Electrocutaneous Display Entrepreneurial Venture

IQP Report
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Abstract

This report explores the potential market attractiveness of integrating the haptic technology of Electrocutaneous Displays (ECDs) into automotive touchscreens. Haptic technology can provide tactile feedback to drivers to improve their driving experience and safety by reducing the amount of time their eyes are off the road. To evaluate the viability of this technology, we carried out extensive research into the industries of automotive displays and haptics, interviewed with stakeholders along the entire value chain, and conducted an end-user survey to determine driver opinions about using haptic technology in car touchscreen displays. The study indicates that there is a promising market for haptic technology in automotive displays.

Acknowledgments

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Authorship Page

Each member of the team contributed equally to this project. Below we tabulate who authored each section.

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Executive Summary

Our IQP team started this project with the idea of an innovative technology that has the potential to revolutionize how we interact with technology and the world around us. The technology is known as Electrocutaneous Displays (ECDs), and they allow for the simulation of the sense of touch through skin contact. After being humbled by the realization that there has to be a need for a product to be successful and not every cool tech hits it big, we knew that we had to narrow down our scope to a single use case that represents a need best solved by our technology. We started by developing a research question, the answer to which is our use case:

"What information is best transmitted through ECDs to whom and when?"

Answering this question gives us our target customer and their needs. To accomplish this, we conducted initial interviews with various students and faculty to find out more. Over the course of several weeks, we narrowed down the use cases to one: automotive touchscreens. This use case answered the question better than any other we came up with; the feeling of buttons being pressed through the touchscreen to drivers while they are focusing on the road is our customer and use case. This left us with a more clear path forward, but we made a lot of assumptions along the way that needed to be validated. Primarily, these consisted of us assuming the landscape of the automotive industry would welcome innovative technology like this and that people actually valued the type of feedback we can give them. In order to validate these assumptions, we looked at them as more research questions that need to be investigated.

Conducting extensive background research and various interviews allowed us to validate these assumptions. Our background research was focused mainly on different forms of haptics, seeing the pros and cons of each and their primary use cases, allowing us to see what has been successful in the past and if our technology is the best to solve this need we identified. When conducting interviews, we tried to get as many links in the relevant value chain as possible. This led to us interviewing several end-users, market analysts, and executives of automotive companies to ensure that we understand the needs and values of all stakeholders involved. After concluding our interviews, our results were looking very promising that our assumptions would be proven true. However we felt that it would be helpful if more data were collected, specifically quantitative data to complement the qualitative data from the interviews.

To that end, we also drafted and sent out a survey. The survey was carefully written to be as unbiased as possible, asking the respondents to rank various interfaces in terms of their preferences and feelings of safety in different situations. We were very fortunate to receive a large number of responses to the survey from a very evenly spread age demographic, allowing us to conduct further analysis into who our target customer is.

The results of our interviews and survey confirmed our beliefs that car touchscreens are only going to increase in prominence, the car market is willing to adopt new technologies, that drivers feel that using touch screens while driving is distracting and that it would be more intuitive if they were able to feel the buttons. That leads excellently from our background research into haptics as there is no system better than ECDs at simulating the feeling of buttons, especially with precise locations, with touchscreens. These results regarding drivers' experience with touchscreens is mirrored in similar studies conducted by other research groups, further validating our assumptions. As our interviews and research led us to choose automotive touch screens as our target use case, and further research validating our assumptions made along the way, this would be an excellent target for initially entering the market with this technology.

Introduction

Imagine what life would be like after losing part of your arm in a serious accident. What would be going through your mind in a scenario like this? You will have to consider all the things you will no longer be able to do. You won't be able to open doors, feed yourself, or dress yourself. A robotic prosthetic arm would allow you to do all these things, but what about thinking a bit deeper? Often overlooked, you won't be able to feel the warmth of your partner's touch, the texture of their face, the comforting squeeze in your hand reassuring you that everything will be okay as they stand by your side. When speaking to amputees about what they want from their prosthesis, they will talk surely about being able to complete their normal tasks, but even more so, they want to be able to hold their loved ones and feel the warmth from their skin. They want to regain this important means through which we connect with one another, and the fear that holds is more gripping than not being able to open a bottle. What if there was a way to restore this sense of touch to these amputees?

The sense of touch is one of the most important senses we have. It allows us to gain lots of information about our surroundings like the temperature, humidity, texture, and rigidity. But more importantly than anything, it allows us to connect with one another in a way that is often taken for granted. In the unfortunate circumstance that someone gets into an accident and loses their arm, today's technology allows them to gain most of the function back through prosthetics. Advanced prosthetics can even use the remaining muscle tissue, through robotics, to allow someone to control their new arm just by thinking about it. More and more devices are coming out trying to meet the needs of amputees, having them able to do more gestures or have a longer battery life, or have a softer touch and many more impressive mechanical feats, but the sense of touch is often overlooked.

