Heads-up Display

Design Document

Abdul Bin Asif Niazi
Muhammad Mustafa
Rehnuma Tarannum
Stanley Mbanwi Mbah
Malik Ehsanullah

Requirements Gathering

Project Overview

Distracted driving and other human factors are the most prominent causes of vehicle accidents. Our idea is to look at ways to reduce the number of distractions drivers have to encounter.

Distractions can come from many sources. Drivers take their hands off the steering wheel and gaze off of the road when fiddling with the climate control system of the vehicle. The same thing happens when they are trying to change the station on the radio or looking for a specific song on their music player. Many vehicles allow drivers to change their GPS settings while driving or look for points of interests. This is a task that requires a significant amount of time and is very distracting.

Other human factors must also be considered when dealing the issue of driver distraction. Many drivers talk on the phone while they are driving, without the use of a hands-free device. A lot of drivers like to check their text messages and emails while driving, some also text or email back. Road conditions can change and if the driver is not listening to a news station, he/she may not realize they must change their driving style. Drivers also get confused when they look at unfamiliar road signs, this also causes drivers to look away from the road and may cause them to lose focus on driving as they are focusing on figuring out what road sign it is.

Many people think the best solution to driver distraction and human factors of accidents is to make driver-free cars. But this solution is a long time away as the technology, both hardware and software, required for this is very new and is still in the testing phase. New laws would have to be introduced about how to deal with the new technology. And public trust would have to be gained about the safety of these vehicles.

Our idea is to implement a more driver-friendly interface and display. We would like to find a way to reduce the number of times drivers have to take their eyes of the road. But also, when they do have to look away, it is only for a brief moment. We also want to find a way to incorporate many of the technologies drivers use on a day to day basis. Using some of these technologies and services is illegal in many places while driving, but drivers still use them. Incorporating these technologies and services into the vehicle will allow the driver to stay focused on the road.

We also want to find a way to provide the driver with a real-time feedback to reduce human factors for vehicle accidents. The feedback can be about current and changing road conditions, current and future traffic conditions and changing weather. The system can also warn drivers if they are tailgating someone, if another vehicle is in an adjacent lane or if any driving warnings have been issued for the road up ahead.

The opportunity is to introduce a system where drivers can still use many of services they enjoy on a daily basis, but in a safe manner. They can receive useful information about their driving and road conditions and adapt to be safer. And they can be less distracted while driving so their attention is more focused on the task at hand.

Script

The script we used for the interview can be found below. The questions below have some follow up questions that we wanted to asked if we received the responses we thought we may get. We did not always stick of the script as sometimes the interviewee would provide answers we did not expect. For those responses, we asked different follow ups to understand why they responded that way and what was their reasoning. We interviewed three participants, all 3 are students at Carleton University studying computer science. The first person was white male in his early thirties who currently does not have a vehicle. He was born and raised in Canada. The second person was a white female in her early twenties who currently does not own a vehicle. She was born and raised in Russia. The third person was a black male in her early twenties who does not own a vehicle. He was born and raised in Nigeria. The reason we chose these people is because none of them own a car but will be in the market to purchase one in the near future. People who own vehicles usually become accustomed to the controls of their vehicle and are set in their driving routines. Due to this, they may not believe the tasks they do while driving are actually distracting to them. Whereas the people we picked drive occasionally, but not enough to get used to a vehicle. Also, they do not always drive the same vehicle, so they have a better understanding of what is distracting while driving.

Q1: What task and how many tasks while driving make you look away from the road?
- If text, ask do you read the message
- If radio, ask if the radio controls are touch screen or physical
- If aircon, ask if aircon is touch screen or physical

Q2: do the vehicles you have driven offer any options that allow you to sync your phone to your car's stereo
- If yes, what does your car have?
- Is it native or did you add something to your car?
- What features do you sync?
- Are there feature that you intentionally don't sync?

Q3: do you ever look away from the road to look at another screen?
- If GPS ask how often?
- If phone, ask how often and why?

----------Show them pictures of different car interfaces----------

Q4: Which of these displays do you find look best and why?

Q5: Which one do you think will help keep your eyes on the road and why?
- Will you play around with the HUD or digital dashboard?

Q6: Is this an option you would look for when purchasing a car?

Q7: Are there any interactive features you wish cars had that are not offered right now?
- Ask about translating road signs?
- Ask about receiving weather updates

Interview notes

Interview 1

The first interview we conducted was with a white male in his early thirties, it took fifteen minutes. He stated the tasks he does while driving that force him to look away from the road. Those tasks are using the controls for the radio, navigation, climate, seat adjuster and windows. He said he has not driven a vehicle that allows a phone to be connected to it.

The things that make him look away from the road most often were changing music, looking for knobs, checking text messages and emails, sometimes taking a call. He said he always checks to see who the text, email or call is from and will only check and reply if it is someone important. If not, he waits until he is at a red light to check.

Before we showed him any displays, he said that if these function were part of a Heads Up Display (HUD), than they would not be very distracting, given that they were well placed. But if they are not well positioned, they may potentially be more distracting as the pop-ups of a HUD may be in the way of important things on the road, making the driver more distracted. He would want the HUD to be customizable and would prefer if the placement of vehicle related information was separate from non-vehicle related pop-ups. He wanted the ability to sync his phone to the car and would prefer buttons on the steering wheel. He also said he would want voice commands but was skeptical about how accurate it would be, especially if music was playing or is other people were talking in the car.

We first showed him a picture of a digital dashboard. He stated that this display still forces the driver to look away from the road. Even if the radio and climate control information is displayed on the dash, along with navigation instructions, it is still distracting. The attempt to make the dashboard look analog does not help. He said that the attempt to make it look good should be abandoned, instead, it should be designed to look very minimal.

We then showed his a picture of a HUD. He liked this a lot more and said ideally, all the feedback information would appear on the HUD and this should eliminate the need for the centre console.

When asked which he preferred, he said the HUD as it is less distracting, better looking and allows the driver to keep his eyes on the road. This is an option he would look for when purchasing a car.

He did not state any features he'd want that are not offered right now. But when the interviewers asked about adding the feature to highlight and translate road signs, he said he liked it a lot, but only if its done well. He stated he would prefer overlay to notification of the road sign. We also asked if he would like night vision to appear of the HUD to show any obstructions up ahead. He liked this idea as well and said it should only appear at night and even still only sometimes, it should not be on all the time.

Interview 2

The second interview we conducted was with a white female in her early twenties, it took twelve minutes. She stated the tasks she does while driving that force her to look away from the road were using the music player on her phone, climate control, radio controls and navigation.

The cars she has driven allow phones to be connected to the car's radio, and she uses the feature to connect her music. She has used a dock for the phone that holds it in place, and uses the GPS and music hands free. She finds holding the phone is distracting her.

She stated that even though the phone is on a dock, it still forces her to look away from the road and she finds this very distracting. She also find using the climate and radio controls distracting.

The only external device she uses while driving was her phone. She said she always checks who is calling her or sending a text message. She sometimes answers a phone call but does not answer text messages as typing is too distracting and dangerous while driving.

We first showed her a picture of the HUD. She said it looks really cool but is not sure if it is practical. She said the system would not be distracting, but some of the notification items were too small in the picture. As for connected devices, she said they should provide notifications but she would not want the message of text to appear. We then showed her the digital dashboard. She said the radio feedback was okay, the speedometer looked okay. She thought placing the GPS on the dash is too distracting as to look at it, the driver has to look down, away from the road. Whereas the dock she is currently using is mounted on the windscreen. She said the colours of the digital dashboard should be customizable and would prefer if there were different themes, as she did not like the analog look for the speedometer. For both systems, she said she would want some sort of voice control so her hands can stay on the steering wheel.

Between the two options, she preferred the HUD but was still skeptical if such a technology actually existed. She said it is a technology she would look for when buying a car.

When we asked if there are any features she wanted that currently do not exist for vehicles, she did not have any ideas. So we proposed having night vision, to which she said yes, but only at night. We proposed translating road signs, which she also wanted, but was not sure if it was possible. She said the display should be customizable and that it should have controls on the steering wheel. We then asked if she would like to receive weather and traffic updates. She said yes that would be very helpful. She also suggested that her navigation should reroute if the traffic is really bad up ahead.

Interview 3

The third interview we conducted was with a black male in his early twenties, it took twelve minutes. He stated that tasks he does while driving that force him to look away from the road. These tasks are using the climate and radio controls, music player on phone and navigation.

He said he has driven cars that allow phones to be connected to them. He uses this feature to make calls and connect this music. He said he usually will read a text message he has received but will not reply as typing is too difficult. He does not use the GPS on his phone as the cars he has driven have built-in GPS. He said that GPS is distracting as it is in the centre console and he has to look away from the road when he is driving.

