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Ambient Technology in Vehicles: The Benefits and Risks

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Abstract

This paper is aimed towards studying, compiling, and analyzing the recent advances and risks of the current ambient technology that is present in modern day cars. The progression of sophisticated technologies inside cars make them an even more comfortable and entertaining place to be in especially during commutes to work, but recent security threats and distractions have been uncovered with the upsurge usage of new technologies. This study also includes a survey that senses the people’s use of car technologies when driving.

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1. Introduction

Since the introduction of automatic air-conditioning in cars in 1954 when the Nash Ambassador rolled out of the manufacturing line\textsuperscript{1}, automated car systems have been on the rise to cope up with the various demands that the consumer fancies. After all automated air conditioning saves the consumer the hassle of raising and lowering the air conditioning fan when he feels hot or cold. That is what the idea of ambient intelligence is all about, making a connection between machine and mankind, where the machine understands the person’s need with minimum effort required from the user.

Nowadays, voice recognition features in cars are widely available especially in the high-end ones, but only a handful of the models produced are efficient enough to entice users into relying on them. Imagine if the user did not have to actually tell the system what to do as in the voice recognition system, but the system knows what the user wants through other means. For example, if you are stuck during rush hour in a traffic jam and you are really agitated, the car’s system should sense that and turn on soothing music to calm you down (or whatever calms you down.) Another example, is that if a person is experiencing a stroke, the car should also detect that and self-drive to

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the nearest hospital or call the emergency line. Vehicles are our main mean of transportation and if we can make it a more intelligent vessel, it will greatly serve us in the future.

Car companies have tried to solve the voice recognition problem in multiple approaches, but they are still not able to reach the point where the system knows what the user means. However, there is an increasing trend towards using online cloud voice analyzer instead of the embedded chips that are currently used. Online voice recognition systems have the advantage of being more sophisticated and efficient, but they still require internet connection and are a bit slower than their on-board counterparts. Both methods of voice recognition (on-board and online) are being researched by various companies and they seem to encounter the same problem of filtering out the background noise that cars are mostly known for, such as the AC fan and outside street noise. Street background noise is especially tricky thing to deal with since the car window can let in or out noises that may interfere with the noise filter.

Other than that, there have been advances in ambient intelligence when it comes to aiding the people drive better and avoid collisions. That is a subject that we will lightly touch on, but not in detail due to its connection with the outside environment rather than the inside of the car.

The nature of the car’s interface is also changing; touch screens and displays are getting bigger and more numerous. Good examples would be the Tesla S or the Volvo XC90 of 2016. This is all is no secret, but what we are interested in is that in an era where even the speedometer is displayed on a screen rather than gauge needles, new information can be shown to the driver just by moving eyeballs instead of the whole head. There are still lots of unexplored functions that could be implemented with this advancement. Integrating your smartphone with your car’s computer interface is also an increasing trend that is snowballing. This is allowing drivers to carry on their personal material and include it even more in their journey to provide a feel at home type of sensation. However, this boon is not without its own dangers.

The security of cars these days is becoming a hot topic since they are becoming increasingly interconnected with everything. Many vulnerabilities have been exposed and are utterly dangerous if not life threatening. Gaining access to the car’s driving system is a danger that could be noted as soon as the driver loses control, but what about stealthily gaining access to the car microphone without the user’s permissions? This is a hidden security breach that many people overlook.

Section 2 will briefly touch on the ambient intelligence milestones that we have reached until now. Section 3 will analyze and discuss the voice recognition issue in modern day car systems and its potential position when it comes to ambient intelligence. Section 4 will examine a questionnaire that we conducted to examine how prevalent certain voice operated technologies are used in our society. Section 5 will talk about car interfaces that are changing and keep changing with newer technologies emerging. Section 6 is all about the security/privacy issues that we are facing and we will likely to face in the near future. While section 7 ends this paper with a conclusion.

2. Ambient technology in cars through time

The invention of automatic gear transmission was patented as early as 1923 by the Canadian inventor Alfred Munro. This invention makes the car recognize when the gear needs to be shifted and did it by itself, by doing so it eliminated the need for the driver to have both hands busy with driving, making the other hand free. The car recognized the driver’s need and makes the correct decision, which is the essence of ambient intelligence.

Moving on forward in time, as mentioned above the automated air-conditioning system also made a significant contribution when it comes to giving the car more power of pleasing the driver as well as the passengers. Small inclusions to ambient car intelligence have also been added. Good examples would be: the lowering of rear sunshades when the gear is on reverse, self-tightening seat belts when first strapping it, and many others. Those were developed around the beginning of the 21st century. After the first decade of the 21st century the cars ambient intelligence has been on a rapid rise. This is due to the massive immersion of computers into the vehicle industry, not only that but a competition of who is more tech-savvy between the different car companies began to act as a catalyst for even more innovation.

