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THE IMPACT OF COLOR ON SECONDARY TASK TIME WHILE DRIVING

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ABSTRACT

Automobile manufacturers have been consistently increasing the amount of new technology in their products to meet consumer demands and to improve desirability. The trend towards integrating an increasing amount of intelligence, as well as media and navigation services, in cars brings challenges for automotive User Interface (UI) design. In-vehicle infotainment systems, along with an increasing number of other features, drastically increase the risk of drivers becoming distracted with secondary in-car tasks. Automotive UIs operated by the driver must demand minimal user attention, and eyes-free interaction should be encouraged.

Although speech and gesture interfaces offer appealing interaction solutions for interacting with car controls, the current general trend in consumer electronic UIs is dominated by touch screens. In an in-car context, the visual information presentation on a display requires careful UI design. The design of touch screen dashboard UIs has followed the paradigms set by mobile touch screen interfaces, i.e. generally requiring the user to interact with a particular, relatively small, area of the screen where a virtual button or other control is located.

This paper investigates the role of color in touchscreen tasks as it relates to driver's glance behavior, identifying strengths and limitations of color in touch screens while navigating in a driving simulation. The study found that participants spent significantly shorter time glancing at touch screens when presented with color targets compared to grayscale targets. The results provide evidence that differences in color for touch targets may reduce glance time away from the road when driving and ultimately reduce the risk of distracted driving.

KEYWORDS

Vehicle Dashboard, Distraction, User Interface, Touch Screen

1. INTRODUCTION

For most people, driving is a necessity. Many people travel to work everyday, run errands, take their children to school; and every time they get in their vehicles, they are taking a risk. Millions of car accidents occur every year, of which tens of thousands prove fatal. There are more drivers on the road every year and traffic can become extremely congested at times.

Driving carefully is a highly demanding cognitive and physiological task. It is important for every driver to stay focused on driving and not become distracted by texting, talking on the cell phone or changing the radio station. Distraction occurs whenever a driver is [1, 2]:

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"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 compels or induces the driver's shifting attention away from the driving task."

It is important to consider all the uncertainties of the environment as well as human behavior. Even though manufactures cannot easily account for the uncertain-ties of the environment around the vehicle, they can work to limit the number of distracting elements inside the car.

Distracted driving is one of the leading causes of automobile accidents in the Unit-ed States. Approximately one quarter of vehicle crashes in the United States result from the driver being inattentive, or distracted [3]. As more technologies move into automobiles, with the intention of making driving more comfortable and enjoyable, they may actually be creating a more dangerous driving environment. Satellite navigation, entertainment systems, detailed system status information and infotainment systems are just a few of the items that unintentionally compete with the road for the driver's attention. These same technologies are quickly becoming a standard for modern automotive manufactures. Designing these in-car features and interactions with the driver's attention in mind as well as possible causes of distraction will help reduce the chances of distracted driving related accidents.

Secondary tasks are one of the leading causes of distracted driving accidents. Cell phone use is the most investigated secondary task associated with driving. Kahn et al. assessed the statistical reports from the National Highway Traffic Safety Administration. They aimed to discuss the impact distracted driving has on crash rates, specifically in relation to cell phone use [4]. Of the 3,331 people killed in 2011 on roadways in the U.S. as a result of driver distraction, 385 died in a crash where at least one driver was using a cell phone (12% of all distraction-affected fatal crashes). These numbers includes answering or making phone calls as well as sending or receiving text messages.

Perceived risk of driving while on the phone is lower than the actual risk. Though it is one of the most common and most risky driving tasks, most users feel that there is a low probability of this behavior causing an accident [5]. Perceived risk could be even lower for integrated systems with the justification that the built-in nature of the device encourages use while driving, creating an even higher chance for distraction.

The percentage of young drivers (age 15 to 19) who are involved in fatal car accidents is higher than the overall average at 21% [5]. This may provide evidence that teenage drivers are more susceptible to distractions from technology while driving. If this is the case, the addition of more technology and interfaces into car systems may exacerbate the issue, further reducing young driver's ability to concentrate on driving. Though the research and documentation of car accidents related to phone use are quite well established, concentration on the effects of other in-car distractions are less represented in the literature and require further investigation. As the number of features in cars continues to grow, manufactures need to concentrate on the impact of these interactions as well as consider how best to implement them to keep them from becoming a distraction.