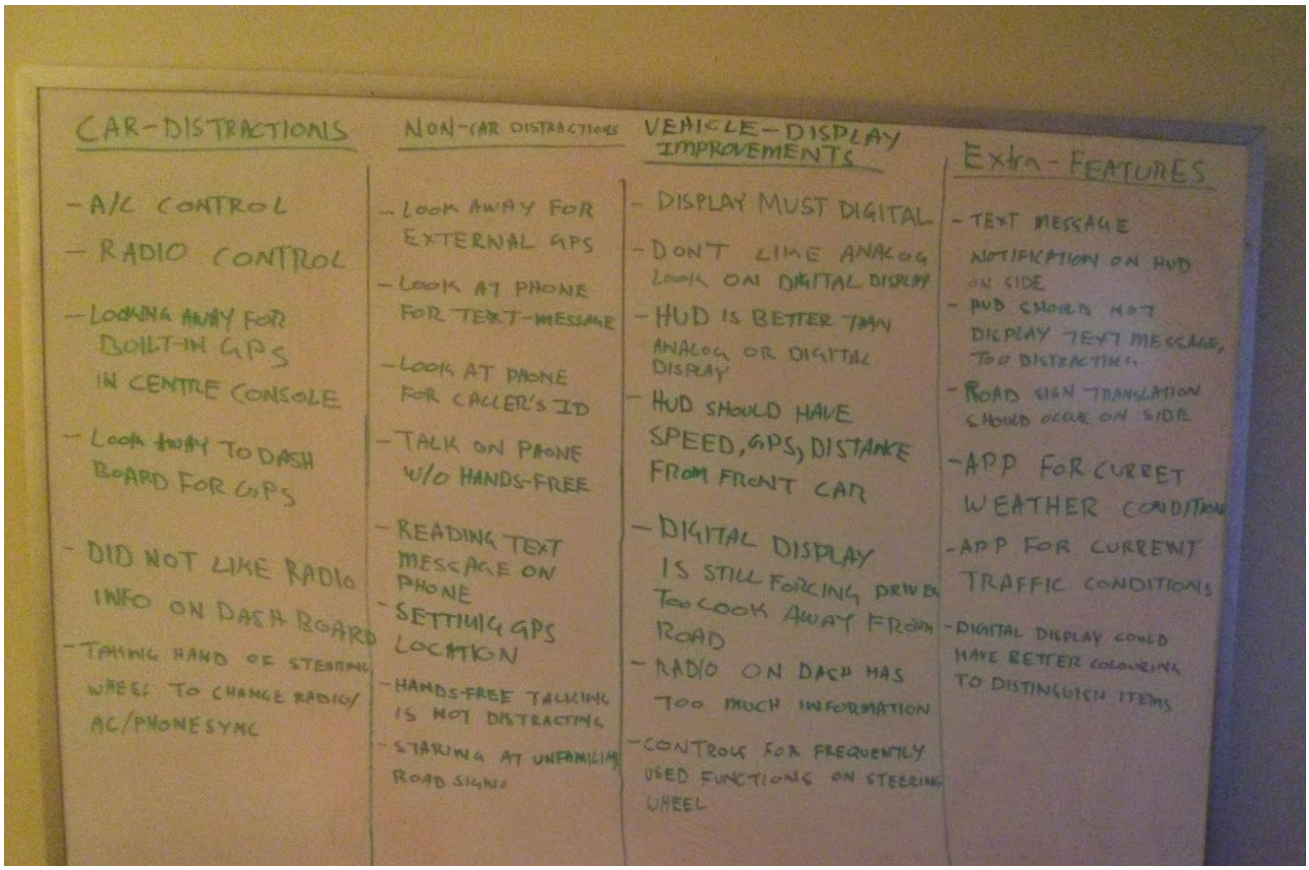
He said there should be controls on the steering wheel for the most commonly used feature of the car, like volume, changing radio, songs. The steering should also have controls to answer a phone call if the phone is connected to the vehicle.

We showed him pictures of the digital dash board first. He said it is not bad, and he liked the idea of having navigation in the dash instead of the centre console, but it is still looking away from the road. He said he would prefers voice recognition over the buttons. He thought the analog look for the speedometer was okay but it should come with other options. He said the dashboard still is not a good place for the navigation system. We showed him the HUD and he said it is way better. He said showing the GPS on the windscreen is perfect and he likes the feedback that can be provided, like how far is the car in front and what speed the car is travelling at. Again he said that voice recognition would be better than buttons. He said the system should notify the driver of incoming text messages but should not display the message as it is distracting. It should also notify the driver of incoming calls and allow the driver to answer, as long as the phone is connected to the radio. All the notifications should come in the driver side bottom corner of the windshield.

Between the two systems, he said he prefers the HUD he would find it less distracting. But, he said, some people may find the system more distracting so it should be customizable. He said the HUD is something he would look for when buying a vehicle and does not care about digital dashboard at all.

Features he wants in a vehicle that are not offered yet are voice recognition for changing music, answering calls, setting navigation location. He also wants read outs about how fast he has to go to overtake a car up ahead to ensure he is not speeding. We asked about translating road signs and he liked the idea. He also liked the idea about night vision display.

Affinity Diagram



Key Requirements

After reviewing the notes from our interviews, we came up with 27 axial codes. These codes fit into 4 categories. Car-distractions, Non-car distractions, Vehicle-Display improvements, Extra-Features.

Car-distractions was the heading for all the codes that have to do with driver distractions that are normal feature of the car and the pictures we showed. These include looking for climate controls, radio controls, looking at built-in navigation in centre console, navigation in digital dashboard. Analysing the data, we came to the conclusion that drivers do not want to look away from the road when they are looking for controls. This would be especially problematic for touch screen interfaces as physical buttons and knobs at least would allow the driver to feel for the controls instead of looking for them on a screen. The physical interface would also provide feedback if touched, whereas a touch screen cannot, the feedback would have to be displayed somewhere. We also found that the participants did not like taking their hands off of the steering wheel, so there should be buttons on the steering wheel that allow the drivers to have some necessary functionality.

Non-car distractions has to do with codes where drivers use external devices that cause them to look away from the road or take their hands off of the wheels. For this category, the majority of the distractions come from the participants' use of their mobile

device. All of them look at their device to see who is calling or sending them a text message, even if they do not answer the call or read the message. Others had to do with setting and reading a portable GPS navigation system or looking at unfamiliar road signs. The finding of this section show that the new system should allow participants' mobile devices to be connected to it. The most important features that drivers want access to is the music player, phone call, text messages and GPS navigation. The system should allow the driver to change songs and view what song is currently being played. It should indicate if the driver is receiving a phone call and from whom and allow the driver to answer and disconnect from the call. The call should take place without the use of their hands and independent from the mobile device. The system should notify the driver is a text message has been received and from whom, but it should not display the contents of the message and this may be distracting. The system should also display GPS navigation information from the mobile device and all the driver to follow the instructions without having to look at the mobile device.

The vehicle-display improvements section is about which system, the digital dashboard or the HUD, did the participants think was better and what their implementations should look like. Participants did not like the analog look the digital dashboard was going for and said they would prefer it to be more minimal. They stated that even though the dashboard is digital and can offer more options, it still forces the driver to too away from the road. The pictures that we showed the participants should radio information on the digital dashboard. They said the dashboard had too much going on and should be reduced to look more minimal, barebones and should only offer the most required information. They did not want to look down from the road and have to search for the information they need.

The participants prefered the HUD system over the digital dashboard. They all said the HUD should at least show the speed at which they are traveling, fuel level, GPS navigation and distance from the vehicle in front. They all said that it should be set up in a way so that it is not in the way of the driver looking at the road and that frequently used controls should be available on the steering wheel.

The extra-features section is about axial code pertaining to extra functionality that the participants said they would want. These are features that have nothing to do with driving. They include notifying the driver of a received text message but not displaying it. The participants were in favour of receiving updates about changing weather, road and traffic conditions. They said the digital dash should come with many themes and the different items should be more distinguishable. The system should be able to tell the driver if he or she is following too closely. The participants were also in favour of having night vision display when driving in a dark area to see obstructions on the road ahead.

Initial Design Prototypes

Digital Dashboard

Our first design is the digital dashboard. The participants we interviewed stated that having to look away from the road to the centre console was distracting. They also stated that they did not like the analog look. Instead, they would prefer something minimal that provided the information they needed, without having to search too much for it.

Using their feedback, we decided not to use dials to display information like speed and fuel level. We used a numeric display that will show the driver their current speed right away instead of the driver having to look where the needle is pointing. The same goes for the fuel level. We chose not to include a tachometer or oil temperature gauge, as is standard in most cars, as most drivers do not use this information. The information is available and can be displayed if the driver chooses another theme, but is not included in the default theme.

The background is black and the vital information, like speed and fuel, is displayed in white. This is so the contrast between the colours will highlight where the driver has to look to find the most relevant information and can do so quickly. The GPS navigation is placed to the left of the speedometer by default. This allows to driver to quickly check the speed and navigation at the same time. This also helps alert the driver of any notification from the navigation system, even while the driver is not looking at the dashboard. The reason for this is the dashboard is in the peripheral vision of the driver's range of vision. So any alerts or changes, as long as they are large and bright enough, will be picked up by the driver's brain.

We will also be using a steering wheel with six buttons. These buttons will be programmed to allow the driver to access and use the most common features of the car. It will also let the driver access these options without having to remove his or her hands from the wheel.

We used Schneider's 8 golden rules of design to create the system and interface. Depending on the theme the driver chooses, the subsystems, like the radio or the GPS navigation, will always appear in the same place and any feedback they give or information they provide will appear in or around them. The terminology that we used for the functions we provide are consistent with that is used in the real world. Driver will be able to increase or decrease the temperature, increase or decrease the volume of the stereo. Change stations, forward, rewind and play tracks. They will be able to look up points of interest by categories, set destinations addresses, track current distance traveled and much more. We even included a following distance feedback that lets the driver know how far the vehicle in front is currently. This goes red and bold if the driver is following too closely for a safe stopping distance, depending on the speed he or she is travelling.

We programmed shortcuts in the steering wheel buttons for the most commonly used applications. These shortcuts change depending on what application is being used currently. For example, we have two buttons for volume, one is to increase and the other is to decrease. If the driver is listening to the radio, these buttons will adjust the volume of the radio. If the driver is listening to music from the phone or is on a phone call, the same two buttons are used to increase and decrease volume for those apps. There are also shortcuts on the wheel to select different applications to use. The driver can toggle between the GPS and radio while driving but can only access the answering calls feature of the cell phone. The driver is not given the option to access the text message part of their cell phone as this is considered too distracting while driving.

Informative feedback is provided by the dashboard for every action that driver does from the steering wheel. On the bottom left of the dash, there is information about which application is currently selected and can be used. If the driver chooses to scroll to a different application, the display will change accordingly. If the driver chooses to increase or decrease the volume, a volume bar pops up and on the right, under the radio to indicate the level. The GPS provides feedback about where the driver currently is and how the next turn is and how

far the destination is. For dangerous situations, like following too closely or speeding, the dash provides warnings in bold and red colour to indicate to the driver that he or she is engaging in unsafe driving practices.

Closure is provided for correcting dangerous driving practices by the warming colours going back to being white and warning signals going away. As for toggling between applications and changing their settings, closure is provided by showing what the driver has changed. If the information does not need to be present all the time, like volume, it disappears from view.