This use case is one of many for the technology this project is investigating. The technology is known as Electrocutaneous Displays (ECDs) and we believe they have the potential to change how we interact with the world. The technology, in more general terms, allows for the sense of touch to be simulated. Whether that is for restoring the sense of touch in amputees, letting astronauts safely feel rock specimens, or improving touch screens by enabling the digital buttons to feel indistinguishable from physical ones, ECDs have unlimited potential.

Our Pre-Qualifying Project began with this technology in mind with the goal of figuring out the best way to bring this technology to the world. The goal of this research project was to identify the most attractive need that this technology can address by evaluating the advantages and disadvantages in different use cases and its impact to the stakeholders in the value chain. To guide our ideation and thought process, we focused on answering the following question for various use cases, additional ones including: integration into touchscreens, telehealth systems for improved remote diagnostics, and increased immersion in virtual reality. “What information is best transmitted through ECDs to whom and when?”

We were able to identify the most promising opportunity by utilizing a variety of techniques including extensive background research and conducting interviews. Through this process, we eliminated potential use cases until we determined a clear winner: touchscreens in cars.

The best information transmitted through ECDs is texture and haptic feedback. We quickly determined that developing texture is too technically challenging for an initial idea to bring to market, so we focused on haptic feedback. We hypothesized that drivers would highly benefit from haptic feedback in their screens when driving as they cannot look at the screen to use it without risking their safety. Not only is this technically feasible, but it is also effective at communicating information back to the user, also answers our question well, and includes a market that is only going to continue growing. But are ECDs the best solution to this problem? To answer this, we investigated many different technologies used for haptic feedback, conducted various interviews, and released a survey to give us a detailed understanding of the market from manufacturer to end user.

Background

Identifying a Need/Use Case that ECD Technology Can Address

In order to address which of these markets was most advantageous to pursue, we made an analysis of each market with some insight from our sponsor. We chose to avoid training/experience-based applications, as the market size of these fields tends to be smaller. Additionally, while the virtual reality market is expected to grow, it is still a niche enough market that our technology could be applied to something that is more commonly used now. Market size is the main reason our device would not be as lucrative in the space industry. While we did pursue medical applications for the technology, we realized there are already systems in place that assist some of these applications such as other optical and haptic feedback sensors on surgical robotics.

Eventually, we discovered a market that we believe our haptic feedback technology could address an important need that we identified in the automotive touchscreen market: haptic feedback in car touchscreens. Driving is a predominantly visual task, and it is well known that looking at screens while driving makes drivers much more prone to accidents. According to the National Highway Traffic and Safety Administration[1], "In 2020, 3142 people were killed in motor vehicle accidents due to distracted driving." As touchscreens become more widely available in cars, those numbers are expected to increase[2]. Distracted driving plays a large role in health and safety concerns industry-wide. Additionally, according to AAA, "Drivers using in-vehicle technologies like voice-based and touch screen features were visually and mentally

[1] (US Department of Transportation, 2023)
[2] (Kimberly, 2021)

distracted for more than 40 seconds when completing tasks like programming navigation or sending a text message.[3]" While driving, it is not recommended to look away from the road for more than two seconds as it doubles the risk of a crash. When going 25 mph, the distance traveled is over 4 football fields. At 65 mph, like on a highway, this increases by over 2.5 times. Increasing the number of distractions in cars leads to drivers looking away from the road, which means that they are more susceptible to crashes and therefore injury. As touchscreens in cars pose a major distraction to drivers, they can lead to unsafe distracted driving.

The current solution to reducing the amount of distracted driving, is to some degree, already implemented into cars. Buttons are commonly used, whether they are turn dials or simple press buttons, all cars today still have these basic electronic elements as a method of control. In fact, there have even been studies done on how long it takes people to find and press buttons, as opposed to touchscreens, a test by Vi Bilagare found that on average, buttons are four times faster to press than elements on a touchscreen. The average time it takes to look at a button is around 1.1-1.4 seconds, placing them in a lower category of risk in terms of distracted driving[4]. When compared directly against the touchscreen, the worst performing car in the study.

Figure 1 - 2005 Volvo V70

Figure 2 - MG Marvel R

[3] (Glinton, 2017)
[4] (Gitlin 2022)

The MG Marvel R (Figure 2) took 1,400 meters as opposed to the best-performing car, which only took 300 meters (Figure 2).