Now driving is also enhanced and aided by computers and cameras. Systems such as the Distronic Plus and Infiniti’s auto drive mode can drive by themselves staying inside the lane and maintaining a distance between the cars in front of them. Moreover, Infiniti has developed a system called Predictive Forward Collision Warning that detects the speed of the car that is in front, but also the car that is ahead of it.
Those are all great advances that make the driver experience much safer and easier, but our focus in this paper is about what the driver gets while he is inside the car that is not directly linked to the road. Voice recognition is a big issue at the moment and it is still evolving. The next section will talk about voice recognition in car systems and will also have some statistics based on a questionnaire performed in a non-English speaking nation.

3. Voice recognition in car systems

Voice recognition in cars is indeed a hot topic these days since voice commands in cars are becoming prevalent yet rarely used since most are not natural language systems and the user has to go through the voice commands and memorize the steps/commands in order for it to function in an efficient manner. As J.D. Power announced during their recent conference on voice recognition systems in cars “Any way you slice it, thats a failing grade,”6. Conversely they also highlighted that it is not easy to develop a car friendly voice recognition system for cars: “The environment of a vehicle is brutal.”6.

Things such as the engine noise and street clamor (especially when the windows are open) are hectic things that have to be filtered and diagnosed. Not to mention the state that the driver has to be always on alert and driving itself can be strenuous at times particularly if the journey is filled with traffic. Filtering the noise has been subject to numerous research10,11 and is improving at an increasingly steady rate. The use of the current voice recognition systems nowadays is reported to be unsafe by several sources, including the American Automobile Association12,13. However there are also other sources who take the opposite view regarding the matter of safety of the car recognition system14.

Another change in the voice recognition domain is that car companies are trying to shift from normal voice recognition systems to natural language systems7. A parallel idea that is slowly gaining popularity is to integrate smartphones even further by involving them in the cars interface. This idea got materialized in Apples CarPlay and Googles Android Auto applications8,9. While Apple has the famed Siri natural voice recognition system, Android is lagging behind with its GoogleNow when it comes to popularity. This is mainly due to Android’s flexible nature, because of its flexibility each company would install their own voice recognition system in the phone’s firmware. A good example would be Samsung’s S Voice.

That is why we have conducted a questionnaire to sense the extent in which the public use voice recognition systems and other uses of car technologies. This questionnaire had very interesting results that we will discuss in the upcoming part of this section.

4. The questionnaire

The purpose of this questionnaire is to find out how often people use technologies that may distract them while driving. The statistics should give us an insight on the direction that ambient car technologies should advance in.

4.1. Method

The questionnaire was performed on a total of 418 people. While the majority of people who participated in the questionnaire had English as a second language, the vast majority see their English language skills as “Good” or “Excellent”. The age group that participated the most ranged from 25 to 64 years old, specifically the 45 to 54 years old age group had the most participation from the group that was previously specified. Most of the participants reported that they had some sort of education that spanned beyond just high school. Most of the participants are Kuwaiti nationals that live in Kuwait and live in a large city.

While there were previous studies on using smart phones while driving and what kind of applications that kept the driver busy, none to our knowledge asked specifically what kind of connection that most used with their cars15,16. Moreover, the frequency of smart phone usage was an important part in the questions asked.

The questions asked are related to the frequency of mobile usage during driving, the voice recognition related features usage when driving, how do they connect with the car, and other stuff as well. There were only 13 questions in the questionnaire; it was made short so that more participants would complete it without leaving midway.
The 400 of the people participated in the survey via a link that was spread in numerous social media platforms. While 18 of the participants filled in a paper survey. The links in the social media had two versions: an Arabic and an English one. The participants chose which one was the better option for them. The questionnaire was designed using SurveyMonkey, which is a well-known and secure surveying website.

4.2. Results

Surprisingly, people who were surveyed that reported that they hold their phones while driving (52%) are an exact match to the percentage of people that answer calls while driving in the US\textsuperscript{16}. There was a substantial difference when it comes to the amount of people who text while driving with the NHTSA survey (20\%)\textsuperscript{16}, but the percentage was very close when compared to the AT&T survey (61\%)\textsuperscript{15}. Of the people surveyed, 63\% reported that they text when driving. 44\% of the total surveyed reported that they do it as common as at least once a week.