Error handling is done by limiting what functionality the driver has access to while driving. The driver is not allowed to scroll through the contacts of their phone to find a person nor is the driver allowed to change GPS navigation while driving. If the car is stopped and not in drive, the driver can access more options of the navigation system and any erroneous entries will not provide a correct destination. Also, certain controls are locked to certain system. The volume controls have nothing to do with navigation system and therefore do not affect that application at all. All the input is limited to using the provided buttons so incorrect input types cannot be entered into any of the systems. As for system malfunctions, like the driver receiving dangerous driving messages when the driver is not driving dangerously, would have to be correctly by the vehicle being inspected for malfunctioning sensors. But the sensors only provide feedback and do not change how the car is being driven.

Reversal of actions are pretty easy as all the controls are on the steering wheel. The only limitation to this is if an incorrect destination is entered to the navigation. If so, the driver will have to stop the vehicle, put it in park and then change the destination. This is done for safety reasons as the driver cannot be typing while driving.

Since the vehicle is being operated by a driver, the locus of control is completely internal. The sensors only provide feedback to the driver, but the driver is allowed to operate the vehicle and the applications of the vehicle in any way possible. There are some automations provided, like a the music player going to another song when the first one finishes, but this can be turned off. And if the car is connected to the driver's phone, playlists can be customized and tracks can be skipped. All other applications are initiated by the user, unless it is a warning.

We have reduced short-term memory overload by building a minimal display system and interface. Any codes or symbols we used are commonly used and known to all drivers. We have also limited the number of things that change on the dashboard regularly to only the speed and navigation. The music player only displays if it is on and shows the progression of the track. The following distance changes but is only highlighted if the driver is following too closely.

The advantages of this system mainly have to do with limiting the amount of times the driver has to take his or her hands off of the steering wheel and moving his or her eyes off of the road. We have limited the number of things that force selective attention so the driver can focus on the task of driving. The features we can included may force the driver to have divided attention. But we have limited the capabilities, streamlined the most common functionality, and moves items in the driver's line of sight. We have only used captured attention to indicate to the driver about dangerous driving patterns.

Storyboards

Default driving display

This is the regular display that John will see while he is driving. He is traveling at 74 mph. He has 99% of the fuel left in the tank. His controls are currently connected to the navigation system, indicated by the NAV at the bottom left. He has his destination set and is travelling a safe stopping distance of 100m.

Following too closely

John is still driving at 74 mph, but he was cut off by a car merging in front of him. This has caused John to be too close to the car in front and he has received an alert. The following distance is now 40m and has become red. John will have to slow down to be a safe distance away again

Volume Control

John has corrected the following distance so the alert has gone. He is now following the vehicle in front at 104m and once again at 74 mph. He has switched controls to the music application is lowering the volume as it is too high

Incoming Call

While John is still on route, he receives a call from Steve Madden. Although the music app is still selected, the only thing John can do now with the music app is adjust the volume. The feedback of the app has disappeared and has been replaced the information for the incoming caller. John can decide to answer this call or ignore it.

Call answered, traffic update

John has decided to answer the call. The remaining information has been removed, just the callers name and talk time are left. While on the call, John receives a traffic update that there is a collision on route to the destination. But it is not in red as traffic is still moving well and it will not disrupt this commute.

Incoming call while on a call

While John is talking to Steve, he receives another call from Maryam Mir. A profile picture does not appear as there is not one attached to her on John's phone. John can now answer Maryam and put Steve on hold, answer Maryam and disconnect Steve, or ignore Maryam and continue talking to Steve. Steve's information is removed from the right top corner and a symbol above the navigation indicates that he is on a call. The top right corner has been replaced with Maryam's information now.

Almost There

Once John is in his destination, the dashboard changes and puts the GPS in the middle. This allows the John to better navigate as he will not have to look for street signs and building numbers. This will keep his eyes on the road and let him be safe.

Heads Up Display (HUD)

Our second design prototype is the Heads Up Display (HUD). The participants we interviewed stated that having to look away from the road was distracting. Although the digital dashboard allowed the users to keep the most commonly used features about their vehicles in their peripheral vision, it would still sometimes force them to look away from the road.

Using their feedback, we decided to build a Heads Up Display as our second prototype. This type of display provides the driver with information directly on the windshield of the car, without the driver having to take her eyes off of the road. Another advantage of this system is the size of the windshield itself. It allows us spread the feedback information on a larger surface so we do not have cluttered feedback. There were a few safety concerns we kept in mind when designing the prototype. One is to ensure the information being displayed on the windscreen is translucent, so the driver always has view of the outside. The second is to ensure the most important information is kept centre to the driver so even when focusing on the road, the driver can view this information. Third, we ensured that the notifications were in a place where the driver was able to recognize an alert, but it was not so distracting or attention grabbing as to shift the driver's focus away from the task of driving. Although the participants of the study stated they would want the HUD to be customizable, due to safety concerns, we would provide the users with themes, that will change the look of the interface but also ensure the display can be operated safely.

As in the previous prototype, we will be using a steering wheel with six buttons. These buttons will be programmed to allow the driver to access and use the most common features of the car. It will also let the driver access these options without having to remove his or her hands from the wheel.

We once again used Schneider's 8 golden rules of design to create the system and interface. Regardless of the theme the driver chooses, the speed and fuel will always be in the central view of the driver. Most alerts will appear at the top of the windscreen so they do not obfuscate the view of the driver. Any additional features must only be displayed when called and should not obstruct the driver's view of the road or other vehicles. The terminology that we used for the features we provide are consistent with what is used in the real world. The system will provide the driver with all the regular features that come standard vehicles today as well as some additional safety features. The safety features include the following distance information that lets the driver know how far ahead the vehicle in front is. This goes red and bold if the driver is following too closely for a safe stopping distance, depending on the speed he or she is travelling. The system also includes lane change feedback to let the driver know if there is a vehicle in her blind spot and if it is safe to change lanes.

We programmed shortcuts in the steering wheel buttons for the most commonly used applications. These shortcuts change depending on what application is being used currently. For example, we have two buttons for volume, one is to increase and the other is to decrease. If the driver is listening to the radio, these buttons will adjust the volume of the radio. If the driver is listening to music from the phone or is on a phone call, the same two buttons are used to increase and decrease volume for those apps. There are also shortcuts on the wheel to select different applications to use. The driver can toggle between the GPS

and radio while driving but can only access the answering calls feature of the cell phone. The driver is not given the option to access the text message part of their cell phone as this is considered too distracting while driving.

Informative feedback is provided by the HUD for every action that the driver does from the steering wheel. Speed and fuel feedback is provided with a numerical output instead of a dial for easy reading and understanding. As the driver toggles between features, the HUD will display the feedback of that feature on the windshield. If the driver chooses to increase or decrease the volume, a volume bar pops up to indicate the sound level. The GPS provides feedback about where the driver currently is, how far the next turn is and how far the destination is. For dangerous situations, like following too closely or speeding, the system provides warnings in bold and red colour to indicate to the driver that he or she is engaging in unsafe driving practices.

Closure is provided for correcting dangerous driving practices by the warning colours changing to white and warning signals disappearing from the windshield. Closure for different applications is provided by showing the changing state of those applications, this is done visually, auditorily or both, depending on the feature. If the information does not need to be present all the time, like volume, it disappears from view so it is not in the driver's line of sight.

Error handling is done by limiting what functionality the driver has access to while driving. Scrolling through the contacts of their phone to find a person or changing the GPS navigation is not allowed while vehicle is moving. If the car is stopped and not in drive, the driver can access more options of the navigation system or phone contacts and any erroneous entries will provide an incorrect destination or incorrect person being called. Also, certain controls are locked to certain system. The volume controls have nothing to do with navigation system and therefore do not affect that application at all. All the input is limited to using the provided buttons so incorrect input types cannot be entered into any of the systems. As for system malfunctions, like the driver receiving dangerous driving messages when the driver is not driving dangerously, would have to be correctly by the vehicle being inspected for malfunctioning sensors. But the sensors only provide feedback and do not change how the car is being driven.

Reversal of actions are pretty easy as all the controls are on the steering wheel, same as the digital dashboard. The only limitation is functionality that is restricted while driving. To correct any mistakes in those features, the driver will have to pull over to access the locked features. This is done for safety reasons as the driver cannot do certain activities while driving

Since the vehicle is being operated by a driver, the locus of control is completely internal. The sensors only provide feedback to the driver, but the driver is allowed to operate the vehicle and the applications of the vehicle in any way possible. There are some automations provided, like a the music player going to another song when the first one finishes, but this can be turned off. And if the car is connected to the driver's phone, playlists can be customized and tracks can be skipped. All other applications are initiated by the user, except for warnings.

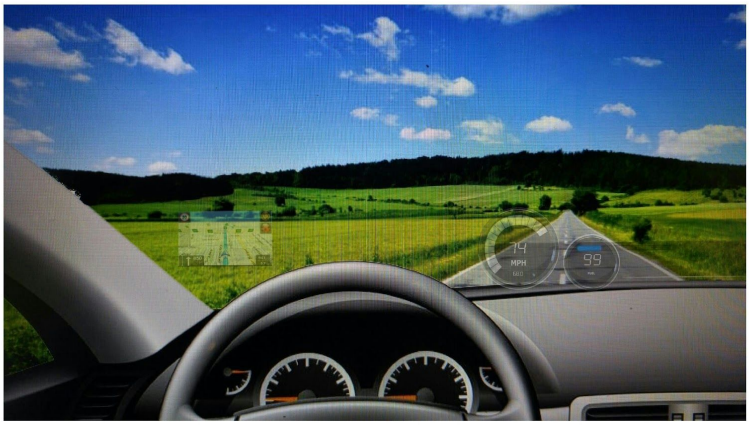
Short-term memory overload is reduced by building a minimal display system and interface. The display of information is spread out and consistent to the driver will not have to look at many things to search for the needed information. Any codes or symbols we used are commonly used and known to all drivers. We have also limited the items that are on the

HUD regularly, most appear when they are being used and then disappear. They either turn off or run in the background until called again.