1.1. Inattention

One of the largest issues with determining how distracting a task can be is the challenge of measuring inattention. Part of the difficulty in studying cognitive distraction has been the inability to isolate the mental components of various tasks [6]. The AAA Foundation for Traffic Safety has provided significant evidence that secondary tasks have an impact on the participant's attention by monitoring brainwave activity. Through their studies, they have been able to measure the mental workload associated with various tasks (on a scale from 0 to 5), such as listening to the radio or speaking with a passenger, while driving. As expected, as the tasks required more conscious thought, the larger the associated workload rating became. Additionally, the study suggests that if the system or interaction failed the user (i.e. introduced errors) or behaved in an unanticipated way, then cognitive workload increased significantly. Using a perfectly accurate system for menu-based navigation (e.g., locate the nearest ATM) yielded a 2.83 distraction level. Once errors were introduced this rose to 3.67 [6]. This evidence could suggest that distraction is directly related to both the type of task (i.e. how much conscious thought is required) and the user's confidence in the systems accuracy. This lack of confidence in the system can lead to users having to dedicate more mental resources to identify errors, compensating for pain points and spend additional time confirming task completion.

The effect of a secondary task on a driver's attention depends on the type of task being executed. Another study examined the effects of secondary tasks and driving environment and their relation to driver distraction [7]. Maintaining a conversation while driving (through a hands-free phone) negatively affects the driver's subjective workload, but not as drastically as tasks that require visual attention such as interacting with the entertainment system. These finding seem to align well with the findings of Hamilton [6]. Horberry et al. [7] provided evidence that tasks that require visual attention are significantly more likely to negatively impact a driver's attention on driving tasks, compared to tasks that are purely auditory based. Since a majority of the tasks associated with infotainment centers in cars rely on visual attention, it will become increasingly important for car manufactures to reduce visual demand, minimizing the chances of distraction.

1.2. In-car Interactions

A number of researchers have investigated the impacts of multiple in-vehicle information systems on car drivers. In one particular experiment, a high fidelity driving simulation was used - 23 participants were asked to engage with two secondary tasks while navigating through a simulated driving experience [8]. Participants were tasked with identifying numbers on a display as either odd or even or identifying letters as either a consonant or vowel. These tasks were paced (presented at timed intervals) as well as unpaced (presented one after another). NASA's TLX (Task Load Index) subjective measures were used as well as paper-based UMIST objective mood measures. The findings suggest that mental workload is significantly higher for all tasks com-pared to the control, aligning with results reported by other research [6,7].

The highest errors were recorded during paced and interrupted tasks. This suggests that requiring participants to respond quickly to consecutive tasks greatly increases error rates. It was also noted that participants seemed to drive more slowly when experiencing higher mental workloads. This was assumed to be a result of subconscious effort to provide more time to react to driving errors. The amount of mental effort these dual tasks require suggest that in-vehicle information system should never require users to manage more than one task at time. Additionally, interactions should be designed to require the fewest number of consecutive tasks possible.

Auto manufacturers regularly strive to meet the changing demands of consumers. This often results in an increasing number of features being packed into their vehicles. As the number of features and possible interactions increase, so too does the amount of information users need to process. Gibson et al. distributed a questionnaire to 35 participants, age 18 to 40, to evaluate user opinion on their own vehicle dashboard design [9]. They hoped to identify the criteria most important to consumers with regard to next generation vehicles. They identified that most participants were satisfied with the physical ergonomics of their current vehicles. Items such as in-vehicle information systems however were viewed as either slightly distracting or having no effect on the driving experience due to little use. Dashboard design and instrument panels were generally seen as adequate with few unused elements. The results of the study show that some features that are being placed in cars may seem appropriate; they may get little use and provide unnecessary information for users to process. Features and interactions being included in vehicles must positively impact the user experience and not become a hindrance or, at the least, visual clutter.

The constant evolution of technology continuously alters what customers expect to receive from a product. One group of researchers aimed to discover which aspects of mobile devices and technology would best fulfil potential customer desires [10]. In this experiment, 32 participants were recruited to be interview about their expectations and desires around technology integration in automobiles. Participants ranged from age 10 to 60 and were split into two groups; Professionals (n=16) and generation Z (n=16) data was collected through interviews lasting no more than 45 minutes and was analyzed with thematic analysis procedures. The results returned nine themes that were considered the most "probable". Nearly all of the themes were related in some way to content or information consumption that would require a display of some kind. Themes such as "All-in-one Tool", "Seamless integration of Information" and "Continuity of Connectivity" would require not only sophisticated communication technology between mobile devices and the automobile, but also any number of displays on which to present information. This somewhat counters the findings from other researchers [9] who have suggested that users are satisfied with the physical ergonomics of their current automobiles but also have interest in advanced features which will presumably alter existing designs. These conflicting ideas leave auto de-signers with the challenge of incorporating new technology in a recognizable and intuitive way while also considering the inherent safety challenges that these new features might exacerbate.