In particular, one test timed how fast users could complete four tasks (activate the heated seat and start the defroster, power on the radio and adjust to a channel, reset the trip computer, and lower the instrument lighting to the lowest level and turn off the center display). In the Volvo, the driver took 10 seconds, while in the MG Marvel, the task took nearly 50 seconds, other touchscreen cars like the BMW iX were not far in front of the MG Marvel, taking 30 seconds to complete the task. In the chart below there is a clear connection between older/button cars, and their touchscreen counterparts and the time it took the driver to complete tasks.

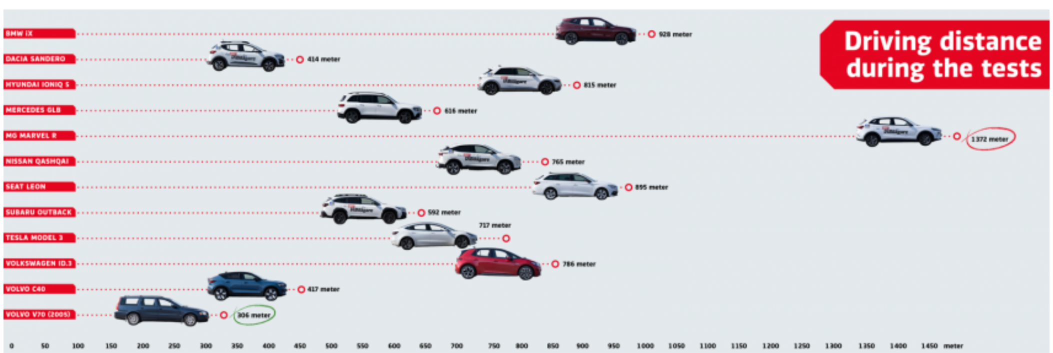

Figure 3 - Comparison of Cars and Task Completion

One of the other findings of the study was that having too many functions and features made it difficult to find the settings that drivers most commonly needed. Simplicity is a key aspect of vehicle control design, in order to reduce the amount of time and cognitive load that it takes to operate a car safely.

Consumer Preferences on Car Touchscreens

Furthermore, not all people like touchscreens in cars. Many forums, news articles, and journals have reported this preference. A common popular community posting site, Reddit, has no less than eight different threads/posts about this specific topic alone, with over 15,000 upvotes, and over 4,100 comments in each thread. Some of the common comments/posts discussed topics like screen glare, fingerprint smudges, time to perform tasks, being able to find/navigate the UI quickly, screen responsiveness, health/danger concerns, previous crash experiences, the difference between car screens and phone screens, the difficulties of touching a screen while moving, and many other related topics. Throughout many posts, some people appreciated touch screens but saw them as dangerous, others liked them, and some Redditors wanted them flat-out banned. Additionally, CNBC posted an article in 2022 titled “Why Some People Hate Touch Screens in Cars” that discusses the increased prevalence of touchscreens, the pros and cons of different control systems, and the different directions that car manufacturing companies are taking.

Other articles such as “Are Touch Screens Getting Out of Control” by Kyle Stock from *Automotive News*[5], discuss the limitations and expectations of the future infotainment industry. The article discusses how touchscreens decrease manufacturing costs (as buttons and switches can be more expensive), how most cars are expected to have screens larger than 11 inches and host convenient and cost-effective ways to sell subscription services or tout new features. The article also draws information from consumer reports of tens of thousands of people’s opinions

[5](Stock, 2023)

on their car's infotainment system, stating that "Every time, the largest, flashiest packages rank near the bottom in terms of satisfaction.

Luxury brands fare particularly poorly, while more pedestrian vehicles — with a more utilitarian approach to technology — are rated more highly." This means that the more complicated and larger the infotainment screen in the car, the less satisfied on average the consumer is with the system, while simple robust solutions (such as buttons) are tied to long-term increased satisfaction of the customer.

Additionally, there are many reports that illustrate people have a preference for more forms of feedback for actions they perform. This is a major issue with touchscreens as they remove haptics, which is an important form of feedback. A paper published in the *International Journal of Industrial Ergonomics*[6], "Effects of Button Design Characteristics on Performance and Perceptions of Touchscreen Use" by Da Tao, Juan Yuan, Shuang Liu, and Xingda Qu, details some of these drawbacks. After analyzing many different designs of interfaces through touch screens, they concluded, in part, that "visual feedback had no effect [on touchscreen performance]." This means that by converting the analog buttons in cars into touchscreens, not only are we removing a key form of feedback, but the feedback is not significantly beneficial to the user. Overall, most sources and communities agree that touchscreens are staying in cars, and becoming more prevalent, however, there are a lot of mixed opinions on the safety, and popularity of these systems in cars.