The advantages of this system mainly have to do with limiting the amount of times the driver has to take his or her hands off of the steering wheel. But the biggest advantage over the conventional dashboard placing is the driver can keep her eyes on the road at all times while receiving feedback from the different features of the vehicle. We have limited the number of things that force selective attention so the driver can focus on the task of driving. The features we have included may force the driver to have divided attention. But we have limited the capabilities, streamlined the most common functionality, and moved items to the driver's line of sight while making them translucent enough to not disturb the driver's view of the road. Captured Attention is only used to indicate to the driver about dangerous driving patterns.

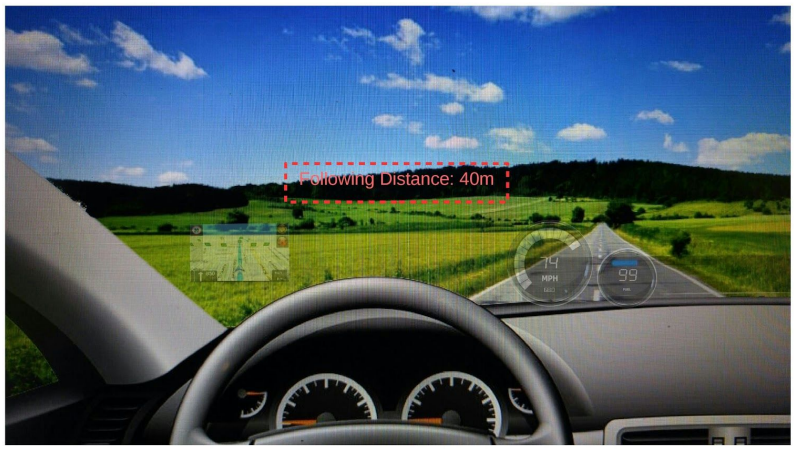
Storyboards

Default driving display



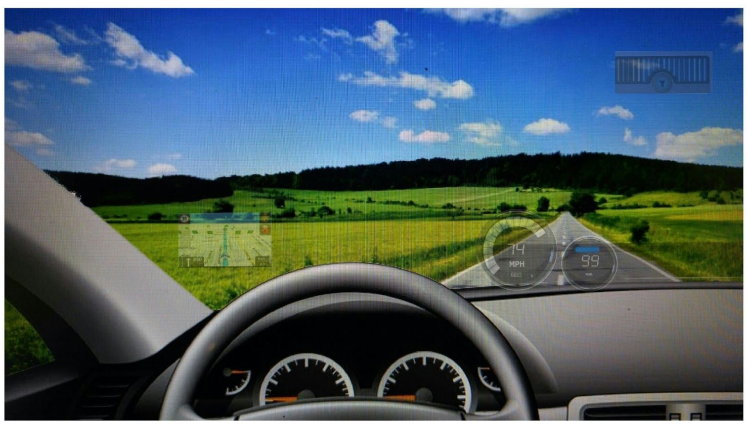
This the default driving display Sally will be seeing most of the time as she is driving. She is driving at 74mph and has 99% of her fuel. She also has a destination address that she entered into her GPS navigation system, which is displayed on the left side bottom of the windshield. She can see all this information without having to take her eyes off of the road.

Following too closely



While Sally is driving, she started following the vehicle in front too closely. This caused a warning event to occur to let Sally know that 40m is not a safe stopping distance when travelling at 74mph. The message appears just off to the left of where Sally would be looking on the road, so it does not obstruct her view. But it is central enough and short enough that she can understand the message at a quick glance.

Volume Control

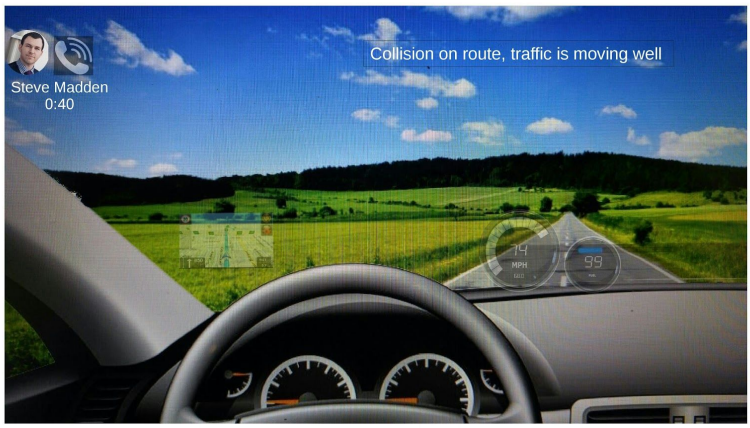


While Sally is driving, a song she really likes starts playing on the stereo. She turns up the volume to enjoy it more. The system provides feedback for this action by displaying a volume bar at the top of the windshield and the actual volume increasing on the speakers.

Incoming Call

While Sally is driving and listening to music, she receives a call from Steve Madden. The system notifies her pausing her music and playing her ringtone to indicate an incoming call. The system also displays a picture of Steve, his name and phone number on the top of the windshield. The information is not obstructing Sally's view of the road. She can choose to answer the call or ignore it. Answering it will keep her music paused and will allow her to speak to Steve without using her hands. While ignoring it will let her resume listening to her music.

Call Answered, traffic update



Sally decided to answer Steve's call. The system provides feedback of the connected call by placing some information about the phone call on the top left of the windscreen. While drving and talking on the phone, she receives a traffic alert letting her know that there is a collision en route to her destination. But the collision is not impeding traffic. All this information is laid out in a way to not obstruct the driver's vision but can be read quickly without the driving having to look away from the road.

Prototype Evaluation and Iteration

Cognitive Walkthrough

For our cognitive walkthrough, we used our low fidelity prototypes. We used scenarios similar to ones used in the storyboards sections above. The entire team was present during the cognitive walkthrough. We had two people making notes, one person facilitating the walkthrough, one person who acted like the system and one person who assumed the persona. The person assuming the persona was kept out of the loop when we were creating the initial design prototypes to ensure he would be looking at the system with fresh eyes in this step.

We used the same 4 tasks for both prototypes. This was done to see which interface was easier to use and quicker to learn. The tasks we chose for the walkthrough were

realizing the driver is following too closely and correcting this, talking on the phone with someone and seeing an incoming alert about traffic, realizing the destination address entered into the navigation system is incorrect and correcting it and merging into a parallel lane.

Digital Dashboard

We started with the Digital Dashboard. We set up the walkthrough by having the user sit in front of a steering wheel staring at a screen. We simulated the digital dashboard by placing pieces of papers behind the steering wheel, where a real dashboard would be. The facilitator instructed the driver what to do and the computer placed certain items of the display. We told the user to explain what he thought the displayed information was about, how would this information be used, and once the information was used, did something happen that let the driver know that the information provided was used.

For every task, we found that the user would identify some change occurred on the interface very quickly but spend some time looking at the interface to see what the change was about. This was most evident in the “following too closely” scenario and the “incorrect destination address being inserted” scenario.

For the first one, the driver realized very quickly something had occurred on the dashboard, but took his eyes off of the road to read the message. We kept the message short, it read Following Distance: 40m. Once he read the message though, he said the red meant that there was danger and it had to do with the following distance. He said the way to correct this was to slow the vehicle until the distance increased. He once again noticed a change on the dashboard, but this time did not spend much time reading it. He said he noticed the red colour switching to white and thought this meant the danger is over.

For the second scenario, the facilitator and the user simulated a phone call between each other. The driver was told to drive as he would normally while having a conversation on the hands free phone call system. The computer placed an alert on the dashboard saying that there was a collision up ahead and that traffic was travelling very slowly. The driver once again looked away from the road to read the entire message before looking up again. At this point, the facilitator ask him if he would like to look for a different route to his destination. He responded yes. The facilitator asked what steps would he take to look for another route, if one did not come to mind for himself. He said he would cancel the current navigation and tell the gps to find an alternative route. The facilitator asked how this would be achieved if the navigation was controlled from the centre console, and worked similar to any navigation system he has used before. He said some navigation systems provide an option that allow you to look an alternative routes and pick one of those to travel on. He said he would click on that tab and select the shorted path. We asked him to simulate that, on an iPad with google maps installed on it. But when he clicked the Maps icon, the computer placed an error message saying, Inaccessible while driving and the facilitator hit the home screen to stop the application from loading. The driver then said he would pull over and change the navigation system, and the facilitator went back to simulating the phone call and saying bye.

The third scenario was merging. Our system is suppose to be able to let the driver know if there is a vehicle his blind spot and if it is safe to merge into the lane he has indicated for. The facilitator told the driver that the current lane is moving, but the two lanes to his left and right are moving a bit faster and the driver is in a bit of a hurry. The driver said

he would move into the left lane as it is suppose to be the fastest travelling lane. The facilitator asked how he changes lanes and the driver provided the signal, check mirror and check blindspot response. We asked him to simulate it but there is a vehicle in his blind spot. He pressed the left signal at which time the computer placed a red piece of paper on the dashboard, the driver continued and said he would wait for the vehicle to pass. The facilitator asked if he would cancel the indicator and or have it running until the vehicle passes. He said he would let it run. So the computer replaced the red piece of paper with a green one. The driver asked if this meant the vehicle had passed. The facilitator said yes, and the driver said he would then merge.

The fourth scenario, we told the driver to navigate from his apartment to carleton university using the navigation system and the roads he used most often. He listed the directions and said he would follow them. The facilitator told him that on a turn that me makes to go south, the navigation is telling him to go in the opposite direction. He said he would check to make sure the destination address is correct. The computer places a piece of paper with 125 Colonel By, instead of 1125 Colonel By. The driver says the address is incorrect and that he would change it. We asked him to simulate it. This time, he said he would stop the car, enter the correct information, verify it and then continue.

From the walkthrough, one thing we found was that the driver would look away from the road to read the entire message before looking back on the road. The green and red lights when changing lanes seem to be intuitive once the driver sees the association between the indicator and the lights coming on and changing. And the learnability of the system seems to be high as once the driver knew he could not change the navigations settings while driving, he remembered it for the next task.

The usability of the system is limited by purpose to ensure the driver cannot be distracted by activities other than driving. We have limited the features to ones the driver can detect and use only using his divided attention or alternating attention, but the alternating happens very quickly and only for the brief moment.