Other interesting findings include:

- The majority of the people who have a voice command feature in their cars do not actually use it (64\%).
- People tend to use the Voice-to-Text feature more often than the Text-to-Voice feature in their smart phones (38\% and 25\%).
- Almost half of the people that can connect their phones with their cars chose Bluetooth (54\%). The rest were people who used their cars application (15\%) and people who used AUX (31\%).
- Interestingly people who either never used a personal smart phone assistance, such as Siri, made up 69\% of the people surveyed. The majority knew of their existence but never bothered using it (63\%).
- People who used the cars voice command feature at least once a month are 7\% less likely to text on a daily basis while driving. Although overall, they are more likely to text while driving.
- Most of the people surveyed either text while driving at least once a day (29\%) or do not text while driving at all (37\%). The rest text while driving but less frequently.

It is worth mentioning that people with applications installed in their car systems were only 4\% less likely to text when driving. There also seems to be a general trend that signifies that the older the person seems to get, the less likely he is to text while driving with the exception of a slight increase in the 18-24 age range.
4.3. Implications

The first thing that we can see is that voice commands in car systems and applications had only a minor effect on the driver to leave the phone alone while driving. The biggest factor when it comes to not texting while driving is age. The results are not a big surprise after all that is what other sources have also found out\textsuperscript{17}, but what was indeed disappointing is that current car technologies had minor or no effect at all.

Even the results of the people who use personal smart phone assistants (such as Siri or Google Now) at least once a week did not differ significantly to the rest of the people who did not use them as much. These results only signify that our current level of ambient intelligence in cars is severely lagging behind when it comes to understanding the driver, hence the point where the driver does not even have to touch his smart phone while driving seems a bit of a far cry. Some of the research regarding this matter looked for a more humanistic solution by persuading the driver through technological means rather than develop new technologies that enable the driver to stay connected when driving\textsuperscript{18}. They also have encouraging results when putting their concept into testing.

5. Car interface

5.1. Displays

Touch screen displays are replacing head units that have physical buttons and knobs, which is a trend that all car companies are trying to catch up on. Like all things, this trend has advantages and disadvantages (as displayed in table 1).

Table 1. Advantages and disadvantages of touch-screen displays

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Multilayer Menus are organized and well labeled, allowing even a person who is not familiar with the car to master it in no time.</td>
<td>• You can no longer do anything without looking at the screen as in the case with buttons and knobs.</td>
</tr>
<tr>
<td>• Software updates allow car interface problems to be solved even if they were discovered after production and distribution.</td>
<td>• Touch sensitivity and accuracy may be an issue with low quality touch displays. Moreover, it will severely distract the driver.</td>
</tr>
<tr>
<td>• Touch screens allow flexibility when it comes to the installation of applications by third parties. This makes the car more integrated with other products (i.e. smart phones and smart watches).</td>
<td>• Wet fingers may interfere with the touch mechanism.</td>
</tr>
<tr>
<td>• Has the potential to even replace smart phone interaction by using CarPlay or Google Auto.</td>
<td></td>
</tr>
</tbody>
</table>

While there are lots of car companies that prefer to stay away from touch displays even with big screens present in the head unit of their cars, many provide a hybrid option of having a touch display that can also be controlled using knobs and buttons.

The head unit’s interface is a big distraction for the driver, that is why there is a study\textsuperscript{19} that decided to take into account the helping hand of the front seat passenger by morphing the head unit into a shared area instead of keeping it most suitable for the driver only. The designs are demonstrated to tremendously increase the driver’s attention to the road and involve the passenger even more with the decision making process. Their design required an extra touch screen to be installed on the front passenger’s side, which will in real life cost the car manufacturer more. There is a slight disadvantage to this configuration, which is that it requires the presence of a passenger and an extra display(which will cost more). The car company Tesla already has the shared area interface that they proposed, but not the front passenger seat display.
In addition, there is a study that experimented to see which type of interface interaction was better; touch screen only, speech only, or speech and touch screen\textsuperscript{20}. Expectedly, speech and touch screen interactions got the best scores in almost every category making it the method with least eyes off the road time, least mentally demanding, least number of lane deviations, and required the least time. This study also noted that the speech only option was far better than the touch screen only option. Similar results can verify the dangers of car touch screen fiddling by another executed study\textsuperscript{21} that found that texting while the phone is on a phone holder (which is mimics the case of a car’s touch screen) is more dangerous than holding it by hand.

Dashboard displays and HUD (Heads Up Display) are also on the rise with the technology becoming more mature, cheaper, and reliable. The ways in which HUDs can be deployed are either by being built-in by the car manufacturer, or acquiring an autonomous HUD display (i.e Navdy), or using your phone with a transparent reflective sticker on the windshield. When we mention HUD we also have to mention AR (augmented reality) especially when it comes to driving. A paper was published\textsuperscript{22} highlighting the direction that AR is to going to and it also mentioned all of the complications that this ripening concept has to take care of. HUDs in windshields can block or distort important details that could result in terrible accidents. The paper also stressed that HUD screens are not going to replace dashboard screens since each part has to display certain information.