Heikkinen et al. conducted a contextual inquiry regarding device and infotainment usage while driving [11]. This research technique involves observing and interviewing participants in the context of real use. Six real life trips were taken with eight passengers; notes and observations about behaviors and conversations were recorded with regard to mobile devices as infotainment interfaces in vehicles. The study shows high demand for utility of mobile devices in vehicles. The participants' motivation for using the mobile devices revolved around their versatility and network connectivity that the vehicle systems could not offer [11]. Participants also noted that the small displays of smartphones are not ideal for visual information in a driving context. Larger displays, such as tablets, were considered easier to retrieve information from at a glance. Participants also desired a sharing of information between systems and devices. The drivers expected closer integration between mobile devices and infotainment systems to add the most value to future cars [11]. These results suggest that customers are looking for and expect their vehicles to support an ever-increasing number of features, mirroring the capabilities of mobile devices. As the number of features in automobiles continues to increase, manufactures should ensure that infotainment systems remain usable by mirroring devices or systems that are already familiar.

In order to help designers quantify what is a good user experience in human-car interactions, the definition of "naturalness" in these interactions must first be defined. A number of researchers used qualitative measures to attempt to define what interactions are considered the most natural [12]. A natural interaction is one that does not tax the user mentally or physically, allowing the user to reach a goal without barriers, thus potentially allowing drivers to maintain better concentration on the main task of driving safely. One study was done by interviewing participants (n=15) to identify what their perceptions of "natural" driver-car interactions were. Participants were interviewed in their own cars while parked. The experimenters probed at concepts such as expectation, feeling, desires, meaning and interaction salience. The most common themes identified revolved around driver control and direct connection with the car. Participants expressed deep interest in having total control and mastery over a car as well as being intimately familiar with the car's status through physical or auditory feedback. Vehicular usability was also a large factor, a need for the car to provide the user with the tools to drive safely through proper ergonomics and intuitive controls. Though most participants expressed heavy interest in these forms of direct feedback, they also expressed through interest in cars sensing, adapting to and assisting the driver. These high-tech creature comforts were highly desirable [12]. This pro-poses challenges to automobile manufacturer to design cars to be both physically engaging and satisfying to drive through feedback and "feel" as well as be comfortable, tech-forward and desirable. It is likely that consumers will become more selective as the features in cars homogenize across brands, making the presentation of information and digital controls an even more critical facet of safety and desirability.

1.3. Interface Design

New interfaces for in-vehicle information systems which utilize radial menus as the primary means of interaction, as opposed to traditional listed scrollable item menus, have been developed [13]. To test these menus experimenters recruited 16 participants (ages 26 to 42) to complete a set of interaction tasks on each interface design while performing Lane Change Tasks (LCT) in a driving simulation. Their results found that there was no statistical significance between the two menu types with respect to lane deviation and error rate. Despite this, the proposed radial menu did rate higher in subjective measures. Although the proposed interface did not outperform the traditional menu in task time or error rates, the study supports the hypothesis that a similar radial menu may improve the user experience or enhance the satisfaction with the system. Alternately, because radial, or pie, menus are used less frequently than other menu types, scores may have been influenced by the menu's novelty. Long term testing with participants would provide stronger evidence regarding subjective measures, as the novelty of new interactions would likely wear off.

Harvey et al. investigated usability issues associated with direct and indirect input systems in In-Vehicle Information Systems (IVIS) [14]. Four main functions (infotainment, comfort, communication and navigation) were evaluated through 20 tasks. They used a fixed base driving simulation and eye tracking hardware to record visual behavior. A manual rotary controller was used as an indirect input while a touch screen was used as a direct input interface. System Usability Scores (SUS) and questionnaires were used to collect subjective data. While both significantly affected the driver's visual attention, the rotary controller had the highest negative influence. These findings are similar to the results of other earlier research [6, 7], furthering the evidence that secondary tasks while driving can have significant negative impacts on mental workload and attention.

Additionally, SUS ratings were lower for the rotary controller compared to direct touch screen input. However, it should be noted that the rotary controller was used as a tool for both navigation and selection, which is an interaction style participants were likely much less familiar with compared to touchscreen inputs. The findings from this study may highlight the usability flaws of rotary controllers with this specific implementation. This may not be true for all contexts; long-term studies could expose different outcomes as participants became more comfortable with these new controls. Regardless, there are potential usability concerns with both direct touchscreen and indirect rotary controls that should be considered by designers implementing similar controls.

Kumar and Kim [15] believe that the design of an automobile speedometer and gauge cluster could significantly impact driver's behaviors. They aimed to discourage drivers speeding by modifying the behavior of an existing speedometer to respond to the speed limit of roads in real time. A "dynamic speedometer" prototype was used as well as a traditional speedometer in the experiment. A driving simulation was implemented with two variations of speedometer. One speedometer was traditional and not responsive to driver behavior. The second speedometer was dynamic and would change based on the speed limit of the road the participant was currently navigating through. Participants (n-25) were university students ranging in age from 19 to 32 years old. The first round of testing left participants unaware that their speed was being measured and were not told of the differences in speedometer. These tests yielded little differences in speedometers with regards to maximum speed over the limit. However, after participants were informed of the dynamic speedometer and that speed was being monitored, subsequent scores did vary significantly from the control. It is possible that these results support the findings of other research [16]; providing more evidence that the presentation of information and controls in auto-mobiles can significantly impact driver behavior and safety.