In terms of the features we have provided, the system appears to be very usable and easy to understand. The alerts are catching the user's attention and, although the driver is looking away from the road to read them, are short and to the point. Once the user learns what he is allowed and not allowed to do, almost all of the controls he needs are at his fingertips on the steering wheel.

Heads Up Display (HUD)

We then moved on to the HUD. This was set up by placing the driver in front of a steering wheel that was connected to a computer screen. We built a simulated environment on a computer, which was hooked up to a TV. The environment we used is shown in the pictures above of the low fidelity prototype. He used key generated events to cause objects to appear. The low fidelity prototype was built in powerpoint to allow for key generated animations.

The facilitator instructed the driver what to do and the computer caused events to occur on the TV.. We told the user to explain what he thought the displayed information was about, how would this information be used, and once the information was used, did something happen that let the driver know that the information provided was used.

For each task, we found that the user would identify some change occurred on the interface very quickly and could identify what the newly appeared object was about. The difference was most evident in the “following too closely scenario” and the incorrect destination address being inserted scenario”.

The first scenario we did was the “following too closely” scenario. As the driver was driving focusing on the road, the computer generated a “following too closely” alert in the middle of the windshield, it said Following Distance: 40m. The driver realized instantly what the message was about and said he would let the vehicle slow down to create more distance. After a few seconds, the red coloured alert disappeared and the driver said he thought it meant he was at a safe distance.

The second scenario we ran was the wrong navigation scenario. The facilitator told the driver to describe how he gets from his apartment in Ottawa, to his parents house in Toronto. The navigation screen we used to show the route of the trip was a screenshot of Google Maps. The driver started describing what he usually does to get on the highway from his apartment, but along the route, the facilitator told him to avoid the highway and keep driving. At this instance, the driver knew that the navigation was taking him through a different route that does not take the major highways. He said he would pull over, change the settings, and then continue on his route.

The third scenario we ran was receiving a phone call while driving. The facilitator and the driver simulated a phone. The computer generated an alert on the TV stating that there was a collision up ahead and that traffic was moving slowly. The facilitator once again asked if the driver would like to choose an alternate route. The driver said yes, and stated he would pull over, look for a new route and then continue driving. For this alert, he did not have to look away from the road and understood very quickly what the alert was about. The scenario simulated him pulling over while on the phone call, finding an appropriate alternative route, and then continuing to this destination. Had the driver attempted to use the iPad, the computer would once again generate an alert and the functionality of the feature would be blocked.

The fourth scenario we ran was merging into a parallel lane while driving. The facilitator told the driver, that the current lane is moving very slowly. The the two lanes to the left are moving quickly. The driver decided to switch to the middle lane. He triggered the indicator, at which point the computer displayed a left arrow appearing on the screen the colour red with a cross though it. The driver stated this meant that switching lanes was not allowed. Then the cross went away and the arrow turned green, at which point the driver switched lanes. The facilitator told the driver then that the red arrow does not mean that changing lanes in not allowed, but that it is unsafe as a vehicle is there. After simulating driving again for a bit, the facilitator once again told the driver that the lane is slow. The driver decided to change to the left lane. This time he indicated and saw the red arrow again, waited for it to turn green and then switched lanes.

Looking at the results of the walkthrough, we can conclude that the driver did not have to take his eyes off of the road to accomplish any of the tasks that he was allowed to do. Looking at the 3 questions to answer in a cognitive walkthrough, the results show that the user was able to understand what the correct action should be to complete a task. Once the correct action was identified, he was able to see that the correct action was available and proceeded to do it. Once the action was taken, the system responded with feedback which the user said he was made aware to understood it to mean that the action taken worked.

The usability of the system is high as all the information needed by the driver is available on the windshield. The controls for the valid functions are available to the driver on the steering wheel.

The learnability of the system is high as well. It The driver was able to decipher most of the symbols, except the merging lanes. But even for that, the driver was able to understand the correct intent. And once the driver was told what was the meaning of the system, he was able to use it and interpret it as it was intended.

Prototype choice

The prototype we decided to move forward with was the Heads-Up Display. There were many reasons why this display and interface were chosen. Our goal for this project was to build a system to reduce driver distractions and the cause of driver errors. The common elements between all the reasons that cause these issues is driver having to take their eyes off of the road, taking their hand off of the steering wheel, and not having adequate feedback regarding their driving. We also looked at the which system was more usable and more learnable from the prototypes we build

The HUD system allows us to combat all of the issue we outlined. The system displays information and feedback directly on the windshield. This allows the driver to see the information and feedback while keeping her eyes on the road.

The system is controllable from the steering wheel. This lets the driver have access to the most commonly used functionality while keeping her hands on the wheel. It also limits the access the driver has to certain functionality if the vehicle is moving.

Although the digital dashboard has many advantages, the HUD allows us to better achieve our goals. The digital dashboard only lessened the distance the driver's eyes have to move to look at the information the vehicle was providing.

The HUD actually eliminates the requirement to look away from the road. The relatively smaller size of the digital dashboard was not of a sufficient size for the information we wanted to display. Either the display was becoming too cluttered when we were adding alerts and notification. Or we had to hide important information when trying to display other high priority alerts. Even if there was not a lot of information on the screen, to ensure the driver is aware of the alerts, it would have to be sufficiently large and was hiding other information.

It expands the amount of information and feedback a vehicle can provide. It also provides us with a larger surface to display this information. The larger surface allows us to better design the display.

Alerts of a similar type can be grouped together. Notifications of missed calls or text messages can be grouped together, weather and road conditions can be grouped together as well. We can use contrasting colours and text to distinguish between high priority alerts and low priorities alerts. All high priority alerts will appear in front of the driver so she can address them right away while still paying attention to the road and other vehicle driving around her.

We can use Norman's design principles to build an effective display and interface system. The larger surface also lets us more realistic mental models. The images will be larger, the navigation can show exactly where on the road to turn or be. Problem solving will

be minimized as many distracting features will be disabled while driving and most common features are available on the steering wheel. We can also ensure that all interactions provide some feedback so the driver is aware that something happened. Using the next step, we will ensure we get the mappings correct for what steps features should take. Constraints will be put on what features are accessible and how to input information to the system. And if anything fails, the vehicle still offers a conventional dashboard with the most practical information displayed on it.

HUD Iteration 1

The first wizard-of-oz test was conducted using the low-fidelity prototype. We asked the participants to interact with the system as if they were driving a car. The participants were placed in front of a steering wheel with a TV. The first screen the users saw was the default driving display. The participants stated they did not like the GPS navigation map. They wanted real time turn by turn updates instead. They did not like the round look of the speed and fuel, they prefer having just numbers appearing. For the fuel, they said it's not necessary to show it all the time.

We then simulated a phone call and switched pictures to the incoming call low-fidelity picture. Both participants stated that they did not like the way the incoming call feature looked, the phone number is not needed if it shows the name and picture. They also said having something animated would be nice, instead of a static image. The placement of the feature so high on the windshield is distracting. They pressed a key on the steering wheel to ignore the call.

This action was used to bring up with default screen and we played some loud music. The users then clicked another button on the steering wheel labelled volume down to lower it. We used this click to bring up with lower volume button. For this slide, the users did not like the placement of the volume display. They said again it was too high and that looking up there for the volume is not natural and can be distracting.

After a few seconds of no interactions, we switched back to the default driving screen then switched to the incoming call again and played a ringtone. The users decided to pick up with phone call using a button on the steering wheel. The display of the answered call should not show the duration and the name, the picture of the person is sufficient. While on the call, a pop up appeared of a traffic update. They said they liked the traffic update and the placement was good. They stated that having this information is really important to them while driving as it may affect what their next decision will be. After 2 seconds of no interactions, we switched back to the default display.

We told the driver that they can try the other two buttons to see their functionality. One button brought up current weather. We had a text description for this but the participants stated they would prefer something graphical.

The participants were asked if they liked the button placement. They said the button placement made sense for the volume, they are right above each other. The answer and ignore call buttons are on the same side as well and right above each other, they liked that as well.

At the end we asked if there was something missing or an aspect of driving that they would like some assistance in. One of the participants stated that parallel parking and

reverse parking is a bit of an issue and implementing a park-assist system would be very helpful.

We decided to take this idea one step further and use it to remove the rear-view mirror completely. We decided to add a rear-view camera and display it at the top of the windshield. This feature will also be used for the parking assist system. The feature will help the driver with parallel parking as well as reverse parking and let them see their rear view whenever they want. It will also alert the driver if someone is tailgating them.

Changes after Iteration 1

We took the participant's input and implemented them into our system. We kept in mind that the system's initial goal is about reducing distractions and increasing safety. We reduced the information shown on the phone call. It was changed to only show the the incoming caller's name and picture. We also added an animated picture for the incoming call scenario that is more consistent with the mental models drivers have of a phone call. We added a text message notification as well. It displays an envelope to indicate that a text message was received.

The speedometer was changed to be completely digital and without any borders. The fuel gauge is not a smaller picture of a fuel tank. The tank image is placed in the bottom left corner of the windshield

We moved the volume bar down below center line of the windshield. When a call is answered, we reduced the feedback to only the name of the person. The updated weather was changed to a graphical output. It now shows, either a sun, rain, snow or clouds, depending on the weather forecast and shows the current temperature outside.

We decided to implement the rearview mirror in the HUD. At the press of a button, the system activates a camera in the rear and displays it at the top of the windshield. We placed it where the rear-view mirror is located. We added a some distance lines that show if the object directly behind you is at a safe distance away or not.

