Demonstration of Head Mounted Displays and its Effects on Situational Awareness

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"Demonstration of Head Mounted Displays and its Effects on Situational Awareness" a thesis by Adam Richard Goetz.

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Abstract

Title: Demonstration of Head Mounted Displays and its Effects on Situational Awareness

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In this investigation, I discussed the use of Head-Mounted Displayed (HMD) Augmented Reality and its effects on a driver's Situational Awareness (SA) while observing two driving scenarios. In this study I showed participants two videos, one with a simulated HMD and one without. Throughout the video, the participants were asked questions about their environment to see if they can retain information presented to them. This included the current speed of the vehicle, the next navigation direction, how many cars are surrounding the vehicle, and several others. These questions will give insight into the participant's SA. This method is called the Situational Awareness Global Analysis Test (SAGAT), and has been used in numerous prior research involving SA. The questions were compiled and analyzed using a 2x3 ANOVA in which two display types were factorially combined with three age groups. It was predicted that the experimental video using the HMD will show a significant increase in SA compared to the no HMD condition. However, none of the factors in this experiment proved any significance. This does not mean there is no merit to HMDs, in fact this shows that HMDs are no more distracting than normal driving. With more research, it could be shown that HMDs can be beneficial to drivers; it has the potential to change how we drive. It also has the potential of reducing the amount of car accidents due to reducing the distractions presented to the driver by increasing their SA. The other possibility could be if it proves to be a distraction. If it is a distraction instead of an aid, we could implement laws and teach lessons early to reduce the amount of drivers willing to take the risk of driving with these devices.

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Acknowledgment

A special thanks to all the participants of this study including my friends, family, and the other volunteers. Without your help this study would not have been successful. Other thanks to my thesis committee and especially my advisor Dr. Deaton who has helped me throughout this entire process.

Dedication

I would like to dedicate this thesis to my wife who has supported, motivated and helped make this thesis possible. Thank you for everything you do.

Chapter 1: Introduction

Situation awareness is a person's key to success and safety in quite literally any situation. Whether it is walking down the street, driving a car, or flying multi-million dollar aircraft around the world. Situation awareness is simply defined as a person's understanding of what is going on and what is likely to happen (Endsley, 1995b).

Augmented reality has made appearances in society as a futuristic device through video games and movies. Augmented reality is a real-time direct or indirect view of the physical real-world environment that has been enhanced, or augmented, by adding virtual computer generated information to it (Carmigniani, 2011). Through these venues of entertainment, it's been shown to have features such as navigation, messages from other people, access the internet, and several other features. Spectators have dreamed of augmented reality for a very long time and it seems that they might get their wish in our lifetime. The system I focused on in this proposal was the Head-Mounted Display (HMD) system. There are already rudimentary HMD systems available for purchase today, like Google Glass (see Figure 1) that projects onto a small screen mounted to the glasses that feed information to the person wearing them. This is the system I am referring to is a fully interactive HMD that will replace regular hands-free devices and reduce the need to use the touch screen that are currently popular in cars and reduce the use of cell phones while driving. These computers often sync to the drivers cell phones and display text messages, social media updates, navigation, and some even link to the internet for browsing. This is the same technology I think will eventually be implemented into HMD.

Figure 1: Example of an HMD, Google Glass (Lendino, 2014)

Problem Statement

The reason I looked into this technology is the recent studies that have been performed on driver distractions demonstrates the importance of reducing distractions and improving driver SA. According to the National Highway and Safety Association (2013), in 2011 distracted driving contributed to 10% of fatal crashes which killed 3,331 people, 17% of injury crashes involving 421,000 people. This statistic only goes up when the driver's age is narrowed to 15-19 year olds. Ten percent of fatal crashes in this age group were caused by distracted drivers. Of these crashes, 21% of them were specifically distracted by cell phones. This age group has the largest proportion of distracted drivers. The effect of distraction does not end at young, inexperienced drivers. Distracted driving effects people of all ages and experience. The statistic does trend downwards as age increases, but any deaths due to distraction, especially cell phones, is too many.

It is unlikely that cell phone use in cars will ever be completely halted until a better alternative is presented. Several states have made laws banning cell phone use without a hands free device, but it has not significantly reduced the amount of their use over time

(Braitman, 2010). The most that can be done is to try and curb the effects that cell phone use has on a driver. The use of hands-free devices is a start in the right direction, but as Strayers and Drews (2007) found in their study entitled "Cell-Phone–Induced Driver Distraction", although drivers looked directly at objects in their field of view in a simulator, they were not able to create a solid memory of it. This means that their Situational Awareness (SA) is still being reduced significantly.

