant

2. Mode-1 vs Mode-3

   T-Value: 0.9248

   Two-tailed p value: 0.3620

   95% confidence interval: From -17.67100230493 to 6.63564230493

   Statistical significance: Insignificant

3. Mode-2 vs Mode-3

   T-Value: 0.9331

   Two-tailed p value: 0.3578

   95% confidence interval: From -2.63591853945 to 7.09237853945

   Statistical significance: Insignificant

APPENDIX B

REPLACEMENT ALGORITHMS FOR CUSTOMIZABLE UI

As discussed earlier, to reduce the driver distraction caused by the infotainment system, based on the user's usage of applications on the infotainment system, it can be customized intrinsically. By doing this, it is deduced that the user will be more familiar with the system and hence spends lesser time looking off the street and this in turn will reduce the driver distraction.

One of the proposed methods to build such a system is to use the classic replacement algorithm techniques for the applications such as:

1. LRU (Least Recently Used)
2. MRU (Most Recently Used)
3. LFU (Least Frequently Used)

LRU

The least recently used (LRU) page replacement algorithm, though similar in name to NRU, differs in the fact that LRU keeps track of page usage over a short period of time, while NRU just looks at the usage in the last clock interval. LRU works on the idea that pages that have been most heavily used in the past few instructions are most likely to be used heavily in the next few instructions too. While LRU can provide near-optimal performance in theory (almost as good as adaptive replacement cache), it is rather expensive to implement in practice. There are a few implementation methods for this algorithm that try to reduce the cost yet keep as much of the performance as possible.

The most expensive method is the linked list method, which uses a linked list containing all the pages in memory. At the back of this list is the least recently used page, and at the front is the most recently used page. The cost of this implementation lies in the fact that items in the list will have to be moved about every memory reference, which is a very time-consuming process.

Another method that requires hardware support is as follows: suppose the hardware has a 64-bit counter that is incremented at every instruction. Whenever a page is accessed, it acquires the value equal to the counter at the time of page access. Whenever a page needs to be replaced, the operating system selects the page with the lowest counter and swaps it out. With present hardware, this is not feasible because the OS needs to examine the counter for every page in the cache memory.

One important advantage of the LRU algorithm is that it is amenable to full statistical analysis. It has been proven, for example, that LRU can never result in more than N-times more page faults than OPT algorithm, where N is proportional to the number of pages in the managed pool.

MRU

Discards, in contrast to LRU, the most recently used items first. In findings presented at the 11th VLDB conference, Chou and DeWitt noted that "When a file is being repeatedly scanned in a [Looping Sequential] reference pattern, MRU is the best replacement algorithm."[6] Subsequently other researchers presenting at the 22nd VLDB conference noted that for random access patterns and repeated scans over large datasets (sometimes known as cyclic access patterns) MRU cache algorithms have more hits than LRU due to their tendency to retain older data.[7] MRU algorithms are most useful in situations where the older an item is, the more likely it is to be accessed.

LFU

Counts how often an item is needed. Those that are used least often are discarded first. This works very similar to LRU except that instead of storing the value of how recently a block was accessed, we store the value of how many times it was accessed. So of course while running an access sequence we will replace a block which was used least number of times from our cache. E.g., if A was used (accessed) 5 times and B was used 3 times and others C and D were used 10 times each, we will replace B.

APPENDIX C

VECTOR MATRIX

In statistics, a design matrix (also known as regressor matrix or model matrix) is a matrix of values of explanatory variables of a set of objects, often denoted by X. Each row represents an individual object, with the successive columns corresponding to the variables and their specific values for that object. The design matrix is used in certain statistical models, e.g., the general linear model. It can contain indicator variables (ones and zeros) that indicate group membership in an ANOVA, or it can contain values of continuous variables.

The design matrix contains data on the independent variables (also called explanatory variables) in statistical models which attempt to explain observed data on a response variable (often called a dependent variable) in terms of the explanatory variables. The theory relating to such models makes substantial use of matrix manipulations involving the design matrix: see for example linear regression. A notable feature of the concept of a design matrix is that it is able to represent a number of different experimental designs and statistical models

Vector, matrix, *N*-dimensional array, table, or dataset array representing the data from which to sample. By default, datasample regards the rows of a data matrix, or the first nonsingleton dimension of a data array, as data elements.

APPENDIX D

DATA FROM EXPERIMENTS

Average Response times

Driver	6 – Icons Average Response Time	30 Icons – Average Response Time
1	0.905	4.6125
2	2.1125	1.545
3	0.9025	5.1225
4	0.98	1.98
5	1.2375	3.0675
6	0.832	7.305
7	0.9975	2.745
8	0.8526	3.355
9	2.3	7.345
10	0.7725	3.445
11	0.715	3.0325
12	0.655	3.32
13	1.7125	3.5575
14	0.755	2.6225
15	0.775	2.3975
16	2.3275	5.78
17	1.59	10.7675
18	1.045	22.7575
19	0.74	4.4975
20	1.32	4.79
21	1.51	5.9825
22	1.69	4.2925
23	1.09	7.3075
24	0.99	2.7975
25	1.245	3.685
26	1.53	2.4825
27	0.9825	2.3925
28	2.0275	3.6675
29	0.8525	2.965
30	0.495	4.24
31	3.3575	4.9275
32	26.395	3.595
33	0.97	2.9025
34	2.05666667	2.09
35	1.195	5.6225
36	1.265	1.62
37	0.7975	1.6425

38	0.745	2.545
39	0.81	2.305
40	1.4875	3.5375
41	1.2325	1.8625
42	0.835	1.5475

Table 5. Average Response Time Table