An Iconographic Approach to Heads Up Display in Automobile

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INTRODUCTION
Augmented reality enhances our senses, such as what we see and hear which makes it very hard to differentiate the reality from computer-generated graphics [1]. Introducing augmented reality into the realm of automotive opens a new gateway which is the Heads-Up-Display (HUD). Augmented reality in personal navigation aids integrates a virtual navigation route into the real-world scene, and we can choose to display a route directly on the windshield with a HUD [18].

Also, the core purpose of augmented reality , in the context of an HUD, is to be integrated with other important visual features in the environment by projecting graphics on the windshield to alert the driver about the weather, road conditions, traffic information, etc. Augmented reality enabled windshield (HUD) shows information exactly where you need it directly in the line of sight [5]. The need of looking down to the instrument cluster or the secondary display is eliminated for drivers since all the necessary information is projected on the HUD. This information includes speed, warning, signals and indicator arrows for navigation [5].

In the case of a windshield HUD information is presented to the driver in a floating manner over the hood which appears to be at a distance of about 2 meters (about 6 feet). Given an HUDs in automobiles, the windshield is enriched with a layer of information right on the street in front of the car from the drivers point of view. Thus reducing driver distraction and increasing driver safety [5].

We want to optimize a user's experience with respect to the interface by providing compelling visuals that avoid clutter. To do this, we want to employ conformal symbology because it gives observers a feeling that symbology is part of the external scene by simulating visual transformations of objects outside the automobile [15],[8]. Designing in such a way is based on the process of form follows function and that the symbology and iconography would be minimalist in nature [8]. Along with the conformal symbology and minimalist design, a standard color scheme would need to be employed that is based on existing color use and visual cues. Greens would indicate safety, and orange would indicate information, yellow would communicate a warning rather [20] and reds would mean danger or error.

SIGNIFICANCE
Moving forward in automotive development, during low visibility conditions, drivers may rely on the iconography of an HUD navigational aide to identify other vehicles, road markers, pedestrians and possible road hazards [2]. Such systems perform real-time displays to allow an affordance of the low cognitive load when being used as an assistance or guide to the driver. HUD Navigational systems keep the driver focused on the road/physical space around the vehicle [7]. In this paper, we want to explore the importance of iconography in HUDs displays.

It is worthy to note that as spatial cognition declines with aging, it becomes an issue for elderly drivers to process flow of information while driving. HUD navigational aides can address their driving issues. By using real-time feedback, elderly drivers will be afforded ease of primary cognitive by using such systems. In mentioned scenarios, elderly drivers will be more attentive to pedestrians [7] [22], and other forms of possible adverse interaction.

There is a discussion in the realm of using currently available geo-tagged information layers that relate to people (social web), places(geo-web), and technology to create new mobile experiences [4], [23] in your vehicle. This combination of information may allow both drivers and passengers a customized city experience that displays only relevant or significant information via HUDs, based on the user's need. In a related study using a driving simulator with HUD suggests that lowering the anonymity and isolation of nearby drivers by revealing relationships and shared interests (e.g., via AR) will reduce aggressive driving behavior[4], [16].

In this paper, we are aiming to find out if icons are better way to communicate to drivers while driving opposed to text-based communication through HUDs.

RELATED WORK

We acknowledge the research currently ongoing in the aspect of information location, cognitive load and viability of HUDs. In our paper, we consider various graphical aspects related to users, interfaces, and interactions to understand the existing trends and uses of a HUD in an automobile.

Users

Often critical activities require visual attention to be distributed among distinct tasks of importance. Such partitioning of attention often causes a lag in the efficiency with which a task is performed on its own with undivided attention. Suppose the primary task is driving, and our secondary task is following navigation/alerts on a display; An unexpected load while driving can make the secondary task distracting and the primary task demanding [27].

The average response time for drivers is less than one and half seconds [14]. The superimposed display requires drivers transmit their attentions within time limitation pressure. Based on McCanns research, when subjects focused on the HUD, there was little effect of conflicting information in the real-world, and vice versa. However, drivers visual attention can not be focused on both HUD and real-world simultaneously [14], [11].

In their paper [13] Robert S. McCann and David C. Foyle talk about how the interpretation time is shortened with the help of HUD. It was found that the response time was approximately 100 millisecond faster when the relevant information was projected on an HUD as compared to the runway surface.