I hope with the induction of HMDs that we can increase SA by bringing relevant information to the driver's attention without drawing the attention away from the road. This would involve navigation, proximity warnings, speed, warning signals, and other alerts. However, developers of HMDs will also want to add other alerts to the system, i.e., text messages, phone calls, social media alerts, and other more frivolous updates. I believe this will be the double edged sword of the HMDs. Although this will keep a driver's attention on the road, it will also take attention away unnecessarily by adding information that doesn't need to be there. That is what this study is about: Will a HMD system that is equipped similarly as to what is currently available in cars make a positive difference in a driver's SA?

Purpose Statement

The purpose of this study was to see if an HMD will create a difference in a participant's Situational Awareness (SA) while in a car and if its effectiveness is impacted by the user's age. The secondary purpose of my study was to create a basis for more research into HMD uses in cars. There have been studies on some uses for HMDs, but not a full system to replace in-dash computer consoles that cars have today. We know in-dash consoles and cell phones are very distracting for the same reason of visually and manually distracting the driver (Wilson, 2010), but how much more or less distracting would it be if all the information you are looking for on those systems were instead presented to you through a device that shows you the information right in front of you? I believe HMDs will be a very helpful feature, but it won't be if it uses all the same features as in-dash consoles and cell phones when in a car. It will reduce manual distraction since there is no need to take your hands off the wheel. It will also moderately reduce visual distractions since there is no need to look away from the road, but parts of the road will be somewhat obstructed by the information being displayed. The main concern, however, are the cognitive distractions that could also be quite severe with all that information being presented while also processing information associated with the area around you. If the participant can recall objects in the environment, then they have retained their SA and the HMD has worked in keeping the driver's attention on the road. If they can't, however, then their SA has been compromised and it will show the Heads-Up display is more distracting than helpful.

Operational Definitions

In order to create a uniform understanding of this study, the following terms have been operationally defined:

Situational Awareness

A person's understanding of what is going on and what is likely to happen in the immediate future (Endsley, 1995b).

Augmented Reality

A real-time direct or indirect view of the physical real-world environment that has been enhanced, or augmented, by adding virtual computer generated information to it (Carmigniani, 2011).

Head mounted Display

A device that is mounted to a person's head with a transparent display that enhances the person's perception of the world with supplementary information. These devices are often connected to the internet to access information through a Bluetooth connection to a cell phone.

Research Questions / Hypotheses

RQ1: Will simulated HMDs increase or decrease a driver's situational awareness (SA) when compared to no simulated HMD?

H_0: Simulated HMD shows no difference in situational awareness (SA) when compared to no simulated HMD.

H_1: Simulated HMD shows a significant difference in situational awareness (SA) when compared to no simulated HMD.

RQ2: Will age have an effect on situational awareness (SA)?

H_0: Age will not have a significant effect on situational awareness (SA)

H_1: Age will have a significant effect on situational awareness (SA).

RQ3: Is there an interaction of display type and age?

H_0: There is no significant interaction of display type and age.

H_1: There is a significant interaction of display type and age.

I believe this study will help provide more evidence in support of drivers being able to use HMD devices while driving by providing proof that they can be beneficial in terms of increasing SA, and therefore, decreasing accident rates. Several states have already banned the use of these devices even though there is not very many studies stating HMDs are distracting or helpful. I hope to find that HMDs can be useful by increasing a driver's SA in order to reduce the amount of accidents.

In the next chapter, I will be discussing several studies and theories associated with this topic. Chapter 3 will then present the methodology associated with the conduct of the present investigation.

Chapter 2: Literature Review

For at least 15 years or more (Kobe, 2000) there has been a very serious –albeit one sided– debate about distractions while driving with the main focus being on cell phones (Kobe, 2000). In the last 10 years there has been more debate as text messaging, internet, and navigation functions have been built in to phones. Every single feature on today's cell phones can cause a huge distraction for drivers in today's busy world. Many states have banned both talking on cell phones without a hands free headset, and also text messaging while driving a vehicle (GHSA, 2015). The only thing legal to do on a cell phone in many states and cities is use the navigation. However, even the navigation can be a significant distraction for drivers because it pulls their attention away from the road.