5.2. Body accessories

Products such as google glass have had large positive reaction from developers, but a less than an enthusiastic response from consumers. Many papers have not only suggested AR applications to be developed for google glass, but also tested what it would be like for the driver to text using google glass while driving. At least three independent papers\textsuperscript{23,24,25} have tested that concept and the results were rather encouraging. All of the paper’s results verified that using Google Glass is better than using the phone to text message even when voice recognition/commands were used while driving. Although they also concluded that no texting at all is better than texting using Google Glass. This could potentially have further implications on activities other than just texting, say receiving a call or reading short notifications that are related to the car.

The emergence of the smartwatch came in to the commercial market by storm. Research in the area of smartwatch applications is an increasingly flourishing one, though not numerous at the moment. A group of researchers previously laid out the concept and foundations to design a smartwatch application that can sense if a driver is drowsy\textsuperscript{26}. It should also be mentioned that the concept is tested and its formulas exhibited. Another group managed to invent a fully functional system that uses either a smartwatch or a sensor-embroiled steering wheel to detect the drowsiness of drivers with more than 97% accuracy\textsuperscript{27}. If car manufacturers apply this application, countless accidents could be avoided especially if the car would automatically park on the side of the driving lane and turn off if a drowsy or a drunk driver is detected. Another possible application of the smartwatch is to detect if the driver has any pulse anomaly and drive him automatically to the nearest hospital, but let us be realistic for now; we do not live in an age of driverless cars just yet. Instead, the car can honk the horn or give an alarm to the nearby cars that the driver of this car is having a medical emergency.

However, enticing as it is to use a smartwatch when driving, active interaction with it should be avoided as much as possible. A study\textsuperscript{28} completed by a group from MIT and Harvard concluded that interacting with a smartwatch when driving can be even more dangerous than smartphone interaction. This leaves smartwatches with the role of the passive sensor that relays pulse and hand movement when possible when driving.

6. Security and Privacy

The issue of security in cars is the biggest obstacle to achieve a much more technologically integrated car. Car companies are being careful for the right reason, after all, modern cars are filled with exploitable modes of communications such as Bluetooth, data transmitted via radio waves, and telematics/Wifi. In order for a car to be truly technologically advanced, it needs more ECUs (electrical control unit). While an ECU is a very essential part of an integrated electrical system, it is a fairly recent occurrence that they are taking up a major role when it comes to controlling the parts of the vehicle that have a direct effect on the driving experience. ECUs have enabled features such as: Park Assist, Adaptive Cruise Control, Collision Prevention, and Lane Keep Assistance. All of these impres-
sive features have had a major dent on the security of the car since an attacker can manipulate them. Two hackers managed to break into many car systems; sabotaging breaks, turning off engines, taking control of the accelerator, and numerous other things. Not to mention the embarrassing keyless ignition study that revealed how a myriad of cars can be stolen by attacking the cipher design, enabling the attacker to sniff out the key within 30 minutes.

VW fought the initial publication of the previously mentioned research in order for it to avoid negative publicity. These vulnerabilities are not without reason, after all, car companies struggle in a competitive market which makes it hard for the transparency of safety to persist. Car manufacturers should follow the aviation culture of safety transparency, in order for the industry to eliminate all ways that a vehicle can be exploited (cyber or physical).

A preventative measure to hack into the ECU was introduced by the microprocessor manufacturer Intel. Their new ECUs work on a network of trustlets, an advanced system of control unit trustworthiness that is being implemented on embedded devices. It mainly relies on the concept of isolation of computing tasks, which is to isolated each ECU so that the attacker can’t mess with the signals that it gives and receives. Intel claims that this new system of ECUs can reportedly give cars “cloud level security”.

7. Conclusion

We studied and analyzed the current level of ambient technology that is available in the current market along with its related research. The majority of people don’t use current technologies while driving frequently, which highlights the gap that current ambient car technology has to bridge. Some technologies are less likely to distract drivers than others like the Google Glass and HUD, but they all require some mental workload nevertheless. Displays play a vital role in this debate too since they are becoming more widespread year by year, and that is why research is suggesting to involve the front seat passenger to do more of the work so that the driver doesn’t lose concentration.

There are many dangerous faults that still exist in today’s car technology. The best way to tackle this problem is by being transparent about it, so that more hands could join in and other companies could avoid making the same mistakes.

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