The commingled division of visual attention has been studied where users were asked to identify shapes on the screen in a simulator while they were driving. The studies showed that as the attention load on the primary task which is driving increased, the rate of identification of the shapes dropped. Hence, if an HUD warning would appear during a high load condition when encountered with heavy traffic, it is likely to compromise the driver's attention. However, an interesting fact is that the rate of identification never dropped below 80% [27]. This suggests that based on the driving conditions and the attention required for the task at hand, the division of attention would probably be much more towards the primary task of monitoring the road and traffic as opposed to any other activity.

There is a need to understand the distraction issues that are currently present in driving applications. The eventual goal is to point out how an HUD can help improve driver perception of surroundings and design a state of the art system by addressing cognition challenges inherent in augmented reality automotive systems [7]. Factors such as visual attention, cognitive capacities, preference for information locations differs for every user. Our research can be a basis for user centric approach to HUD development.

Interfaces

"HUDs overloaded with information, especially those using the textual output, can create the effect known as cognitive capture [4], [28]. Using textual outputs requires more interpretation time, which is not recommended in an HUD design for a car. Symbols are interpreted much faster by humans [4], [24] and conformal type of symbology for navigation has been proposed [6]. Hence, we suggest the use of symbols. It is important that the HUD system invokes a User-Centric design approach when taking into account the design and functionality of such systems [2],[4], [3].

Cars traditionally convey relevant information to the driver in 1 of 3 task areas. Primary (Physical world through the windshield), Secondary (the dashboard display below the windshield and instrument controls on the steering wheel) and Tertiary (middle console and audio/climate controls that are not necessarily driving impacting) zones [7]. As the driver moves away from the primary zone, their attention is further diverted which may have an adverse impact on their driving ability. Such Heads-Down-Displays (HDD) introduce visual clutter, taking the driver's attention away from the Primary task zone. This distraction away from the Primary zone is further increased when factors such as inclement weather or nighttime are introduced [2], [29], [9].

The interfaces to perform primary, secondary and tertiary tasks are physically located in separate areas of an automobile. Our research will explore design for the interface that combines the function and information required by users to perform primary, secondary and tertiary tasks more efficiently.

Interactions

Interacting with personal interfaces while driving can lead to problems as drivers have limited cognitive and motor resources. To support the primary and secondary tasks, Visual information AR on real world objects in the form of a heads-up display windshield interface will help greatly [7]. Primary tasks involve direct interaction with the real world and the best way to display the augmented information is in a heads-up manner. The AR application should be designed in a way that the tertiary tasks (example: entertainment or social interactions) do not interfere with the primary tasks (maneuvering the vehicle) [7]. Our research is not just looking at how

Figure 1. AVL lab

HUD can help in showing additional information while driving but we are also at understanding how interaction capabilities with such information can be improved. This enables users to get the most accurate, relevant and on-time information to be helpful for users.

AR based systems could be helpful in enabling users to visualize relevant information on HUDs. This information could be enhanced with the user interactions and gestures and voice controls to provide more accurate details as required by the user.

PROBLEM STATEMENT

While driving in the real world, there are N number of things one has to take into consideration to drive comfortably and to avoid accidents. People often use dashboard displays for car status information, navigational aids (such as a phone or GPS device) for road directions and center console instruments for climate control, audio adjustments, and collision detection/avoidance. Reading the information from these devices is not an easy job, it requires the driver to shift their attention from the line of sight at least for a brief moment a brief moment. A driver's' eyes need to adjust to the shorter distance also known as "accommodation" before the information flow can begin. This adjustment occurs when processing the visual difference between the oncoming traffic and the proximity to display information. Frequent changes in focal length will expedite the tiredness of drivers eyes [5]. Combining factors such as accommodation and reading the various displays can take up to half a second with current instrument panels. To that end, a driver averting them at a speed of 120 km/h (75 mph) they will be driving blind for about 33 meters (36 yards) [5].

Due to the various streams of information the users are processing, and the rate and amount of accommodation, we feel that a HUD type system based on icons and colors is best suited to assist a driver for maximum information display.

RESEARCH QUESTIONS

RQ1. Related studies discuss areas of focus and attention [2], [4]. While these studies are of great importance, there is an assumption of using iconography and images to display information. For our research we want to evaluate the User's response to text based HUD versus a graphical approach to information display.

RQ2. Moving beyond Question 1, We want to evaluate the impact color may have on the iconography used in the graphical approach to information display. Will changes in the icons color inform the users of items such as warnings, errors, etc..