1.4. Touch Screens

To alleviate some of the inherent visual demand of touch screen interfaces in cars, researchers implemented secondary input devices and evaluated their effectiveness [16]. This study used 24 participants that each completed a series of tasks with each of the four secondary inputs (rotary controller, touchpad, touch screen and steering wheel controls). Tasks were drawn from common In-Vehicle driving related activities; menu navigation, text entry, list item selection and navigation map manipulation. Subjective measures were also recorded. The study shows a significant difference in task time with touch screen controls taking the shortest amount of time and the touchpad taking the longest. Visual behavior paralleled this trend, showing the number of glances and total glance time being lowest for touch screen controls and highest for the touchpad.

However, the touch screen had significantly longer glance duration compared to the rotary controls. Touch screen controls also showed the lowest negative impact on driving performance [16]. Subjective measures showed that the touch screen was overwhelmingly preferred for all tasks except list selection where touch screen and rotary controls were both highly preferred. The results of this study support the notion that performance and subjective opinions have, to some degree, a correlation. Touch screens and rotary controls may be rated higher as they are more familiar to most users and, in this environment, should be more intuitive. Touchpads and steering wheel controls may have their benefits but may take longer periods of time to be-come familiar.

Eren et al. investigated combinations of button size, location and contrast for touch screen menu buttons for in-vehicle controls [17]. The aim was to discover whether touchscreen interactions, an inherently visually demanding task, could be completed with zero visual demand. 24 participants used a driving simulation and asked to maintain a constant speed while following the vehicle ahead of them. While driving, buttons of varying contrast, location and size were displayed on a touchscreen beside them. Participants were asked to touch the buttons as quickly as they could while keeping their eyes on the road as much as possible. A significant difference in the number of glances was found with respect to button size. Additionally, although there was a reported significant main effect of button location on glance frequency, no significance was found between individual button locations or button contrasts. Though this study aims to identify the best combination of button size, contrast and location, it unfortunately does not test the effect of several buttons on screen at once. Since all in-vehicle systems present several buttons at a time, this study may not accurately represent the visual demand of traditional in-vehicle systems. Participants behavior could be affected had there been the threat of clicking the wrong item or by being visually distracted by other elements on the screen.

There is increasing evidence suggesting that the presence of touch screens in auto-mobiles increases the likelihood of distracted driving. Researchers studied the impact of different interfaces on glance time for secondary tasks while driving [18]. A driving simulation was set up via video game simulation utilizing a steering wheel with foot pedals. Participants were instructed to navigate a predetermined path in the simulation while performing tasks on three different interfaces; a conventional car radio, a virtual touchscreen copy of the conventional car radio and a modified touchscreen interface. Each participant completed three tasks on each device. Participants (n=21) ranged in age from 18 to 72. Glance times were measured from video recordings taken during the experiment. The findings from the study suggest that users take longer glances toward controls when they are presented on a touch screen compared to traditional physical controls. However, the modified touch screen controls did outperform the virtual copy of the traditional controls. This suggests that though touch screen controls have been identified as requiring longer glances, the layout and design of the interface can positively impact glance time and, subsequently, driver distraction.

1.5. 3D Interfaces

Other research has investigated the potential and limitations for stereoscopic 3D regarding visualization of in-vehicle information systems [19]. One particular experiment developed an in-car spatial visualization concept that exploits 3D for system output. A number of in-car tasks were given to participants to complete in a non-driving simulation. Participants were asked to wear the 3D glasses for the duration of the experiment, including non-stereoscopic tasks. Results from the 32 participants were used in the study suggest that the stereoscopic 3D increases attractiveness, improves users recognition of system state and may improve user experience. However, there was no noticeable difference between the stereoscopic and non-stereoscopic on user workload. Also provided by the study are suggested guidelines for future development of stereoscopic interfaces. Although there is evidence here that users found this system enjoyable and attractive, it is possible that it would be highly distracting and create higher chances for driving errors. The study does not measure the impact of the system on participants while driving and would need to be further investigated to determine the value of the proposed system [19].

Augmented Reality (AR) is slowly making its way into the automotive industry and is a large topic of interest in concept cars. Rao et al. analysed the influence of augmented reality on the design of in-vehicle architecture [20]. They looked at the possibilities of AR on the vehicle's windshield as well as on screens displaying imagery from external cameras. Through their review, they discovered a number of technical and logistical hurdles that limit AR and its use as a tool in automobiles.