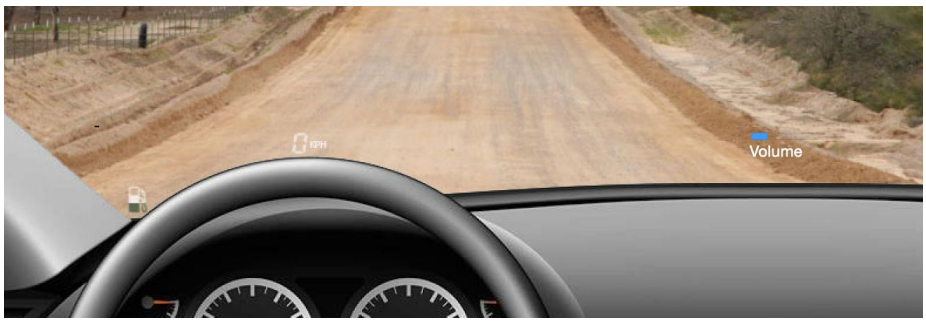
Other new features were in between the iterations. We added a display of what song is currently playing. This feature was incorporated with the calling system. If an incoming call event occurs and a song is playing in the background, the system pauses the playing media, and begins the incoming call scenario. If the driver chooses to the ignore the call, they system notifies the driver that he has a missed call and starting playing the media again from the same place that it was paused. The system also says the name of the person that is calling you.

HUD Iteration 2

After making the changes, we conducted another wizard-of-oz usability test. We used two different participants and ran through the same scenarios. The test started with showing the participants the default driving screen. They said they liked the new speedometer and fuel display.

The system starting playing music, simulating the driver driving and listening to music. The participants liked the way the system displayed the currently playing song. The steering wheel had 2 buttons labelled volume. The participants were able to use those to lower and raise the volume, it is not something they were instructed to do. After the fact, they

stated they just wanted to play with the wheel and the music was loud. We showed them a key on the keyboard that can be used to pause and play a track. They pressed it and said the feedback images and text were where they expected them, near the volume bar.



We then simulated an incoming call. The system paused the track that was playing and started the incoming call simulation. The participants liked the new incoming call animation. The participants responses indicate they liked the minimal look and that they did not find it distracting. They were able to quickly see who was calling and make a decision. The participants pressed a button on the steering wheel to answer the call. They answered the phone and liked the way the system indicates that a phone call was answered. They also liked the fact they did not have to remove their hands from the steering wheel.

We then had them hang up the call to demonstrate that the system will continue playing the track after the call. Their comments suggest they appreciate the fact that the system remembers and begins playing from the same place it left off.

Next, we simulated a text message being received. An envelope appeared on the screen and the computer made a notification sound. The participants knew instantly what this notification image and sounds meant. The participants asked if they could check the message but we told them that this functionality was not implemented as it is considered too distracting.

When they tried the weather notification application, they stated the image looked good. It was easy to decipher what the weather conditions will be for the day and what the current temperature is outside.

Then they tried the rearview mirror application. The feedback we received from this was positive. The participants said the placement of the application made sense. They liked the notifications about whether vehicles are a safe distance away or not.

Overall, the feedback for Iteration 2 shows that the system is highly usable. The notification images are intuitive to understand and are similar to what the participants see in other applications. The placement of applications that are in vehicles, like volume and rearview mirror, is where the participants expect them to be. The display is not cluttered and a lot of empty space is left so the driver's view is not obstructed.

The limiting functionality is done on purpose to ensure the driver cannot be too distracted. Once the participants were told this, they agreed. The learnability of the system is also high, as we have limited the interactions. This way the users do not have to remember too many keys or functions while they are driving. The steering wheel has been labelled so the participants know what button does what. But since there are only 6, they are not difficult to learn.

High-Fidelity Prototype

HIGH FIDELITY DESIGN:

Using the prototype design as our base designs and the feedback from the interview process, we unanimously decided to design the HUD. The HUD projects information on to the windscreen in front of the driver, informing, assisting and alerting the drivers while they drive. This limits the number of interactions the drivers would be doing, allowing them to focus on the road and keeping their hands on the wheel most of the times. Drivers would be interacting with the HUD using toggle button on the wheel, hence this would prevent drivers moving their hands around to do certain demanding interactions. Our HUD can be customizable, allowing the driver to change the hue, texture and skin of the display but the functionality is programmed to assist based on pre-set functionality and cannot be changed.

During the interview process we discovered that reviewing text messages and incoming/receiving calls were one of the popular concerns for the participants. Participants would not usually reply to the messages, but instead would check who had sent the message and how urgent the message was. Similarly incoming calls was also a concern,

although participants said they don't receive calls while driving, but would usually check who was calling. Using those comments, we decided to display these as notifications. For the incoming call, we designed a phone image to represent the incoming call. The phone image vibrates allowing the drivers to relate to a mental model of a phone ringing. The color scheme chosen for the image was picked not to be flashy, since it would distract the driver from the road. Calls are not a warning of any sort and don't require immediate attention, thus we design it to be easy on the eyes. It pops up at the bottom right with the image of the person calling and the name underneath. A voice notification also informs the driver to who is calling. Using the Gestalt Principles of proximity and connectedness, the bars for the phone image are placed close to one another leading to the vibrating phone image, which also highlights the hierarchy visual design, showing that the phone is ringing. Once the driver decides to decline the call using one of the toggle buttons, a notification at the similar position appears where there was an incoming call. The missed call notification is represented as a conventional image of a red circle, with a phone in the centre facing down. If the driver receives a message, an envelope representation beside the missed call image appears. The envelope is enclosed, representing that the message is received but hasn't been read. All these three notifications appear at the bottom right of the windscreen beside one another, following the principle of similarity, to represent similar information together, making it easier for the driver view these notifications, and not making an effort to look around, thus resulting in less distraction. We also made sure that the image sizes did not differ from one another, so that equal preference was given to the notifications. We did not find it necessary to label the missed call image. The reason for that is, since the missed call image replaces the incoming call image at the same position on the screen, the driver can automatically associate with the conventional image, having a mental model a call been missed.

The second interactions that we decided to show was the radio controls. This involved volume increase and decrease using toggle buttons respectively. The driver can also, pause and resume music that is being played, using respective toggle buttons on the wheel. The representation of the both these functionalities follow Getalt's Principles of proximity and similarities, since both closely related features are represented together. The toggle button to reduce the volume is placed below the button to raise the volume. The reason for this decision is that the driver or a person generally has a mental model of volume increase as increase in pitch, thus the button is placed above the reduction of volume. The pause and resume images are displayed above the volume display on the HUD. As the button is pressed to increase or decrease the volume the volume display bar moves and responds respectively, giving feedback to the driver's interaction. The volume bar disappears after 5 seconds. We show the name of the track and the artist information, as per the notes taken from the participants from the interviews.

The third interaction is the GPS navigation system. Our GPS navigation system uses the real-time updates, and projects the real-time directions to direct the drives to their destination. The driver feed in the destination into the GPS system, towards the start of the trip. While on the trip, real-time direction pop up from the HUD on the screen and disappear once the respective instruction was followed by the driver. The driver has the option to turn off the GPS system using one of the pre-set toggle buttons on the wheel. The navigation assistance appears in the centre of the screen. The visibility of the of the directions were set to be translucent, so that the driver would still be aware of the road once the navigations

pops up onto the screen. We used arrows and brief sentences with voice navigation, so it is easier for the driver to follow using principles of visual paths.

The fourth interaction is that the driver can view the current weather conditions. Majority of the cars these days display the outside weather in digital format. According to the participants in the interview process, participants encouraged weather conditions being displayed at disposal but it was not necessary since they would usually adjust as per their judgement while driving. We decided to go with displaying the weather conditions with respective images depicting the current weather, with the temperature displayed in Centigrade and/or Fahrenheit with the current city and state beneath the temperature. The image would be displayed in the top left corner and can be hidden using one of the toggle buttons.

The last important feature we programmed to be displayed on to the HUD was the rear view display with parking assistance. The purpose of this was to revolutionize the driving experience by removing the current rear view mirrors. We allow the drivers take a glimpse of the rare traffic, in case to see if someone was tailgating or wasn't on a safe distance to reverse the vehicle. The rear view display assists drivers with colored parking line assistance and safe distance messages. Green lines represent everything to be okay, and red lines represent danger. We decided the colors since those are conventional colors to represent and the driver would have it easier to recall. The display appears on the top right, since that where the drivers usually look to check their rearview mirrors. The image is an opaque image, not blocking the driver's current front view. The borders around the image were designed to automatically change color to opposite colors from the background, making the image stand out so the driver can view without any interruptions and confusions.

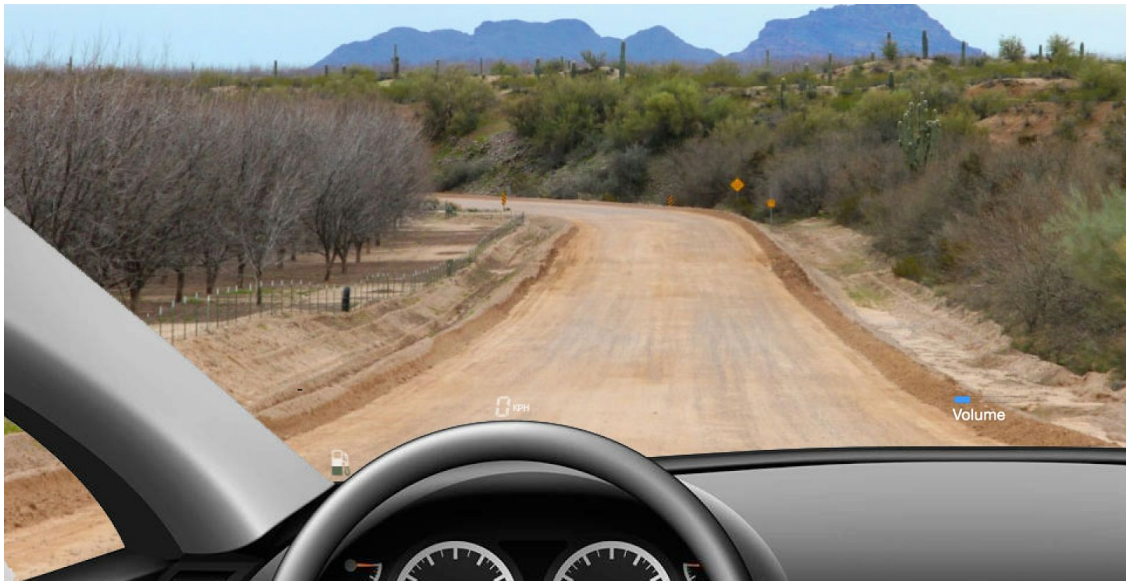
To demo our design we used the QT IDE to build our prototype and used the Logitech g27 steering wheel with buttons on it making it possible for interacting with the system. There were certain interactions and functionalities we unanimously decided to leave. One was giving the driver the option for night vision. The reason to do so was that we tried implementing everything the participants had mentioned as priority since those were the usual tasks assumed people do on a regular basis. One other functionality we wanted to implement, that goes hand in hand with the rear view display, was lane change assist and collision warning. In that case drivers would be displayed with side display when changing lanes and would be warned if they were in danger of a collision. The reason we could not implement this was because we had run out of buttons to show this interaction.