[6] (Tao, Juan, Liu, Qu, 2017)

Car Display Industry Analysis and Market Trends

As ECDs are a possible solution to this need, we wanted to assess the history and current state of the market. Upon some investigation, we found that most of the major car companies plan to continue to have touchscreens. Mercedes recently launched the new 1.4 meter “hyperscreen”[7], BMW has launched the all-new iDRIVE generation infotainment center[8], The Tesla Model S has had a focus on the digital instrument panel and driver-machine interface since 2018[9], and the Toyota Mirai features three top-level digital screens[10]. From the first touchscreen in cars, The Buick Rivera 9-inch graphics control center in 1986[11]. There are now touchscreens in 97% of cars globally. The general consensus amongst car manufacturers is that screens are not going away, and will only become more popular in cars.

The automotive display market follows the trends of car manufacturers. North America Automotive Display Market was valued at USD 4,969.10 million in 2021 and is expected to reach USD 8593.8 million registering a CAGR of around 9.56% during the forecast period, 2022 - 2027[12]. Other sources place the US automotive smart display market size to reach 11.14 billion by 2021. The market for screens in cars is rapidly growing and offers a good competitive space to capitalize on.

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[7] (Robinson, 2021)
[8] (BMW, 2023)
[9] (Nerad, 2023)
[10] (Nerad, 2023)
[11] (Kew, 2021)
[12] (Mordor, 2020)

Stakeholders in the Value Chain of the Automotive Touchscreen Market

After assessing the touchscreen car market as a large and growing market for ECDs, we wanted to understand the different stakeholders in the value chain to determine if there is a product-market fit for our technology. Seeing as ECDs are just a part of a car, they are affected by a lot of different stakeholders. For instance, while our target is to meet the needs of the end user in terms of safety and performance, we would be selling our idea to car companies that compete with each other to give the best experience to the end user. These smaller companies are owned by larger parent companies that make major decisions based on the markets created by user needs. These parent companies include Toyota, General Motors, Volkswagen, Stellantis, Daimler, BMW Group, Renault Nissan Mitsubishi, Tata, Hyundai, Geely, Saic Motors, Ford, Honda, Suzuki, Mazda, Ferrari, Subaru, Tesla, and each has different amounts of share and pull within the market. Something that makes the automotive market unique in general, is that there are only a few main players when it comes down to who the customers are. This impacts the way that sales are targeted to the screen manufacturers, who have to make each screen targeted at specific models of cars. Additionally, the technology implemented into screens can be but is not always owned by separate screen companies that sell to car companies. Many of these companies design, manufacture, and partner with the car companies that create the specification sheets for future iterations of car screens. In other words, the screen market is controlled by a give-and-take relationship between the screen and car companies. Lastly, all of the features of in-car screens are selected and manufactured using components that are sometimes outsourced to other companies. This can place direct limitations on the capabilities that our design can implement. For instance, if the ECD design needs a certain amount of chip processing power, we need to make sure it can fit into a preexisting system supplied by a component supplier/manufacturer. After looking at how different sections of the market interact, we found that it would be most beneficial to focus on the needs of the screen manufacturers, the car companies, and the end users. This will help us to get a realistic assessment of where we fit in, and how the needs of the users drive the needs of other sections of the market. Figure 5 is a block diagram that describes the way that different needs stack in terms of driving the market, and the way that ECDs are impacted by multiple tiers of the existing market.

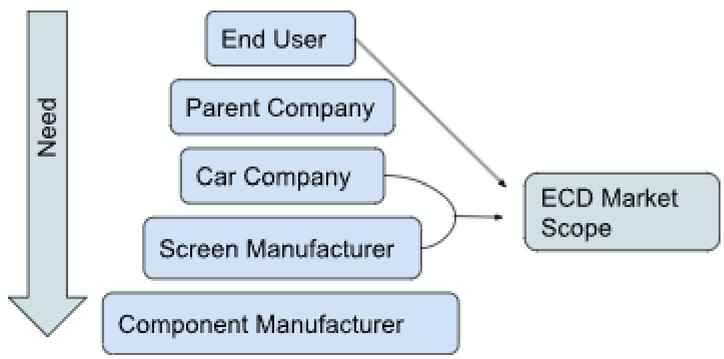

Figure 5 - Need Table and ECD Scope

The three main stakeholders that ECD screens are impacting include the end user, the car companies, and the screen manufacturers. This is because users dictate the overall direction of the market, and it is their safety that we are ultimately targeting, therefore we have to cater to their needs, and interest in the technology. If there is a clear need given by the users, we next need to see how this would be implemented.

Since the second stakeholder is the car companies, they are the ones that cater to the users. They would be the people creating the standards and specifications that mandate new technology, so our idea would have to be "sold" to them in hopes that it impacts their bottom line sales with end users. The margin for the car companies, in general, sits at around 2.3%[13] However, infotainment systems make up a larger percent of that number given all of the software and hardware features that it can offer the driver.