HYPOTHESIS

Our Hypothesis is that users will value the use of iconography and color over plain text when displaying information in a HUD. Iconography will display important and relevant information more quickly compared to plain text. The users will have a more organic connection to icons rather than plain text. We also feel that color will help to inform the users of the current state of the information.

METHODOLOGY

Our goal is to explore which format of displaying information on a HUD is more desirable for drivers. Different formats/scenarios that we will be evaluating are the followings: text vs. monochronic icons vs. color coded icons vs. different type of icons. This study will utilize the Virtual Reality Theatre in the school's Advanced Visualization Lab (AVL) as opposed to physical prototypes. This will provide an immersive experience for the participant, which will simulate to real world conditions as much as possible. The projected video will display from the driver's point of view looking out of the windshield, all the information that is considered essential, such as speed, system status and navigation. We will overlay the evaluation elements (text, icons, etc.) to appear in the driver's field of view. Our hypothesis is that this will help identify the driver's preference.

The study will be conducted in three phases. Phase 1 will involve a pre-test questionnaire to get a general idea about drivers acceptance for an HUD. The goal of this questionnaire is to find out the comfort level and the information viewing preference of our participants based on the existing technology. Phase 2 will be the actual evaluation where we will identify the user's preference of the format in which the components are displayed on a HUD and the reason for their choice. Phase 3 will include a follow-up questionnaire to gauge the effectiveness of the evaluation method and how well the user adopted the proposed display elements.

All three phases will help us evaluate whether the participants prefer a text based HUD or a graphic based HUD. It will further help us understand if color and design play an important role in informing the participant of items such as warnings, errors, etc.

EXPERIMENTAL PROCEDURE

Phase 1: Pre-Test Questionnaire

Figure 2. AVL lab

In the first phase, participants will take a short survey. It will involve around 20-30 participants recruited through facebook. This survey will give us a general idea on an individual's point of view about HUDs. Participants will be asked questions such as: make/model of their car the frequency of use (car) date when they started driving navigation aid of choice if any any issue with existing navigation aids If so, what is it and would they prefer HUDs?

The above questions are only to find the participants take of HUDs . Therefore, we may change/add the questions based on what we find useful as we progress through the study.

Phase 2: Evaluation of Prototype

Phase 2 will involve 6-10 participants from Indiana University-Purdue University at Indianapolis (IUPUI) student body population. This evaluation phase will take place at the Advanced Visualization Lab (AVL) at IUPUI in the Informatics Department with a video prototype which uses text and graphics.

While the video is being played, participants will be asked to observe and give real-time feedback on their preference and the reasons for their choice. Open-ended questions will be asked while they see the components displayed on the big screens.

Phase 2 of our project will help us expand more on our the research question and understand if the existing display of information in automobiles is the best way to showcase relevant information while driving.

Experimental Setup

As mentioned before, phase 2 will be in the Virtual Reality Theater located in the AVL at IUPUI. The Virtual Reality Theatre utilizes 3 10x10 screens that can be configured to surround the participant during the evaluation. This increased immersion will assist the participant in connecting with the system displays.

The participant will sit in front of the screen at a distance of 6 feet. This distance is based on previous work discussing optimal viewing angle and distance of a HUD system for automobiles. A video prototype will be displayed on the screen. An audio video recorder will be used to record the evaluation session. The evaluation session will be approximately 40 minutes followed by a post-task question and answer session. This phase will involve both open-ended discussion and quantitative information gathering such as participants preference of each icon/text over the other.

Procedure

An overlay of text/iconography is projected on the screen in front of the participant. Based on prior research we have considered the following aspects to understand the driver's preference for text/iconography.