Studies

According to Rosenberger (2014), there are three types of distractions: (1) Visual distractions involve looking away from the road, (2) Manual distractions involve taking your hands off of the wheel, and (3) Cognitive distractions involve taking your attention off the road. Cell phones cause all three of these types of distractions and often all at the same time. This is a main reason why cell phones can be very dangerous to drivers. Cell phones cause visual distractions by making the driver look away from the road to read text messages, look at navigation, or to see who is calling. They cause manual distractions by making the driver take their hand off the wheel in order to pick up the phone to answer the call, respond to text messages, or just about anything else involving the phone that the driver wants to do. The last distraction is what researchers have shown is the worst type of distraction. When talking on a cell phone with a person who is outside the car, researchers have found that driver performance is at its worst (Rosenburg, 2014).

A study by Strayer and Drews (2007) showed that using a hands-free device only reduces visual and manual distractions, but did not decrease cognitive distractions. Their experiment consisted of two studies. Both studies used a high fidelity simulator and eye tracking sensors to track what the participant was actually looking at. The first study focused on the conditional probability of participants recognizing objects they had looked at –objects identified by the eye tracker that the participant had looked at the most– when driving under two phases. In the first phase, the participants drove the simulator with no cell phone use. In the second phase, participants drove the simulator while talking on a hands free headset to a confederate having a typical conversation. They found that in a simulator, drivers talking on a cell phone using a hands-free device were not able to form a durable memory of an object or its location. The second study they performed examined how drivers strategically reallocate attention from less-relevant information from the simulator to the cell phone conversation while keeping the primary attention on the task presented by the simulator. This study differed in procedure from the first by using a two-alternative forced choice recognition-memory paradigm in order to see where the participants were placing their attention when driving. They achieved this by placing 30 objects relevant to safe driving, like cars, pedestrians, signs, etc., into the simulation. When the participants were asked to recall the items they had seen, they were also given 30 objects that were not in the simulation to serve as foils. The participants were not informed that there would be a memory test in order to truly test their recall ability on either of these studies that were performed. They found the same result for both of these studies. They found that those participants that were on their cell phones could not create durable lasting memories. However, the second study had promising results that showed, despite the distraction qualities of cell phones, it is possible to train the human brain to talk on a phone hands-free and drive due to the ability to prioritize the driving as paramount to the conversation.

Another major distraction for drivers is the navigation programs installed on cell phones and in car dashboards. Although this program may be very useful in getting to new places with the best and quickest route, it has the same inherent problem as text messaging (Wilson, 2010). Often when driving using a navigation system, the driver is constantly taking their eyes off the road to check the route. There have been several studies trying to validate using Heads-Up Displays (HUD) with several having good results (Shahriar, 2014; Rusch, 2013). A HUD is a display that a person can see through but can display supplemental information to the immediate environment (see Figure 2).

Figure 2: Example of a Heads-Up Display.

A thesis paper by Shahriar (2014) found that Heads-Up Display navigation, when compared to other personal navigation devices, helped reduce eye movement and distractions while giving the participants the same navigation instructions. Shahriar used a high fidelity simulator with sophisticated eye tracking equipment to measure how often participants look away from the road. Participants used three types of personal navigation devices and a heads-up display navigation system. When compared, the HUD kept the drivers attention on the road significantly more and driver performance was increased significantly. This is, however, not the only way HUDs can be useful.

Another study that was performed was a study by Rusch, Schall, Gavin, Lee, Dawson, Vecera, and Rizzo (2013). This study was performed to see if the use of an HUD could be used as an early warning alarm for any upcoming potential hazards. Drivers were asked to drive in a simulator multiple times on multiple different routes. They were instructed to react to potential hazards by flashing their high beams. None of the hazards were sudden or obscured unless the driver was tailgating a lead vehicle. The HUD would highlight a hazard approximately 350 meters from the hazard. The participant was then asked about the presence of a primary and secondary target. Reaction times and responses were analyzes for both the HUD trial and a control with no HUD. Rusch et al. found that the HUD cueing provided a promising means to improve driver safety. It has the potential to reduce reaction time and increase hazard detection.

Although these seem like very useful features of an HUD, there are many features that will be distracting. The main focus of my experiment, however, is the head mounted displays as replacements to sync with cell phones as well as vehicles in order to replace the need for in-dash computers as well as the need for having to pick up a cell phone. They will have many features not only for driving but also the link to cell phones will give updates for text messages, phone calls, social media and emails. This is not available today in cars, but I anticipate that it will be in time. With more time and research into proper technologies, I think it will replace in-dash computers. I would think it will be marketed as a safer alternative, but in reality, it will be just as distracting cognitively and visually, instead of manually like the in-dash computers where the driver has to manually take their hands off the wheel and touch the screen to navigate the screens.