The last and largest stakeholder that heavily impacts product market fit, is the screen manufacturers. The manufacturers currently not only produce and sell their screens to the car companies but also innovate the field and suggest specifications to the car companies themselves. Not only would we need to partner with them to implement our idea into their current screens, but we would need to gauge their interest and aversion to the risks that it would account for in their business models. The current margin for most of these companies hovers at about 13%, however, this changes based on which screen manufacturing company you speak with.

The main manufacturing companies are LG Electronics, Samsung, Panasonic, Visteon, Continental, Robert Bosch GmbH, and Denso, additionally, some car companies will manufacture their own screens and not purchase screens from an outside seller. (A large example of this is that Toyota owns Denso. That means that technically their screens come from in-house production, however, these internal companies will sometimes still contact outside manufacturers depending on their needs). The screen market also has a few large players. LG Electronics, Panasonic, Continental, and Visteon own about 75% of the market, with Viseton taking about 40% of it. However, the OLED screen market in cars currently belongs almost entirely to Samsung, while the rest of the competition uses TFT (thin film transistor) technology as part of an LCD (Liquid crystal display). Some companies like Robert Bosch make the harnesses and software as a third party to interface the displays into the cars, and though they would be related

[13] (Macrotrends, 2021)

to our project, we would not be directly involved with them. The products work on a four to five-year cycle, and this slow cycle is what causes a lot of the smaller companies to enter the market. In sum, ECD technology would likely become a licensable patent to whichever manufacturer is looking to implement new technology and give them a competitive advantage when selling to car companies.

To fit into the market, we would need to make a prototype of an ECD, put it under patent protection, and pitch the idea to screen manufacturers and car manufacturers together as a way to differentiate user experience in the cockpit, and improve safety.

Alternative Technologies that Generate Haptic Feedback

While ECDs are new technology, haptic feedback is not. There are also many ways to create haptic feedback. Some of the most commonly known ways to create haptic feedback are vibration responses, and a physical movement induced by mechanical, pneumatic, or hydraulic forces to push against the skin.

In analyzing the possible success of ECD screens in the market, we chose to look into similar technology that has been implemented into screens. These include the (1) Magic/Force touch developed by Apple, (2) 3D touch by Apple, (3) the haptic feedback in Playstation systems, (4) VR haptic feedback gloves, and (5) HUDs (Heads up displays).

a) Magic/Force Touch

Touchscreens and haptics have been paired frequently. Magic Trackpads, or Force trackpads have been around for a while. In essence, what it does is allow the device to be able to determine different levels of force. It does this with a force sensor on the screen.[14] [15] Following this, the device then uses haptic feedback to convey this information. Most people like this utilization of haptics and the depth of touch. In March of 2022, the tactile trackpad was announced to be released, and all current models of Apple laptops continue to implement this feature into their design. On the whole, when asked about this, article 16 by *Computerworld* writes about the positive features and aspects of force touch, including the feel of the device. But Apple is not just innovating in terms of sensing, it also innovates in terms of haptics. An article[16] released in 2022 describes Apple's current attempt to put haptics in trackpads, describing some of the benefits such as "clicks being registered equally, increased options in terms of size and shape, software tuning for user customization, extra feedback to the user, new gestures, increased control, and new interfacing opportunities to pens and brushes." Many of these new features could change the way that we interact with laptop trackpads, but similar technology could eventually be adapted to interface with car touch screens as well. However, Apple's innovation in haptics does not stop there.

b) 3D Touch

Apple has also made massive gains in terms of currently existing and accessible haptic technology, as close as your wrist. Apple uses a technology called 3D touch, which implements haptic feedback. 3D touch was used in iPhones and Apple watches. While it has since been removed from iPhones because of the complexity of the screen production[17]. Apple still maintains the technology in trackpads and watches. In an article by Forbes, they discussed some

[14] (Picardo, 2022)
[15] (Wikipedia 2023)
[16] (Coppock 2022)
[17] (Esposito, 2021)

of the criticism surrounding 3D touch in a phone[18]. In summary, they noted that anything in terms of UI could be built in instead of having the physical feedback, the feature was not as magical as promised, and older versions of the phone didn't have it, so UI needed to be developed for the functionality of 3D touch for devices without it. Additional articles describe the 3D touch as unintuitive, and the fact that it has a learning curve that takes time to adjust to can put some users off[19]. This led to it being removed from phones that we see everyday. Unlike phones, however, a car screen can not always be looked at, so simplifying UI design becomes a much larger issue. Despite 3D touch's criticisms, many people to this day are still strong supporters of 3D touch and haptics in phones in general. Communities on platforms such as Reddit have made hundreds of posts describing some of the pros of 3D touch, such as its creation of dynamic interfaces, and simplistic shortcuts that helped the fluidity of intentional user navigation, and their dismay at its removal. [20][21]

c) Playstation Vibration

Aside from Apple's forefront in haptic feedback, other companies have been investing in haptics as a way to improve gaming. Sony has made it an essential feature of its designs. Many of the PlayStation models use haptic feedback to send information to the player when they have taken damage, gained health, or as additional feedback[22]. This design allows an individual to experience what is known as "full immersion" allowing users to feel the game. Implemented