The first of these hurdles being the problem of tracking both the driver's movements and the movements of external objects. In order to properly display images on either screens or windows, the system has to be able to compensate for the viewers point of view and for the movement of 3D objects in the real world. Though progress on this technology is being made, augmented reality in a car can still hardly be considered a mature technology [20]. Other than technological barriers, AR faces a number of challenges around high standards for safety and durability. With the technology in such early stages of development, it's hard to determine how AR can be used (specifically regarding on window displays) and how it will affect driving performance. Information being displayed directly on the windshield in front of the driver will most certainly raise concerns about driver distraction and road visibility. More research needs to be done to determine if imagery on car windshields will help drivers perform better or introduce more visual clutter that can distract drivers from the road.

2. EXPERIMENTAL METHOD

To determine whether an interface as "usable" for an in-vehicle system hinges on how one defines the term usability. There have been several attempts at defining usability for computer systems. Authors such as Donald Norman, Brian Shackle, Nigel Bevan, Ben Shneiderman and Jacob Nielsen have created their own ideas for standards or guidelines for usability [14, 21, 22, 23, 24]. Though some concepts they provide overlap and agree, no two definitions are the same. What seems to influence the definitions the most are the contexts in which the system is being used.

Many systems evaluated through these definitions are ones in which the interaction between the human and the interface is considered the primary task. When driving a car, however, tasks such as adjusting the radio and selecting a destination for navigation are secondary to driving safely. This change in hierarchical task importance can have significant effects on the definition of usability in that specific context. This is especially important automotive design. An interaction that is relatively "usable" as a primary task may not be intuitive enough when users are driving. This definition of usability must adapt to the environment in which the device is located. Because of the risks involved with distracted driving, all areas of a systems design must be thoroughly vetted to maximize driver and passenger safety.

2.1. Research Questions

To examine these factors a number of experimental hypotheses were proposed :

- Ho1: Task time for color and grayscale touch screen buttons during a driving simulation will not be significantly different.
- Ha1:Task time for color and grayscale touch screen buttons during a driving simulation will not be equivalent.
- Ho2: Glance time for color and grayscale touch screen buttons during a driving simulation will not be significantly different.
- Ha2: Glance time for color and grayscale touch screen buttons during a driving simulation will not be equivalent.
- Ho3: The number of glances for color and grayscale touch screen buttons during a driving simulation will not be significantly different.
- Ha3: The number for glances for color and grayscale touch screen buttons during a driving simulation will not be equivalent.

2.2. Participants

A total of 32 participants were recruited for the study and were selected based on a first come, first serve basis. Participants were predominantly students from the State University of New York at Oswego. The participants were ethnically diverse and consisted of 20 males and 12 females. All participants were required to have a valid driving license but not required to have a minimum amount of driving experience. Participants initially completed a background questionnaire regarding their gender, age and driving experience. This pre-task questionnaire revealed that the participant pool had an average of 13.5 years of driving experience and estimated that they drove an average of 10.6 hours a week. Of the 32 participants, only 8 reported having a touch screen display in their personal vehicles. The participant mean age was 30 years (SD = 14.8).

2.3. Research Equipment

The test was run on a Windows desktop personal computer that was brought to the testing site. A Hori Apex[1] steering wheel controller was used as a means for participants to control the simulated vehicle. One of the reasons for using this particular control system was the attached realistic gas and brake pedals, providing a more natural driving simulation. The simulation itself was run through the Project Cars driving simulator[2] and a 24 inch HP IPS screen was used to display the simulation. The monitor and steering wheel controller were set up on a standard size table with keyboard and mouse next to the steering wheel for ease of access by the experimenter. Participants used a standard computer chair which provided height adjustment, allowing them to find a comfortable seat position before beginning the test.

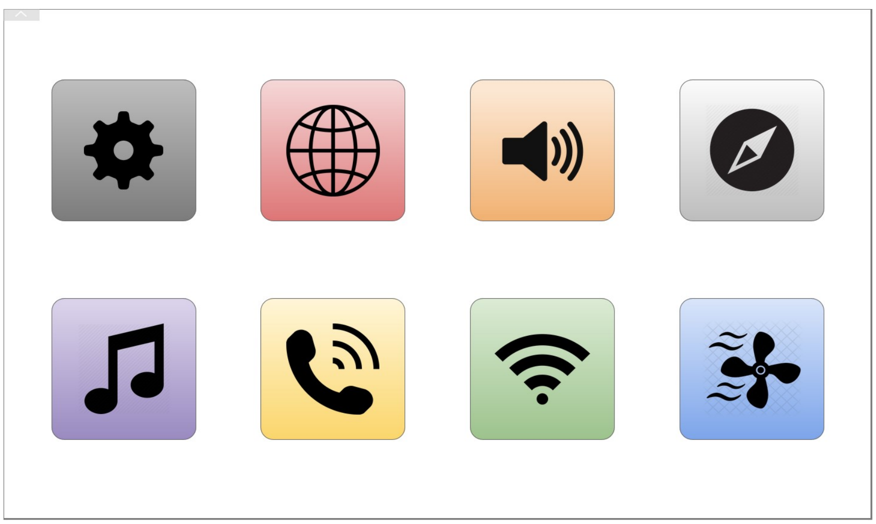

Figure 1. The arrangement of touch screen targets. The layout of the touch screens for both the color and greyscale experiments was the same.