These studies show that HUDs have a potential to decrease distraction qualities by removing the need to look away from the road and removing the need to take their hands off the wheel by using voice commands. The fact that the HMD is closer to the user's mouth will help increase the accuracy of the voice commands, and the constant access to the internet through the Bluetooth connection on the cell phone will increase the dictionary capacity of the device. This is compared to in-dash consoles that don't always have the constant connection and have a microphone in the dash which can be easily drowned out by music, road noise, etc. (Harpie, 2015)

I am adding another aspect to my study that these experiments haven't accounted for, by adding in the participant's age. Gurtner, Reinhardt, and Soyez (2014) performed an experiment entitled "Designing Mobile Applications for Different Age Groups". This experiment was performed to find if different age groups valued different aspects of a mobile business application. They separated the ages into three groups: under 25, 26-50, and over 50. The under 25 were considered digital natives representative as the group of people on the borderline of education and professional life. The 26-50 year old group represented people that have high involvement in work related activities, their cognitive abilities are distinct, and their use of technology in everyday life is confident. The last age group is anyone over 50 years old where the cognitive abilities, especially in relation to new complex technologies, are decreasing which leads to fewer and lower adaptations of innovation (Rogers, 1995). This study focused on age and its effects on using technology. This is similar to what I have done in my study as well. I am focusing on how a form of technology will aid a driver and if their age will increase or decrease the effectiveness of the aid. The HMD will only effect the driver if it provides the information the driver needs. The Gutner study showed that different age groups value different aspects of new technology so the HMD must provide all those things to be effective over all age groups.

Theory

The theory of situation awareness is built upon several other components and theories. The main component for my study in building situation awareness is the working memory. I will also discuss the capacity theory of attention, multiple resource theory, and interface design.

A person's working memory is best described as a temporary memory storage for new information to be mixed with existing information. This allows a driver to form predictions as to what may happen in the near future. However, since it is a temporary storage, it constantly needs to be updated. New information needs to be presented to adapt to new situations. This is why I believe the HMD will be useful. It can constantly keep the driver up to date about many aspects of the road in order to better inform the driver about the environment. The more information provided to the driver and accessible, the easier to predict future accidents

Wickens (2008) developed a theory labeled multiple resource theory that attempts to explain how a person can multitask and how much they can multitask. Multiple resource theory consists of three dimensions. The first dimension states that a person obtains information through certain modalities including speech and sight. The second dimension is the information is then coded as spatial or verbal and stored in the working memory. However, if a person receives too much spatial or visual information, the working memory will start to suffer. The third dimension is the stage. This refers to how the information is used, whether it is encoding or perceiving the information, making a decision with the information through central processing, or responding to the information either manually or vocally. To better visually explain this theory, Wickens created a cube (Figure 3). The best way to use this 2x2x3 cube is to think if it split up into "cells" with a limited capacity. Once a "cell" has been filled, the brain can no longer properly process that type of information. The best example of this is multitasking while driving. According to this theory, the reason texting and driving is so cognitively detrimental to a driver is that the brain has filled the visual spatial cell. Once this cell is filled, the brain's ability to process new information is significantly diminished. However the brain can still process other types of information.

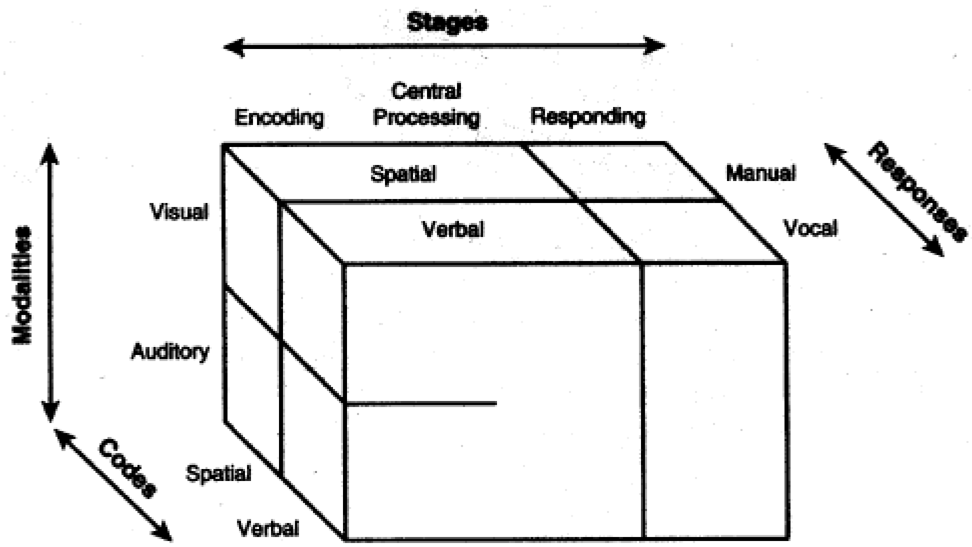

Figure 3: Wicken's visual explanation of Multiple Resource Theory.