[18] (Spence, 2019)
[19] (Spence, 2015)
[20] (Reddit, 2023)
[21] (Daodao, 2023)
[22] (Jones, 2022)

back in 1997, haptic feedback is an essential part of modern PS5s and is widely considered the industry standard.

d) Haptics in VR

Haptics is also being innovated in the modern day into the VR space. Companies like Tesla, Manus, and Haptx are designing new ways that people can interface with VR[23]. Many of these implemented solutions use things like pressurized fluids or gasses that apply resistance to human movement. Other more mechanical solutions involve motors that restrict movement, or re-tensionable resistance bands that apply counteracting force to the muscle movements within the hands. These give the user physical force feedback that is synched to software. While this is an innovative technology, it is the bleeding edge of what we are currently able to create in terms of complex haptic feedback, and is not currently widely available. ECDs also have future possible applications in this field as a way to simplify some of these devices by using electrical rather than mechanical stimulation. Some of the biggest downsides of these systems are that they usually cost anywhere between 3,000 - 15,000 USD, mainly because they need to be highly customizable to the user.

There have also been similar implementations of haptics for safety and proposed safety haptics. This includes safety in aviation, as well as construction. For instance, haptic feedback is slowly being implemented into flight sticks for pilots because of the overwhelming number of systems/parameters that they need to constantly monitor. Current flight sticks have haptic feedback that serves as an alert in case of an emergency or warning. In current publications, the haptics found in aviation have proven to increase the amount of awareness that pilots have when

[23] (Teslasuit, 2023) (Manus, 2023) (Haptx, 2023)

operating aircraft.[24] Additionally, haptics have been used for physical feedback when people are at risk of hurting themselves. An invention by Strongarm is a safety sensor that observes the amount of weight that an individual is carrying, then gives them a haptic warning signal when it judges them to be carrying an object that is too heavy and could damage their back[25]. While this solution is not currently widely used, it is slowly being adopted as a new safety standard.

Lastly, we also found implementations of haptics in cars with the Volkswagen Cadillac haptic feedback, and moldable/textured screens by Visteon. An article written in 2019 discussed some of the possible implementations of haptic feedback in cars and saw it as a possibly helpful safety implementation[26]. This being said, some car manufacturers have attempted to do it in the past. For instance, Volkswagen implemented capacitive steering wheel controls with haptic feedback, but after a short amount of time, they became wildly unpopular due to people being able to accidentally turn on or off the controls by accident, and not feeling the haptic vibration response from the switch[27]. Similarly, Cadillac implemented vibrational haptic feedback through its touchscreens in 2011, though discontinued it due to its lack of precision. The haptic feedback involved vibrating the entire screen itself which some users found irritating. Lastly, there has been some innovation by Visteon. An article posted in 2018 mentioned their new POLED textured screens. Essentially, they have designed a screen that can be shaped so that it can imitate haptic features/feelings. Not a lot has been released on this new technology as it is still in development. Previous implementations of haptics within cars demonstrate the key niche needs of this market, and some of the challenges that implementing haptics in cars faces, such as precision, placement in UI, and general intuitiveness.

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[24] (Schmidt-skipiol, Hecker, 2015)
[25] (Strongarm, 2022)
[26] (Breitschaft, Clarke, Carbon, 2019)
[27] (Gitlin, 2022)

e) HUDs

Other competition that ECDs might face include HUDs and the current industry standard. HUDs have been around for a while, and were first widely seen in the 80s in Corvettes, however interfacing with them can be difficult. While most people appreciate them for simple displays, using hand gestures with them can prove to be gimmicky as the technology is not fully developed. In addition to this, correcting HUD errors with hand gestures can be incredibly time-consuming, and still involves the driver taking their hands off the wheel. An alternative to this is Audio/Voice commands in cars. These have been proven to work well for certain more complex tasks such as navigation or texts, however, they still apply what is known in the industry as a “cognitive load” on the driver which can still be a safety hazard. Similar to gesture control, correcting errors in voice commands can also be difficult while driving compared to a button. Lastly, one could opt to have nothing and just interface with the touchscreen by itself. Many people are alright with this opinion, particularly younger consumers, and have become somewhat used to being semi-distracted or utilizing the touchscreen well enough that they feel it does not inhibit their driving. These alternative methods of interfacing with cars are possible competition for ECD, and much of the goal of this paper is to find out if the advantages and disadvantages of this other technology outweigh the pros and cons that come with ECDs.