A Samsung GalaxyTablet 10.1 was used to display touch targets on the 'dash-board' that were used as the tasks for the experiment. The tested interfaces consisted of a series of images which

[1] The HORI APEX full size steering wheel and pedal system provides an authentic driving simulation. The wheel is programmable and adjustable, with the ability to change from 270 degree to 180 degree turn ratio on the fly and fine tune other settings such as dead zone and pedal sensitivity. The system also provides realistic vibration feedback. More information at : http://stores.horiusa.com/racing-wheel-apex-for-playstation-4-3-and-pc/

[2] The Project Cars 2 simulator provides a highly realistic simulation of driving with a wide range of officially licensed cars and environments. The simulator focusses on the realism of authentic handling of the vehicles, and provides a full range of driving conditions (including driving on ice, dirt, gravel, mud, and snow). More information at : https://www.projectcarsgame.com/

represent different functions that could be accessed via touch screen in an automobile (Figure 1). The interface presented targets that varied in both colors and symbols or in symbols alone. Axure RP 8[3] software was used to create the interfaces that would present the touch targets to participants. After the interfaces were created in Axure RP 8, they were published to Axure Share so that they could be accessed on the Samsung Tab during testing.

The Gazepoint GP3 Analysis Professional System[4] was used to capture partici-pants eye movements throughout the test. The software Gazepoint Control and Gazepoint Analysis was used to record and analyze the data (number of glances and glance time for each glance). The experimenter used the Sprint Stopwatch application for android to record individual task time and overall task time.

After each section of tests, participants were asked to complete a questionnaire based on the NASA Task Load Index (TLX) [25, 26].

2.4. Experimental Design

A within-subjects design was used for this research study. The independent variable was the color of the touch targets on a touchscreen. Symbols for the touch screen remained the same for both conditions (Figure 1), however the touch targets were arranged in a different order to prevent familiarity of icon position influencing task time. The dependent variables are number of glances toward the touch screen, glance duration and total task time (calculated by adding all glance durations for each task).

The experiment was set up in a testing room with minimal distractions on the State University of New York campus. Upon arrival, participants were given a consent form which they were instructed to read over and sign if they agreed to the proposed conditions. Participants were also informed that they have the right to discontinue participation in the experiment at any time and for any reason. If they chose to re-move themselves from the study, the experimenter would remove their information and data from the experiment without consequence to the participant.

Task instructions were given orally and visually. All participants were introduced to the system and asked to sit in front of the steering wheel controller and to familiarize themselves with the feel of the controls and pedals. If needed, they could adjust the height and position of their seat to put themselves in a comfortable driving position. After taking a moment to adjust seating height and position, Each participant was given time with the simulation to practice driving and maintaining consistent speed. The intent was that this practice will minimize the chance of driving errors due to the simulation and controls feeling different than the cars participants were used to (Figure 2).

[3] Axure RP Pro is a wireframing, rapid prototyping, documentation and specification software tool aimed at web and desktop applications. It offers drag and drop placement, resizing, and formatting of widgets. Axure Share allows developers to share Axure RP prototypes with others. More information at : https://www.axure.com/

[4] The Gazepoint system was used as an input device for this experiment. The system uses video images from which the participant eye position is extracted - providing quantitative measures of the eye movement events and their parameters. Software is used to visually represent the data, so that the visual behavior of multiple participants can be graphically analyzed. More information at : https://www.gazept.com/

Figure 2. A participant undertaking the experiment.

After participants felt comfortable using the system, the simulation was reset and task instructions were given. Participants were told to drive normally on the correct side of the road while maintaining a driving speed between 50 mph (88 kph) and 60 mph (96 kph). They were also instructed to stay within the designated lane and that deviating from the lane would count as a driving error. Emphasis was placed on driving safely as they would in the real world and that all tasks must be completed before the course ended reaching the end of the road within the simulation.

While driving, participants were instructed to complete a series of secondary tasks on a touchscreen. Secondary tasks involved recognizing identifying and selecting touch targets by symbol or color/symbol combinations (Figure 1). The target was orally specified by the instructor; for example "Select the wi-Fi button." or "Select the orange volume button" at timed intervals. After selecting the correct touch target, there was a 10 second delay before the next target was specified. Whether the participant completed 'color' tasks or 'symbol' tasks first was equally distributed and randomly assigned, ensuring that half of the participants attempted 'color' first and the other half attempted 'symbol' first. After completing tasks for their first condition, the simulation was reset and subjects repeated the experiment with the display presenting the visual information which they had not yet seen. After each series of tasks were completed, the participants were given a brief questionnaire to assess their experiences with the controls. When testing was complete, participants were provided with a debriefing form and given the opportunity to ask any questions.