Endsley and Jones (2012) discussed two main philosophies when designing an interface system for any technology. The first is technology-centered interface. This philosophy follows an engineering standpoint. Engineers design a system with the sensors needed to perform every function. Then a display was formed to show the user each of these systems and functions and how well they were performing or its current status. This interface works for some time, but as technology advances and more sensors are added and more displays are added, the more work a user has to do to keep up with the information. The more usable philosophy is called user-centered design

Endsley and Jones also discuss user centered designs which is based on several principles with the end goal of raising the situation awareness of the user. It is mostly suited for complicated systems, which is suitable for HMDs. First, technology should be organized around the way users process information and make decisions. The second principle addresses the point that technology should be organized around the way users process information and make decisions. The third principle refers to the idea that technology must keep the user in control and aware of the state of the system. All of these principles can be summed up as technology should be intuitive to use. A user should not have to extensively search for the information they need on a system. Instead, they should have the information needed for the task readily available. This type of design is important to this study because participants need to be able to interpret the information given to them easily without the extra workload of searching for information that will impact their mental capacity. The HMD is supposed to aid the driver, not distract. In order for this to be successful, the driver needs to be able to find and interpret the information as seamlessly as possible, which is the direct goal of user-centered designs.

The last theory I will discuss is Diffusion of Innovation. Rogers (1995) defines this theory as the process by which an innovation is communicated through certain channels over time among the members of a social system. HMD is a new innovation and needs to diffuse, in this particular situation, through the marketplace in order for society to deem it a good or bad innovation. In this book, he describes 5 different groups of adopters of innovations. The first group is the innovators who create this innovation and are thus the first to adopt. The second group is the Early Adopters who are part of the social group closely integrated with the innovators. The third group is the early majority which adopts new ideas before the average member of a social system. The fourth group is the late majority which adopt after the average member has adopted. The last group is the Laggards who are the last to adopt to a new innovation. These groups are important to my study because HMDs are currently still in the early adaptors stage of diffusion and not readily available to even the early majority group. However, because of the possibility of this innovation diffusing into the market in the near future, researchers must first make the product safer for the early majority to have a favorable enough adaptation in order for the late majority to adopt quicker due to their apparent skepticism of new technology. Although it is uncertain how much age is related to these groups, it is clear that age effects the cognitive abilities of individuals which does correlate to these groups. Individuals with higher cognitive abilities in general are more willing to adopt innovations when compared to individuals with lower cognitive abilities (Rogers, 1995)

In Chapter 3 I discuss the methods I used to achieve my results. I discuss the participant requirements, the design and manipulation of the experiment, the SAGAT measurement I used, and the step by step procedure I used for the experiment. All of these are very important so that anyone wishing to replicate my results will have a thorough description of this process.

Chapter 3: Methods

Participants

The participants were 42 people with varying age and gender. The number of participants was determined using G-Power (Faul, 2007) which calculates the required number of participants needed for the type of study being performed based on the statistical method that is needed to achieve a significant outcome. The statistical analysis I used was a 2 x 3 mixed ANOVA, independent variables being Type of Display (HMD vs No HMD), and Age (Young, Middle, and Old). Display Type was the within subject variable, and Age was the between subject variable. The parameters used in calculating the optimal sample size with G-Power were as follows: Effect size = 0.35 (medium), $\alpha = 0.05$, power = 0.8, with 6 groups (3 levels based on age and 2 levels of measurements).

All participants were current legal drivers of varying ages and genders. Participants were gathered one at a time in a common controlled environment to participate in this experiment. There were 3 groups: 1. 18 through 25 with driver's license, 2. 26 through 50, and 3. Over 50. These groups were specifically chosen based on Rogers Diffusion of Innovations theory (1995) and used in a recent study by Gurtner, Reinhardt, and Soyez (2014).

Participants were asked to arrive one at a time to a single location to participate in this study. This was to create a sterile environment which would control any confounding factors that could affect the results like background noise, pets, children, television or any other distraction that would pull attention away from the videos or instructions.

Design and Experimental Manipulation

As stated earlier, this study used a mixed 2 x 3 factorial ANOVA to compare the effects on SA while driving a car with and without a simulated augmented reality (within subject variable) as well as examining the effects of age (the between subject variable) on SA. In other words, the independent variables is the Type of Display (HMS vs No HMD), and Age (Young, Middle, and Old). The dependent variable was the measure of SA based on the SAGAT. This statistical analysis permitted the evaluation of the main effects of Display Type and Age, as well as the interaction effects of Display Type with Age.