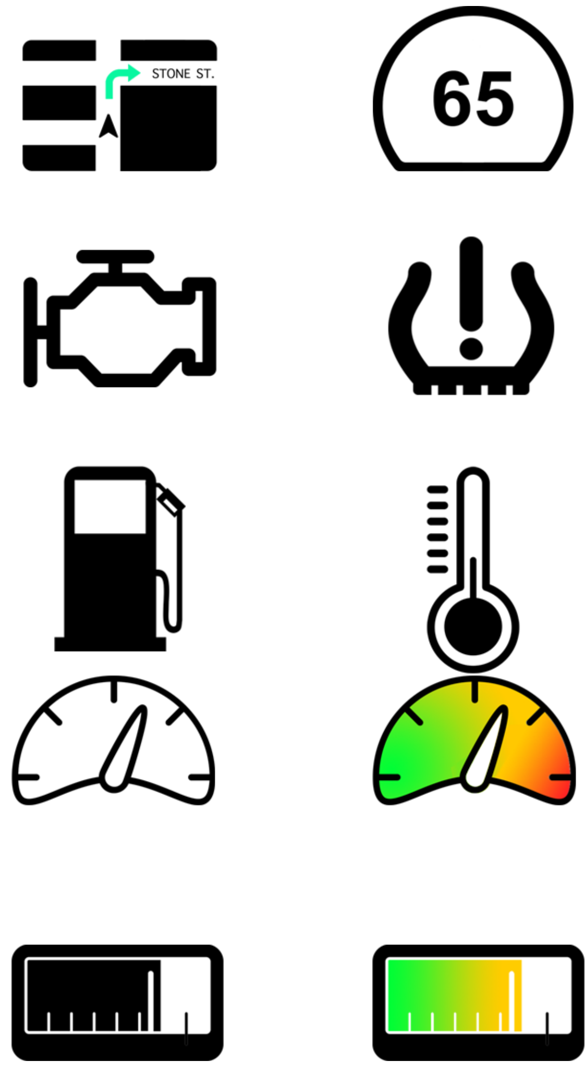

Figure 3. iconography

The text/icons for each aspect will be displayed for comparison in the following sequence:

1. Text and monochromic icon
2. Monochromic icon and a colored icon
3. Options of colored icons
4. Text and all icons together

Participants will be asked to compare and choose text/icon for each component for every aspect (speed, vital stats, navigation). Once they choose a particular text/icon, they will be asked for an open-ended feedback about their preference and the basis of their choice. Quantitative information gathering such as participants preference of each icon/text over the other will also be recorded.

Quantitative data will be collected in this phase, and we will get the results what kind of icons (or text) will be meet most participants expectation. And the results will somehow evidence the necessity of providing customized HUD icons settings.

Even though we will not get any qualitative results or feedback from phase two, we still can get some hints from the notes and video taken from the phase. We will focus on participants facial expressions and infer that if they are pleased to experience the text and icons showing on the HUD. These assumptions wont directly affect the evaluation results. However, it will help us to predict the results of phase three.

Phase 3: Post-Test Questionnaire

Participants will fill out a post-task questionnaire which is sent via email after a few days. The reason we are conducting the post-task questionnaire after a few days is because we want to let the participant think more about the evaluation, and we also want to see if their answers to the questionnaire change in any way as opposed to our observations and the feedback we obtained during the evaluation. The questionnaire will be made using an online form and will gather both qualitative and quantitative information about the study. This will help us pull some useful metrics to make analysis of the information obtained.

These papers were used to learn more about the concept: [25], [13], [8], [10], [12], [21], [17], [19], [26]

PARTICIPANTS

The participant population is automobile drivers of different age groups. We will recruit around 40 participants in total for our study of which 20-30 participants will be recruited for phase 1 and 6-10 participants will be recruited for phase 2 and 3 of our study. We chose to go with 20-30 participants for phase 1 as a means to receive a decent sample set of quantitative information to inform phases 2 and 3. We chose to go with 6-10 participants for phase 2 and 3 because we believe that after 8 participants, we will get diminished results. Due to phase 3 being a post task questionnaire, the participant set will remain the same for phases 2 and 3. For Phase 1 we will utilise Facebook as our sourcing method. This will allow us to draw from a large pool of connections and enable us to reach the large target participation count of 20-30 in our stated target research demographic.Phase 2 and 3 will involve participants who belong to the IUPUI population as the university has students from diverse backgrounds and will allow an affordance of participation in our study. The gender distribution will be almost equal across the different age groups. Informed written consent will be obtained from all participants.

RESULTS

Pre-task Questionnaire

The responses from the pre-task questionnaire clearly suggested that the concept of an HUD in a car was widely accepted. All 30 participants who took the pre-task questionnaire survey liked the idea of an HUD in a car giving us a 100% positive response for the very idea of an HUD. However, only 50 percent of the participants preferred the combination of text and iconography as the format for information being displayed on an HUD.

Evaluation

One of the research questions was to evaluate the users response to text-based information versus a graphical approach to display information. After conducting 8 usability studies we have data that shows that icons trump text for display of any information. However, users did prefer a combination of iconography and text when it came to the display of information that gave continuous feedback.