Participant performance included a number of measurements (such as total task time in seconds, number of glances, glance duration), these were the within-subject dependent variables. Touch target color (grayscale or with color) was taken as the independent variable. The rejection level of significance for all analysis was set to $p = .05$. The number of glances and glance duration were recorded through the eye tracker. Task time was recorded by both the eye tracker and also measured by finding the sum of all glance durations for each task. Subjective measures were also taken in the form of likert scale questions to rate the participants impressions and opinions of each interface type.

Table 1. Total glance times and number of glances

Participant Number	Total Glance Time		Number of Glances		Total Time / Glances	
	Color	Greyscale	Color	Greyscale	Color	Greyscale
p1	23.11	23.87	20.00	17.00	1.16	1.40
p2	10.79	10.57	11.00	11.00	0.98	0.96
p3	4.99	10.75	8.00	17.00	0.62	0.63
p4	15.09	18.09	16.00	18.00	0.94	1.00
p5	5.62	6.76	15.00	12.00	0.37	0.56
p6	9.01	8.74	13.00	8.00	0.69	1.09
p9	14.59	13.00	17.00	12.00	0.86	1.08
p10	9.08	14.40	14.00	16.00	0.65	0.90
p11	11.70	19.75	16.00	17.00	0.73	1.16
p12	9.44	11.28	9.00	13.00	1.05	0.87
p13	13.62	17.33	14.00	14.00	0.97	1.24
p14	9.89	10.73	11.00	9.00	0.90	1.19
p15	9.99	13.38	8.00	8.00	1.25	1.67
p16	21.39	11.57	21.00	10.00	1.02	1.16
p17	8.01	19.58	10.00	23.00	0.80	0.85
p18	9.59	17.43	11.00	24.00	0.87	0.73
p19	6.53	14.29	11.00	12.00	0.59	1.19
p20	11.20	7.67	21.00	16.00	0.53	0.48
p22	10.78	10.11	18.00	20.00	0.60	0.51
p23	8.58	15.14	18.00	27.00	0.48	0.56
p24	9.68	12.81	15.00	17.00	0.65	0.75
p25	4.36	8.32	10.00	15.00	0.44	0.55
p26	14.09	16.85	17.00	15.00	0.83	1.12
p27	9.19	17.11	10.00	19.00	0.92	0.90
p28	8.71	11.58	10.00	12.00	0.87	0.96
p29	6.23	10.36	9.00	9.00	0.69	1.15
p30	8.71	16.21	15.00	22.00	0.58	0.74
p32	6.19	10.59	13.00	16.00	0.48	0.66

3. RESULTS

There were 32 participants in total, each was tested under both conditions (color and greyscale). Data from four participants were excluded due to data collection errors. For example, the eye-tracker not tracking properly or participants were not in the line-of-sight of the eye-tracker. The data from the remaining 28 participants was analyzed to identify difference in glance time, number of glances and total task time between conditions (Table 1).

3.1. Task Time

The collected glance times were first analyzed for normal distribution using SPSS Statistics software. The data followed a skewed distribution that is typical of task time data. To compensate for this skew, the data was transformed with a log base 10 function. The transformed data followed a much more normal distribution, allowing the use of parametric t-test.

A paired sample t-test was used to compare the differences between total glance durations per task in color touch target tasks and grayscale touch target tasks. When analyzing the transformed data, there was a significant difference in task time be-tween color touch targets ($M=.98$, $SD=.17$) and grayscale touch targets ($M=1.11$, $SD=.13$) ; $t(27)=-4.35$, $p<.001$ (Figure 3). This suggests that color touch targets in infotainment screens influence glance time for completing tasks. Specifically, it suggests that touch targets of varying color require shorter glances to complete tasks.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	TransformedColor	.98289	28	.169143	.031965
	TransformedBW	1.11073	28	.134893	.025492

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	TransformedColor & TransformedBW	28	.496	.007

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	TransformedColor - TransformedBW	-.127839	.155414	.029371	-.188102	-.067576	-4.353	27	.000

Figure 3. Total glance times (transformed log10) paired t-test.

3.2. AverageTask Time

Average glance times were calculated by taking the sum of all glance times across all tasks and dividing that sum by the total number of glances for those same tasks. This data followed a roughly normal distribution. A paired sample t-test was used to compare the difference between average glance time for color touch targets and average glance time for grayscale touch targets. Analysis revealed a significant difference between times for average color (M=.77, SD=.22) and grayscale (M=.93,SD=.29) glances; t(27)= -4.51, p<.001 (Figure 4). These results suggest that the average glance toward an infotainment screen with grayscale touch targets would be higher than that of a system utilizing color specific touch targets.