Both of the conditions followed the same structure. The participant watched one video in each condition of a driver going on a 10 minute drive with several turns while navigating through traffic. There was no background music so as to not compound the distractions. The video continued until the driver reached the destination. One video had no augmentation and the other had a simulated augmentation. These videos were taken separately but were recorded around 5 PM on different weekdays where there is adequate sunlight and no adverse weather conditions. The traffic condition was approximately the same since the two videos were taken at approximately the same time during the day. The augmented video was recorded using a specialized app that provided the speed, navigation, and other details. The presentation order of the conditions was counter balanced to inhibit practice effects.

Instruments

I measured participants' SA using a technique called Operator-in-the-Loop Situational Awareness Global Assessment Technique (SAGAT). The SAGAT was created by Endsley (1987a) and further supported in her article in 1988 discussing the process and validity of the measurement. It consists of a series of questions that are asked intermittently throughout the video. The questions were based on the surroundings of the vehicle and the disposition of the vehicle, e.g., number of surrounding cars, current speed of vehicle, safe to change lanes, etc. This is all relevant information that the typical driver needs to know at all times and is pertinent to a drivers SA. These questions were asked at similar time intervals for both videos for consistency.

There are some studies that compare several different methods of measuring SA. Jones and Kaber (2005) compiled numerous studies that assessed and validated the SAGAT method. Further support for the SAGAT as an objective measure of SA is reviewed in Salmon's article (2009a). The authors compared three methods of measuring SA –SAGAT, SART and the NASA TLX− and found that the SAGAT was the only method that showed a statistically significant correlation with participant performance.

The SAGAT provided correct vs. incorrect answers. There were 20 questions over the course of the video, with a single question being asked during each pause in the video. The answers given by the participants will be indicative of the participants SA during the videos. Endsley and Bolstad (1994) demonstrated the reliability of the SAGAT with four pilots in two different simulations trials. When the SAGAT was tested and re-tested for correlation with SA, they found the SAGAT's test-re-test reliability quite high: 0.99, 0.98, 0.99, and a 0.92. Gugerty (1997) showed good reliability in his experiment involving a driving task for recalling the percentage of cars, the recall errors, and composite recall errors. The even-odd reliabilities of the study were 0.92, 0.93, and 0.96 which in general supports the reliability of the measure.

Procedure

After the participants sign up for the study and arrive at the test site, they were briefed on the purpose of the experiment and asked to sign an informed consent. After the informed consent is signed, they filled out some basic background information. Once that is complete, they were given a set of instructions about what will happen and what to expect. They were given some example questions (not the full list) so that they will not be caught off guard when questions are asked. The two videos were counter balanced to avoid practice effects within the study. They then watched the first video (either the HMD or non-HMD condition), followed by a brief intermission of 5 minutes, and then the second video was shown. After the data was collected, the participants were debriefed and the experiments came to a close.

Data Analysis

The first research question −Will simulated HMDs increase or decrease a driver's situational awareness (SA) when compared to no simulated HMD?− was answered by the within-subjects F ratio of the 2 x 3 ANOVA statistic. The first F ratio evaluated whether the main effect of display type impacts the SA measure. If the F statistic is not significant then the null hypothesis is accepted and there is no significant difference between the simulated HMD and the non-simulated HMD. If the F statistic is significant then we reject the null hypothesis and conclude there is a significant difference between the simulated HMD and the no simulated HMD.

The second research question − Will age have an effect on situational awareness (SA)? − was answered by the between-subjects F-statistic of the 2 x 3 ANOVA. The F-ratio showed if the main effect of age has a significant effect on SA. If the F-statistic is not significant then we accept the null hypothesis and conclude there is no difference between the three age groups and SA. If the F-statistic is significant, then we must reject the null hypothesis and conclude there is a difference between one or more of the age groups on SA. This was determined by using a Tukey post hoc test to identify which age groups showed a difference when compared to each other.

The last research question −Is there an interaction of display type and age− was answered by the interaction F-statistic of the 2 x 3 ANOVA. The F-ratio determined if there is an interaction between age and display type. If the F-ratio is not significant then we accept the null hypothesis and conclude that there is no interaction between age and display type. If the F-ration is significant, then we must reject the null hypothesis and conclude that there is an interaction between age and the display type.

In the upcoming chapters, I discuss the results of the experiment and whether they were significant or not. After the results are explained, I discuss the implications of the results and any possible issues that were experienced with the experiment.