After assessing the current industry standards, previous implementations, and competition, we asked ourselves some key questions. “What makes ECD technology different? And is it more suitable for automotive car screens and specific functions?” The answer to these questions allow~~s~~ us to see if our technology is truly useful and unique compared to other solutions. Some of the key differences in our technology as opposed to existing technology, comes from the design of the product itself. Rather than having physical stimulation, the technology enables us to provide electrical stimulation through the use of electrodes, this allows for the precise control of the textures and feelings within the screen regardless of the individual's ability to view the screen. It also gives the users a sense of feedback about the actions that they have performed. They also do not have to vibrate or move the entire device such as other haptic solutions, and this can oftentimes allow for more durability of the device as it does not need to have any mechanical action, which is the main issue with current prototypes that involve moldable screens. Lastly, certain things that would be incredibly difficult/impossible/expensive to implement mechanically, such as the texture of fur, would be doable and cost-effective with the power of ECD technology. Lastly, ECDs offer the advantage of being highly customizable, as they can be implemented and reconfigured easily to suit the specific response needed in various applications. This means that if the screen were to only want haptic feedback on a section at one time, it could be instantly reconfigured to give different haptic feedback based upon its implementation into software, thus saving on costs.

Technology	Applications	Advantages	Disadvantages
ECD	Car touchscreen Education Training[28]	Inside of screens New technology Allows for an additional form of control Can be implemented with a UI system to confirm selection Creates feedback	Adds a R&D, Design, and manufacturing cost
HUD	Cars, Projectors, Games, VR	Easily Visible	Does not provide haptic feedback
Force/Magic Touch	Laptop Trackpads	Allows for an additional form of control	Adds a manufacturing cost
3D Touch	iPhone, iPads, and Apple Watches	Allows for an additional form of control Users generally like it Simplifies UI	Adds a manufacturing cost
Vibrational Feedback Haptics	Playstation Controllers, Aviation, Most Phones, Notification systems Training Systems	Can be implemented with a UI system to confirm selection Creates feedback Can act as a notification	Adds a manufacturing cost
Mechanical Haptics (Tensionable bands, Pneumatics, Hydraulic)	VR Space Training devices	Creates feedback Can act as a notification Allows for an additional form of control	Adds a heavy manufacturing cost

Table 1 - Haptic Technology Table

[28] More of these applications can be seen in the background section

In summary, after analyzing the industry, the competitive landscape, and the end user problems in a car. We needed to conduct research to support our hypotheses about both the market, and what value that ECD technology can add. We conducted interviews, structured interviews, and surveys to better understand if the product-market fit is attractive.[29, 30]

[29] Received lots of help from our advisor writing this section
[30] See Methodology, and Results/Analysis Sections of the paper

Methodology

This section presents the methods used to perform market research with the goal of identifying the needs and best business approach for integrating ECDs into car screens. These methods were developed through our work during our PQP and with the collaboration of our advisors and sponsors.

Objectives

From our background research we found a need in the car screen market. That need is to overcome many of the drawbacks in safety and usability unique to the touch screen interface. Through this research we have made several assumptions that need to be confirmed before making any conclusions on the best way to approach this need. Reinstating these assumptions as research hypotheses allows us to more clearly confirm or deny them through market research. These hypotheses are as follows:

- Users value the tactile feedback from physical buttons, dials, and similar.
- Users feel touchscreens in cars are unsafe and distracting while driving.
- Users are interested in a safer and less distracting way of interacting with their infotainment systems.
- Car companies are continuing to integrate touch screens into their cars.
- New technology is willing to be accepted and integrated into the cockpit of cars.
- Car companies are willing to adopt new technologies into their infotainment systems.

Identifying the Need: Car Screens

At the beginning of our project, we had nothing but the idea of a technology that had the prospect of revolutionizing everything about how we interact with technology. We were quickly humbled by the business-oriented realization that in order to sell a product, an actual need must be addressed. This led us to consider our main question again: "What information is best transmitted through ECDs to whom and when?" After conducting initial research and looking into various uses for haptic, we came upon the answer of touchscreens in cars. This answers the question perfectly, as there is a quickly expanding customer base of people driving cars with touchscreens. Additionally, unlike traditional physical buttons, touchscreens require the user to look at them, creating a dangerous problem while driving. Button location and action confirmation from touchscreens are best transmitted through ECDs to drivers when they cannot take their eyes off the road.