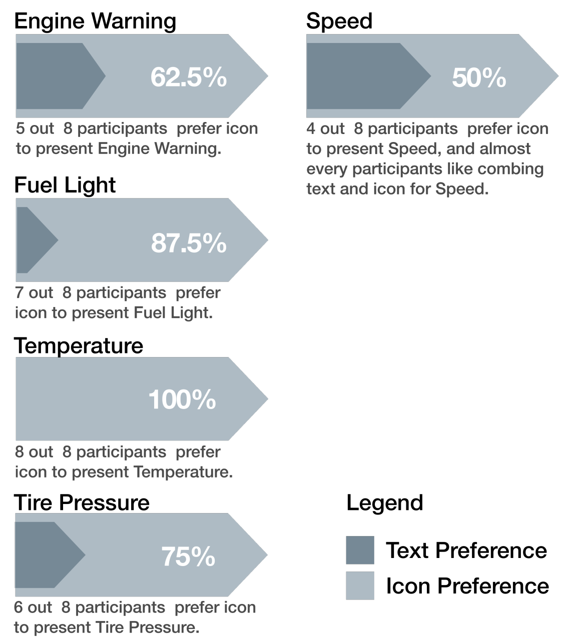

Figure 4. Result

We used teal, yellow and red colors to test if color impacts display of information in any way. The reason we chose teal was because it is a color that is not available in nature, it also looks more futuristic and is not affected by the weather outside. We went ahead with yellow and red as our other colors because they are common colors available on the car dashboards and they are also associated with representing information based on severity.

When it came to choosing a color that made the most sense for an icon, all users liked the teal color as it was soothing on the eye and very much visible no matter what the weather.

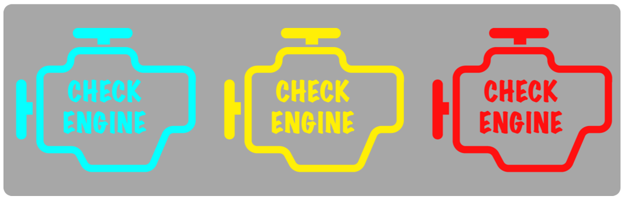

Figure 5. Colors used for icons

However, users preferred seeing icons based on severity. For example, they wanted to look at the fuel icon in orange when they had 5 more miles to go as opposed to red which will be shown when they have just one more mile to go.

Figure 6. During Evaluation

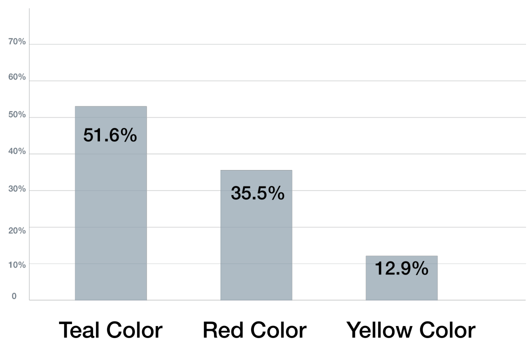

Figure 7. Results for color preference

Post-task Questionnaire

The post-task survey was a System Usability Scale (SUS) questionnaire. The analysis on responses from post-task questionnaire shows the HUD concept received a converted score of 85.94. Having such a high score helps to reinforce the viability of such a system.

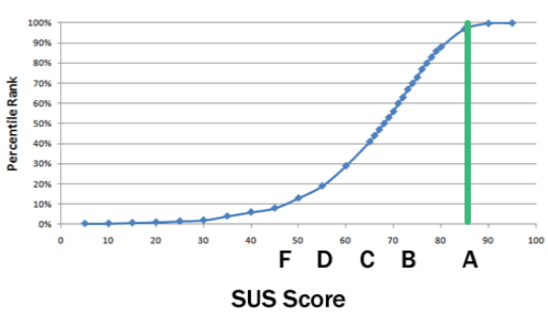

Figure 8. System Usability Scale Result

DISCUSSION

We hypothesized that icons trump text when it comes to displaying information and our participants did agree in most of the scenarios which included check engine, tire pressure, temperature warning and fuel up saying that icons made information easily comprehensible. However, speed was an outlier. Participants felt that speed was a parameter which requires continuous feedback and the participants wanted to see the speed they were going at along with the speedometer.