Chapter 4: Results

Introduction

This chapter will discuss the statistical findings of the data that have been collected. The goal of the data interpretation is to answer the three research questions. The data collected will reflect whether or not an HMD will have a significant difference on a drivers SA. The data will also reflect if age had an effect on a drivers SA as well as any interaction between age and HMD. There were fourteen participants in three separate age groups making a total of 42 participants (n=42). Each participant watched two video with 20 questions each for a total of 40 questions. These responses were then scored with the amount of correct and incorrect and coded into a spreadsheet. All data were analyzed using IBM SPSS Software™. The data that were collected weres analyzed using a mixed methods 2x3 factorial ANOVA with follow up Tukey post-hoc tests if required. First we must fulfill the requirements to see if the ANOVA is a valid test to run for these data. There are seven required assumptions that need to be met to ensure the ANOVA provides accurate results.

Assumptions

The first assumption is that the independent variable is a constant variable. In this study, the independent variables were measured on a scale from 0 to 20 for each of the two videos. This fulfills the first assumption

The second assumption is that the within-subjects have at least two levels. In this study, the two condition levels are the videos the participants watched. Each participant watched two videos, one with an HMD overlay, and one without the HMD overlay.

The third assumption is the between-subjects have at least two levels. In this study I have three levels which are dictated by the age of the participants. These levels are 18-25, 26-50, and over 50.

The fourth assumption is the detection of outliers. According to SPSS using a box histogram, there were no significant outliers that could affect the outcome of the ANOVA test.

The fifth assumption is that the data has an approximate normal distribution. According to the Shapiro-Wilks statistic, the HMD data has a significance of p=0.000 and the No-HMD data has a significance of p=.039. For the data to be classified as normally distributed it must have a significance greater than p=0.05. However, recent literature has suggested that ANOVA statistics do not need to necessarily meet the assumption of normality, as described by Norman (2010), and will yield nearly correct answers even for manifestly non-normal and asymmetric distributions like exponentials. In other words, the ANOVA is robust enough to find significance without normality in a data set.

The sixth assumption is that the data has equality of variances for the variables. The Levene test based on means was used to test for equality of variance. Although the no-HMD condition came back with no significance, there was an issue with this test in the HMD condition F=6.881, p=0.003, which is significant. Fortunately for this report, this does not particularly effect the analysis because unequal variances increase the chances of type 1 errors (Moder, 2010) and none of the F-statistics were significant except the interaction which when analyzed with a Tukey post hoc, also proved to be non-significant.

The seventh and last assumption is known as sphericity. This is measured using Mauchley's test for sphericity. For this study, since Mauchley's test is not significant, thus, the data did not violate the assumption of sphericity.

Descriptive Statistics

This study used a sample size of 42 participants. The specific ages and genders were not collected for this study. Participants were simply asked to choose their age group until every group had 14 participants. Information from the SAGAT of the average scores and standard deviations of each group is listed in Table 1.

Table 1: Means and Standard Deviation.

Variable	**Mean**	**S.D.**
Age group 1 - HMD	16.57	1.651
Age group 1 - No-HMD	16.57	1.785
Age group 2 - HMD	17.29	1.383
Age group 2 - No-HMD	16.14	1.610
Age group 3 - HMD	16.52	2.167
Age group 3 - No-HMD	16.00	1.739

ANOVA Analysis

A 2x3 mixed methods ANOVA was conducted to analyze the data that were collected. The independent variable was the age group of the participant (18-25, 26-50, 51+). There are two levels to the second independent variable, the No-HMD condition and the HMD condition. Since each participant completed both levels of the second independent variable, the mixed methods ANOVA is the best method to find if there is any difference between conditions. If there is any statistical significance, the p-values must be below 0.05. Table 2 shows the outcome of the ANOVA analysis.

Table 2: ANOVA Table

Variable	**Sum of squares**	**DF**	**Mean Squares**	**F**	**Sig.**
Display type	5.762	1	5.762	1.554	0.220
Age Groups	24.667	2	3.374	0.629	0.538
Display type with Age Group	4.667	2	2.333	3.374	0.045
Error	144.571	39	3.707		

Research Question 1

The first research question to be answered is: Will simulated HMDs increase or decrease a driver's situational awareness (SA) when compared to no simulated HMD? This question is answered by the "within-subjects" portion of the ANOVA. The F statistic showed that there was not a significant difference between the no-HMD and

HMD conditions, F(1,39)=1.554, p= .220, and therefore we must accept the null hypothesis. The null-hypothesis states that there is no significant difference between the SA of the No-HMD and the SA of the HMD conditions.