User Manual For HUD (Heads Up Display)

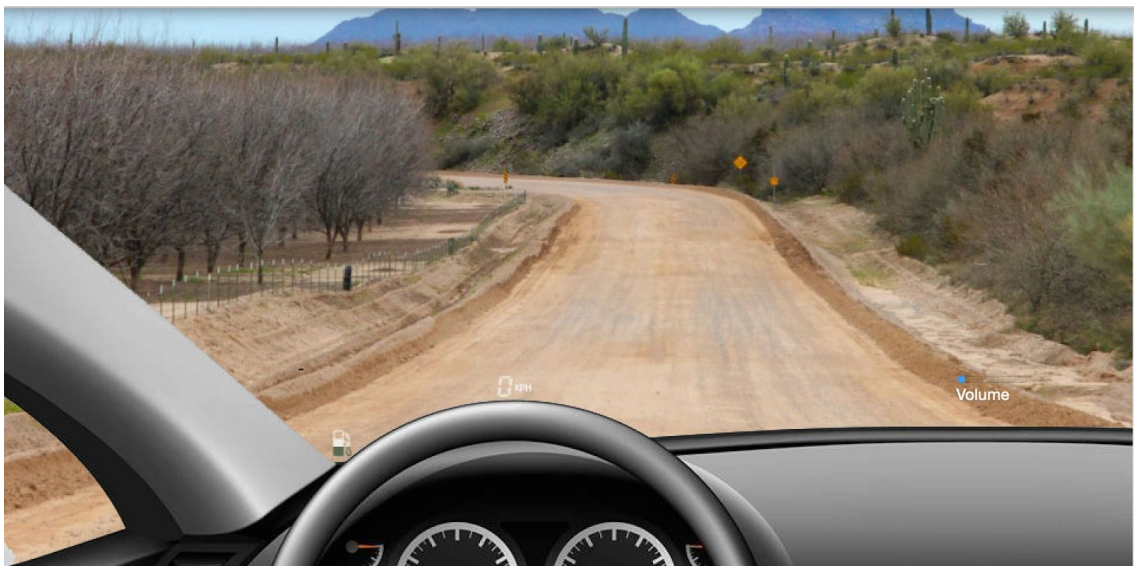
The following is a manual of instructions for operating the HUD features and functionality. Below is a breakdown of features of the HUD organized by the buttons of the console.

Console Right Column Buttons

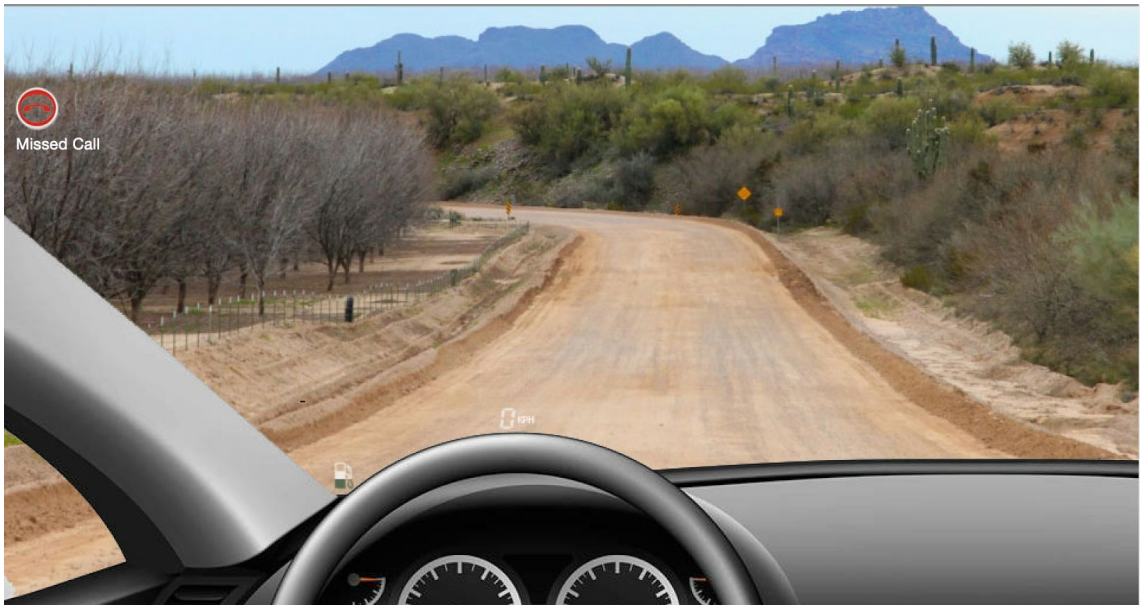
1.Top Right Button : **Increasing Volume,** so if user wants to increase the volume, they can repeatedly press this button until desired level of sound is achieved.



2. Centre Right Button : **Decreasing Volume**, so if user wants to decrease the volume, they can repeatedly press this button until desired level of sound is achieved

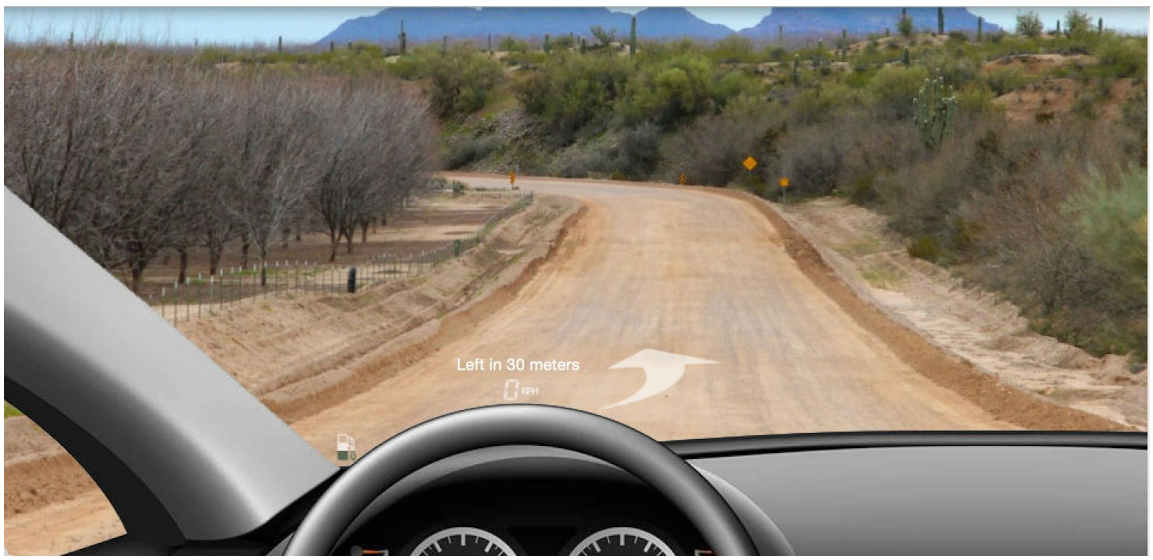


3. Bottom Right Button : **Reject Call Feature**, so upon an incoming call if the user decides to not take the call at the moment, they can reject the call by pressing this button.

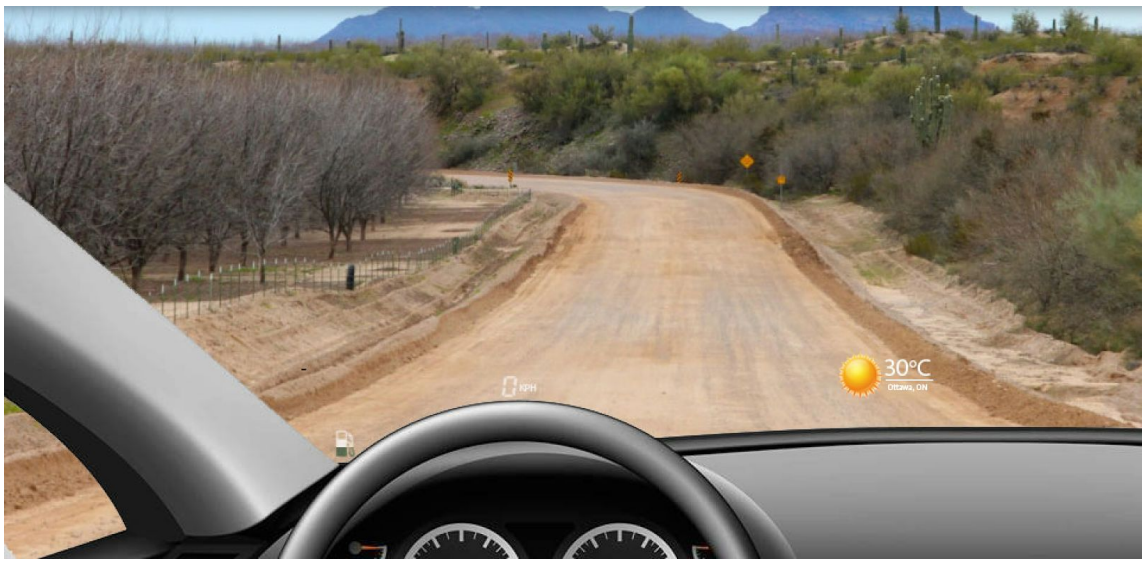


Console Left Column Buttons

1.Top Left Button : **GPS,** if the user decides to use navigation, they can press this button to enable the HUD navigation feature and if they choose to exit navigation mode at any point after the navigation is enabled they can press this button again for disabling the navigation feature.



2. Centre Left Button : **Weather**, if the user decides to display current weather condition, they can do so by pressing this button, the weather display remains enabled until this button is pressed again.