3.3. Number of Glances

The number of glances across all tasks were totaled to get the number of glances for color touch targets and grayscale touch targets for each participant. A Wilcoxon signed-rank test was performed to calculate the differences between the totals. The test revealed that the type of touch target did not have a statistically significant impact on the number of glances (z=-1. 36, p=.173) (Figure 5). The median number of glances for color touch targets was 13.5 and the median number of glances for gray-scale touch targets was 15.5.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	ColorGlanceTimeAverage	.76857	28	.224644	.042454
	BwGlanceTimeAverage	.93182	28	.294026	.055566

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	ColorGlanceTimeAverage & BwGlanceTimeAverage	28	.758	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	ColorGlanceTimeAverage - BwGlanceTimeAverage	-.163248	.191653	.036219	-.237563	-.088932	-4.507	27	.000

Figure 4. Average glance times paired t-test.

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles 25th	Percentiles 50th (Median)	Percentiles 75th
ColorNumOfGlances	28	13.61	3.919	8	21	10.00	13.50	16.75
BwNumOfGlances	28	15.32	4.930	8	27	12.00	15.50	17.75

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
BwNumOfGlances - ColorNumOfGlances	Negative Ranks	8[a]	12.81	102.50
	Positive Ranks	16[b]	12.34	197.50
	Ties	4[c]		
	Total	28		

a. BwNumOfGlances < ColorNumOfGlances

b. BwNumOfGlances > ColorNumOfGlances

c. BwNumOfGlances = ColorNumOfGlances

Test Statistics[a]

	BwNumOfGlances - ColorNumOfGlances
Z	-1.362[b]
Asymp. Sig. (2-tailed)	.173

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Figure 5. Number of glances Wilcoxon ranked test.

4. Discussion and Conclusions

The results shown in this research provides evidence to support the proposed hypothesis that there would be a difference in glance times and task times when using different touch interfaces in a driving simulation. The data from this experiment seems to agree with the literature, supporting the idea that touch screens with different color touch targets are easier to identify at glance than grayscale touch targets that rely solely on icon recognition.

Evidence suggests that looking for items quickly in secondary tasks benefits from more deviation in visual representation than iconography alone. When relying on symbol recognition glance times may suffer and be longer.

Previous studies have looked at the impact of secondary tasks in driving performance but few have investigated the impact of aesthetic design decisions on these tasks. Identifying strengths or weaknesses of aesthetic design decisions, designers and manufactures can refine their products to improve usability and customer satisfaction. There are numerous design choices that influence task performance while driving. This study provides information that can help guide future studies that wish to investigate other essential design considerations for infotainment systems.

The physical controls of the Apex racing steering wheel were difficult to get used to, according to most participants. The lack of feedback in the petals and steering wheel made controlling the simulated vehicle very demanding. Many reported having difficulty maintaining a consistent speed due to the lack of haptic and auditory feed-back. The learning curve associated with the unfamiliar controls might suggest that participants should perform better in the second condition. However, since the conditions were assigned randomly, this effect should be minimized. Additionally, the course used was intentionally windy with several hills. This was intended to force participants to pay attention to their driving at much as possible. Participants were also unfamiliar with the road which is likely to cause more cautious driving. These factors could have influenced driving performance.

Though on-screen images and eye movements were recorded with the eye tracking hardware, the number of glances and glance time had to be manually identified and documented by the experimenter. The eye tracker successfully tracked eyes while participants were looking at the monitor displaying the driving simulation but was unable to record eye movement on the secondary touch screen display. These times had to be manually recorded by watching each screen capture and noting when participants looked away from the simulation and when they looked back. This method was consistent across all participants, meaning data should be consistent, but is not an ideal form of data collection.

Intended touch targets for each task were called out orally by the experimenter. In most cases this implementation worked well. However, in some instances, the participant had difficulty hearing what the next touch target was. Other challenges stemming from this technique included participants forgetting what the next target was before the images appeared on the touch screen. Because there was no visual cue, participants had to ask the experimenter to repeat themselves, calling out the target again. Lastly, a small number of participants had trouble identifying the correct icon by name due to unfamiliarity with the iconography. In these cases, number of glances, glance duration and task time would have been skewed slightly.

There is a small body of research that has been undertaken on the impact of secondary tasks while driving, but there are more and more distractions integrated into the vehicle and it is important to analyze the impact of these additions. Almost all automobiles in production have touch screen interfaces. Manufactures need to be aware of the influence of all design decisions that go into these interfaces, including color choices. These decisions can affect overall appeal of the product (make if feel more premium), improve usability and improve safety.

Since a number of participants reported difficulties with their interactions with some of the physical controls on the Apex racing steering wheel (specifically the lack of feedback in the petals and steering wheel), any future work would probably be undertaken with a more responsive higher end device. Although the authors believe that enough participants (32) undertook the study to generate meaningful results, any future work would benefit froma larger participant pool. In particular it would be useful to have multiple groups of participants, some who have experience with touchscreens in cars and some who don't, so that this effect can be examined using the data generated.

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