Research Question 2

The second research question to be answered: Will age have an effect on situational awareness? This question is answered in the between F-statistic of the ANOVA. The F-statistic showed that there was not a significant difference between age and SA, F(2,39)=0.629, p=.538). This means we accept the null hypothesis and conclude that there is no difference in age groups for SA.

Research Question 3

The third and final research question to be answered is: Will there be an interaction between age and display type on situational awareness (SA)? This question is answered by the interaction portion of the ANOVA. The F-statistic showed that there was a significant interaction between age and display type F(2,39)=3.374, p=.045, eta squared=0.703. This means we reject the null hypothesis and accept the alternative hypothesis that states that there is a significant interaction between age groups and display types on SA. The Tukey post hoc test was used to determine if there were any differences between the individual age levels at each level of display type. This test came back as insignificant on all combinations. There are two possibilities as to why there was a significant interaction, yet post hoc tests did not reveal any significant differences on any of the simple effects. The first possibility is there was a type 1 error, meaning it showed significance despite there not being any. The second possibility, and the more probable of the two, is there was simply not enough power to detect any significance due to the size of each of the age groups. When age group 1 and 2 were compared (collapsing over display types) the significance was $p=0.958$. When age group 1 and 3 were compared the significance level was $p=0.104$. The group comparison that was closest to being significant was the comparison between groups 2 and 3 with a probability level at $p=0.057$. If one is willing to raise the acceptable p-value to 0.06, then this would be a significant result. If the groups were larger, perhaps these numbers would have shown some significance, especially the comparison between age groups 2 and 3.

In the next chapter, I will be discussing the implications of these results, as well as shortcomings of the study. I will also discuss possible future research to better identify the abilities of HMDs and their effects on a drivers situational awareness.

Chapter 5: Discussion

Conclusion

The main purpose of this study was to find if Head Mounted Displays would be an effective aid or a distraction to a driver's situational awareness. The other purpose of this study was to find if age was a factor in determining a drivers SA, as well as if there were any interactions between age and display type. However, none of these showed any real significant differences. The results of the interaction showed slight significance but when analyzed with the Tukey post hoc test, there were no significance differences between any of the age groups.

All these results point to HMD's being neither helpful nor hurtful to a driver's SA across all ages. Although we have to accept the null hypothesis, this also means that the HMD is not having a negative effect on SA either. This tells us that the human brain may not be using all of its resources observing all the information that it is being given. This gives some indication that HMD's might be safe to use while driving but will need more research to prove safe or not.

Research has already shown that HUD's can increase a driver's SA when used properly. It stands to reason that HMD's would have a similar effect when used in similar situations. This study shows that they are at least not distracting the driver to any significant level. With more research and more programs, this technology could be used in several significant ways.

Shortfalls

This study does have some shortfalls with how it was conducted. The biggest issue was the manual input of responses from the participants. With this method, participants were able to edit answers or wait until the video had started again to answer this question, despite being asked not to do so multiple times. Also the participants were not as diverse as one would hope. All three age groups were filled but ages were often clustered at the bottom and top of the ranges rather than being spread across them evenly. Also, most of the participants were female, which was not collected or analyzed in the data but could be a further area of research. However, the biggest shortfall with the participants was the size. The results indicated that in order to get a more accurate conclusion, more testing must be done with a larger sample size as well as correcting the aforementioned shortfalls.

Future Research

There are several areas of future research to be explored on this topic. This study was a very low-fidelity study and will need further testing in higher fidelity environments in order to truly test the qualities of HMD's and the effects on SA. The best method would be to fit participants with an HMD and have them use a driving simulator while answering a SAGAT. Using a higher fidelity situation would give a better indication and would give a more accurate prediction as to the effectiveness or distraction that HMDs will have. All of the HUD studies that were outlined previously in this report could be re-investigated using an HMD instead of the HUD. These involve the navigation test and the early warning test. It would also be wise to test other situations like receiving notifications, or other normal cell phone operations that would be distracting since the HMDs are linking to a cell phone. It would be a mistake to assume everyone would only use the technology in the most efficient way. If the driver simulation testing proves to be significant improvement on SA, it would be fairly easy to proceed forward to a closed test track experiment in an operating vehicle. This would be the most accurate and still safe way to test the usefulness and/or distraction caused by HMDs.

With this technology being consumer ready in the upcoming years, more research needs to be done to see the possible effects and uses for this technology. With instant access to information at our fingertips and presented directly into our eyes, the possibilities of uses are endless. That being said, the possibility of misuse are endless as well.

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