3. Bottom Left Button : **Assisted Parking,** when rear parking the user can press this button that will display a view of current position and provide parking assistance by simulating real time lane lines in order to guide to safe rear parking.

Usability Inspection Evaluation

The team conducted a Heuristics Evaluation of the high-fidelity prototype. We used a four-point scale with 1 being lowest

Evaluator: Abdul Bin Asif Niazi

1.Gas Tank is always displayed

Rating: 2

Although it provides visibility of system status, it is not needed all the time. It fails the flexibility and efficiency heuristic. It takes up space unnecessarily on the display. It should only appear when needed. Because of this, it also fails the aesthetic and minimal design heuristic as well. The tank should be a type of error message and appear only when the fuel becomes an issue. The system could present the driver with a list of nearest gas stations and ask the driver if she would like to be navigated there.

2.Not being able to change tracks

Rating: 4

This violates the match between system and real world heuristic. When the user accesses the stereo controls, having the ability to change tracks is always assumed. The reason this could not be implemented is because the console was out of buttons. It fails the consistency and standards as this action is considered normal on all stereo controls but does not appear in the prototype

3.Missed call notifications

Rating: 2

This fails the matching between system and real world heuristic as well as the consistency and standards heuristics. Most phones list how many missed call events have occurred, but the system does not provide this feedback. It should provide this feedback if more than one missed call event has occurred.

4.Notifications

Rating: 2

This fails the visibility of system and the consistency and standards heuristic. The envelope does not distinguish if the notification is about text message, email or some other type of message. Other systems display envelops for many different notifications. But they show different types of envelopes for the different types of messages.

Evaluator: Rehnuma Tarannum

The following is my Heuristic for the HUD system. Its detailed analysis of the problem that I have noticed in this system upon mapping Neilsen's Suggested Heuristics to the system.

1. **Gas Tank Feature always visible**
   Rating : 2
   This a minor problem that violates the following Neilsen's Suggested Heuristics
- **Visibility of System** this feature is needed only when gas tank is empty so should not be visible all the time .
- **Fails flexibility and efficiency of use**, the fuel tank takes up unnecessary space on the display since it is not always needed.
- **Help users recognize,diagnose and recover from errors**, this feature should only appear as form of an error that the user needs to tend to.

2. **Not being able to change tracks**
   Rating : 3
   This a moderate problem that violates the following Neilsen's Suggested Heuristics
- **Match between system and the real world,** since we provided stereo features it is natural for the user to expect track change feature but unfortunately we could not implement it since we ran out of buttons on the console that could initiate this feature.
- **Fails flexibility and efficiency of use** since it is an essential and quite a usefull feature that is missing in the system.

3. **Missing number of missed calls**
   Rating : 2
   This is a moderate problem that violates the following Neilsen's Suggested Heuristics
- **Fails matches between system and real world,** the manner in which this feature was implemented is a disconnect from the real world because in the real world along with a missed call notification phone would notify the number of missed calls.
- **Fails consistency and standards,** the manner in which this feature was implemented is a disconnect from the real world because in the real world along with a missed call notification phone would notify the number of missed calls.

4. **Not Detailed Message Notifications**
   Rating : 2
   This is a moderate problem that violates the following Neilsen's Suggested Heuristics
- **Visibility of system status,** the envelope icon can interpret many different kinds of notifications, email from different accounts, text message therefore this icon may cause confusion as to what kind of notification is this.

- **Consistency and standards failed**, the envelope represents emails and text messages. This is not the industry standard hence can be confusing for users.

Evaluator: Malik Ehsanullah

These are flaws I have noticed in the system and violate Nielsen's heuristic suggestions:

1) GPS directive arrows superimposing on the objects in front of the vehicle:
Rating: 4

This is a major problem that violates following Nielsen suggestions:

- **flexibility and efficiency of use**: The GPS arrow representing next direction should be under-imposed by the vehicles and/or other physical objects appearing in front of the car. The arrows for GPS should be able to adjust to the physical objects, if it doesn't it will cause major distraction.
- **recognition rather than recall:** If an object or a vehicle in front of the user's car covers a large part of the arrow than this might be cause confusion as well.

2) Size of the phone features:
Rating: 2

This is a minor flaw that violate following Nielsen's suggestion:

- **Aesthetic and minimalist design**: The design for the icons representing missed calls and messages and other phone related icons are too big and might cause a distraction for the driver. The system already uses audio notifications to alert the user thus having icons covering a large area is unnecessary.

3) Steering wheel feature labeling:
Rating: 3

This is a major flaw that violates following Nielsen's suggestions:

- **Help and document**: The HUD system deals with a huge array of features and only control user has over the HUD is through steering wheel therefore proper labeling of action performed by each button is necessary. The system prototype that we have developed doesn't properly label the feature on the steering wheel.
- **Flexibility and efficiency of use:** The system doesn't have any walk-through for new user either.

4) No notification notifying user whether song is paused if it was ever played:
Rating : 2

Recognition rather than recall: When the user pauses a song, the system doesn't leave any long-term notification on the main display. The media icons are programmed in a way

that they disappear after 5 seconds of being used. This was done to prevent clutter from happening on the windshield but it also keeps the user oblivious to the current state of the system. The user is left to figure out whether the media is turned off or it was paused.

Evaluator: Muhammad Mustafa

These are flaws I have noticed in the system and violate Nielsen's heuristic suggestions:

1. **Gas tank icon**
   Rating : 2

- **Visibility of System status**: This icon needs to display information only when the tank is nearly empty or when some sort of emergency. Being present at all times make no sense.
- **Flexibility and efficiency heuristic:** it takes up unnecessary space on the HUD.
- **Help users recognize,diagnose and recover from errors**: this feature should only appear as form of an error that the user needs when needed..

2. **Weather icon**
   Rating : 3

- **Visibility of system status:** It should not be at the user's disposal. I think the weather icon should be displaying information permanently on the screen, at a translucent visibility, changing at real-time.
- **Consistency and standards:** Both centigrade and fahrenheit should be displayed with high and low information. In my opinion road conditions should also be a part of this design

3. **Message icon**
   Rating : 2

- **Visibility of system status:** as the envelope notification does not distinguish it as a text message or some other kind of message such as voice mail.
- **Consistency and standards:** because the envelope represents emails and text messages. This standard is not upheld the system does not distinguish between them.

4. **Missed call notification**
   Rating: 2

- **Fails matches between system and real world:** as it does not show how many missed calls have occurred. If more than one calls are missed, the count does not increment.

Evaluator: Stanley Mbanwi Mbah

1) Gas tank not showing additional information:

System is designed to keep the user informed about what is happening. For the gas tank notification that system should suggest the closest gas station for the ease of control so that your car doesn't get stuck. I'd rather have this suggestion and just to empathize this violates visibility of system status of the Nielsen's Heuristic. I have rated this system flaw 2 out of 4.

2) Not being able to change track:

In the real world everyone would like to take full control over the music stereo. To be able to feel relaxed and have control over your stereo is something everyone wants. I'd rather have a system that gives me total control over this gadget. Lack of this violates recognition rather than recall of the Nielsen's heuristic suggestions. The reason why we didn't implement this feature is because we ran out of buttons on the steering wheel. I have rated this system flaw 2 out of 4.

3) Missed call notification not displaying number of missed calls:

The missed call notification feature that we have added to the system doesn't notify the user how many missed calls they have missed. In addition to that, the system doesn't distinguish between the voicemail and regular text messages. This violates recognition rather than recall Nielsen's heuristic suggestions. I'd rather have a clear distinction between voicemail and regular call. I have rated this system flaw 1 out of 4.

4) Weather not showing short or longer term weather condition:

Weather condition is a necessity when you are driving. If there is suppose to be a weather condition option on the system it should be a permanent low light feature superimposed on the screen. Hitting a button should not bring it up. It has to be automatic and able to communicate the high and the low while you are driving and not just the current weather condition. In the current system we have failed to implement that and this violates consistency and standards principle. I have rated it 2 out of 4.

Consolidated Usability Inspection

Fuel Level notification

All of the group members stated this as an issue. They all stated that it unnecessarily appears all the time and should only appear when needed. Some also stated that when the fuel level is low, the system should suggest to the driver where the closest gas station is. It violates the flexibility and efficiency, aesthetic, minimal design and visibility of system and

help users recognize, diagnose and recover from errors heuristics. Most of the team members rated the severity of the issue a 2 out of 4.

Not being able to change tracks

Three group members that not having the functionality to change tracks is an issue. The members stated that this functionality is expected on all stereo control and should be included on the steering wheel. This lacks the match between system and real world, flexibility and efficiency of use and recognition rather than recall heuristics. The severity of the problem was rated a 2, 3 and 4 out of 4

Phone feature notifications

All the group members found issues with how notifications about phone features appeared. They stated that missed calls notifications should display how many calls were missed, if more than once has occurred. It should also distinguish between emails and text messages and display how many of each have been received. It was also stated that the size of the phone notifications icons may be too big and cause a distraction. This violates the matching between system and real world, consistency and standards and the recognition instead of recall heuristics. Most group members rated this type of problem to be a 2 out of 4.

Weather Notification

Some group members had issues with the weather notification application. One group member said that it should appear all the time, not at the discretion of the driver. The other said it should display the day's high and low temperature. It fails the visibility of system and consistency and standards heuristics. They both rated it a 2 and 3 out of 4

GPS navigation

One group member stated that the arrows projected due to the navigation system should take into account any objects in front if the vehicle. It should not obfuscate the view of the driver. This violates the flexibility and efficiency of use as well as the recognition instead of recall heuristics. It was rated a 4 out of 4.

Workload distribution

Abdul Bin Asif Niazi
- Helped write the report
- Helped design the system
- Helped with the interviews

Rehnuma Tarannum
- Helped code the system
- Helped with the design of the system
- Helped with the interviews

Malik Ehsanullah
- Helped code the system
- Helped with the design of the system
- Helped with the interviews

Muhammad Mustafa
- Helped write the report
- Helped with the design of the system
- Helped with the interviews

Stanley Mbanwi Mbah
- Helped code the system
- Helped with the design of the system
- Helped with the interviews