We also wanted to see if color made an impact on the message being conveyed by the icons displayed on an HUD. The participants gave us valuable feedback in this aspect, as they mentioned that they would prefer different colors for the icons based on the severity of the parameter being represented.

SUMMARY OF USER INPUTS

Check Engine

Participants felt that both the icon options for check engine shown to them during the evaluation where a little confusing even though one of the icons is the general standard icon that is displayed on a car dashboard.

"If you are not a driver and you are not familiar with the icon, I dont think one can recognise it"

However, participants preferred the first icon over the second. Also, the color red was chosen by all participants to represent check engine icon due to the nature of it.

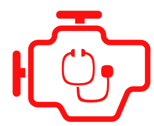

Figure 9. Engine Color Icon

Fuel Light

Both the fuel icons were appreciated by the participants as they felt both conveyed the meaning. However, statistics show that the first icon was chosen by most participants. Participants felt that having the color of the fuel icon change based on the number of miles you could drive with the fuel left would be intuitive to the driver, where red represented very low fuel which would allow one to travel only a mile.

"It would be great if I could know the number of miles I could travel with the fuel I have"

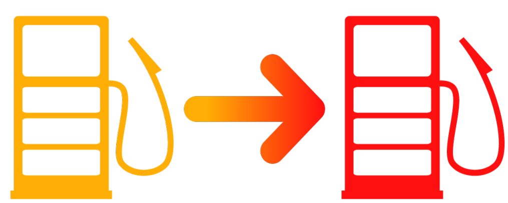

Figure 10. Fuel Color Icon

Temperature

All participants chose the first icon that was displayed during the evaluation for temperature warning and they associated this parameter with the color red. The icon chosen by the participants was the general standard icon that is used on most car dashboards to represent temperature.

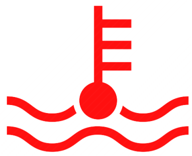

Figure 11. Temperature Color Icon

Tire Pressure

Although all participants chose icon over text for representation on an HUD, this parameter gave us interesting results as both drivers as well as nondrivers could not recognize the icon that is generally used in the dashboard of every car. All participants chose the alternative icon suggested by us as opposed to the universal icon being used. All of them preferred the usage of a warning color over an emergency color and hence chose teal to represent this information as it was not a major emergency. One of the participants also suggested that having an indicator that showed which tire was low in pressure would add more value to the icon.

"Does this icon on my dashboard represent tire pressure? I had no clue about it"

Figure 12. Tire Pressure Icon

Speed

Speed was a parameter where all participants did like the first icon displayed during the evaluation but found value in representing text along with the icon. Participants also suggested that they would like to see the speed limit of the particular street they are driving in. Also, having a color variation of the icon based on the speed as opposed to the single colored icons we displayed would add more value to the speed icon as it provides a visual cue to the participants if they were going above or below the speed limit.

"The speedometer is very helpful but without the numbers its useless in my opinion"

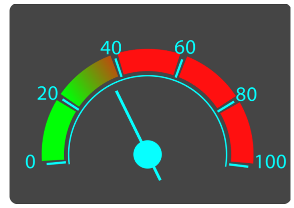

Figure 13. Speed Color Icon

DESIGN RECOMMENDATIONS

Here is a mock up with all the feedback from our participants.

Figure 14. Final Mock up

CONCLUSION AND FUTURE WORK

Users preferred iconography over text as text was distracting and difficult to read while driving. Iconography along with color conveyed the impact of the message (warning/emergency) more effectively. Colors indicate the severity and convey the urgency of the message. For example, red indicates an emergency and an immediate action. Check Engine requires an immediate action so users wanted to see check engine in red, whereas fuel-up is more like a warning message and does not require an immediate action so users preferred orange or teal for the fuel-up icon.

Our current study did put our participant in the driving scenario but however, it did not put the participant under the cognitive load of driving i.e. the participant focused purely on imagery being shown without being distracted by the primary task of driving. In future, we would like to create a system that would not only test the process but would also engage our participant in the driving scenario.

It is challenging to present any information to the user on the windshield, without distracting the user while driving. In our study, it was discovered that size of the iconography is also an important aspect that we will consider in future. Since different users had different preferences for color and type of iconography, providing an option to customize and personalize their representation on the HUD should be an avenue that should be further explored. Also, the placement of iconography and the time for which it appears needs to be determined for the information being projected on the HUD.

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