These initial research methods greatly assisted us in narrowing down our potential use cases by highlighting the intersection of what is needed and what is feasible. One of our initial ideas included life-realistic texture gloves for virtual reality, which was quickly shut down as it is extraordinarily difficult to develop and there is not a large need for it. Another idea was to have it integrated into spacesuits to allow astronauts to feel the texture of specimens, but this suffered from the same issues as the virtual reality application. Another idea was to integrate it into smartphones to allow for the feeling of texture and assist the visually impaired by having braille on screen, but these were shut down as braille is becoming less popular and it would be difficult to make anything in the smartphone that would have enough detail to deliver information beyond what could be shown on the screen. With car touchscreens, however, that problem is mitigated as any amount of feedback from the screen, no matter how detailed, is valuable as it would enable the interface to be used more easily and, in more ways, while driving when the user is not looking.

Initial Interview Format: Structured

For our initial interviews we used a structured interview format. To do this, we created a list of questions we planned on asking, had the interviewee answer the questions, and then moved on. This was minimally beneficial, as the most essential information we gleaned from the interviews was when the interviewee had a story to share about what we were discussing. The information we were hoping to gain from these is why people preferred using some interfaces over others for different tasks. This would allow us to make conclusions based on if our technology integrated into the touchscreens of cars could make up for some of the shortcomings of the interface by allowing for similar feedback from classic interfaces like buttons and knobs.

Interview Format: Unstructured

After discussing these findings with our team, we decided to use a more unstructured interview format in hopes of encouraging these stories and more meaningful discussion. We found this was significantly more beneficial and led to us having many key insights to help us narrow down and change the scope of our potential use cases to car touchscreens. These are laid out in our results and analysis section. Instead of simply going through a list of questions, which was practically equivalent to a survey, we altered our questions to act as prompts. We would still ask basic background questions, but the remaining questions asked were meant to encourage them to think and give more meaningful answers in the form of stories. This enabled us to dig deeper into why a similar technology would have been helpful to them and why; really boiling down the core essence of what our product should solve. At the conclusion of each of our interviews, we asked for introductions to anyone else they believed would be willing to be interviewed or would have any insight into a key use for the technology. This is the interview format we used for all our interviews.

Philosophy Behind Prompts

One of the most important aspects of these interviews is how the questions are structured. This is the main aspect we struggled with most as there is a very delicate balance to be made. On one end, we want to lead the interviewee as little as possible, so the stories, emotions, and thoughts we get from them are more meaningful. On the other hand, we have to give them some amount of information regarding what we are doing, otherwise, they have no prompts to respond to. Ultimately, as we are primarily interested in finding the need for our technology, there is no reason to talk about the technology itself in detail during these interviews, but instead, discuss what it can do for them.

Prompt Examples

These are examples of questions that would be asked in hopes of getting the interviewee to share a story or experience from their life. If an insightful response is prompted by any of these, follow-up questions to dig deeper will be asked.

To End Users:

- Do you feel distracted or unsafe when using car touch screens while driving? Why or why not?
- What information would you want the most from a haptic interface in the screen of your car?

To Car Companies:

- How willing are companies to integrate new technologies into their cockpit?
- What is the path innovative technologies like holographic HUDs take to become mainstream?

Follow-Up Question Examples

These are examples of follow-up questions that would be to dig deeper into a response given by the interviewee. The purpose of these is to find more meaningful details as to what about our technology would be helpful and why in their given scenario.

- If the interviewee tells us that they feel unsafe when entering new information on their GPS.
    - What about this action makes you feel unsafe?
    - Do you think you would feel more safe if you were able to feel the buttons and keep your eyes on the road?

- If an interviewee tells us that they really like the feeling of mechanical keyboards and think that should be implemented.
    - What about the feeling of the mechanical keyboards do you like?
    - Do you think it is critical to be able to customize the feeling from the buttons?
- If an interviewee tells us that they don't really use the screen for anything besides volume and temperature.
    - Would you prefer a different kind of button, like a slider, for those kinds of controls?
    - Are those controls appropriate to being used with a haptic interface?

Survey

In addition to interviews, we also conducted a survey targeting end users to help further solidify the conclusions to our hypothesis but also to give quantitative data for analysis. We ensured that the survey questions were unbiased towards any given interface by generalizing the survey to all interfaces. Additionally, we collected age ranges to help identify who, more specifically, our target market should be. The questions themselves, along with the results and analysis thereof are in the results and analysis section. The survey was sent out through various public channels such as discord servers, through email, and several other channels.

Results and Analysis

a) Survey Introduction

We conducted a survey with 10 questions about demographics, car interfaces, controlling various systems, safety, distractibility, general preference, and the reasoning behind the user selection. Our survey had over 90 responses. In our demographics section we asked the age of our participants. Due to the small sample size, the results from the participants are directional only. However, the results were cross-referenced to studies conducted by Consumer Reports[31] and similar response patterns were found.

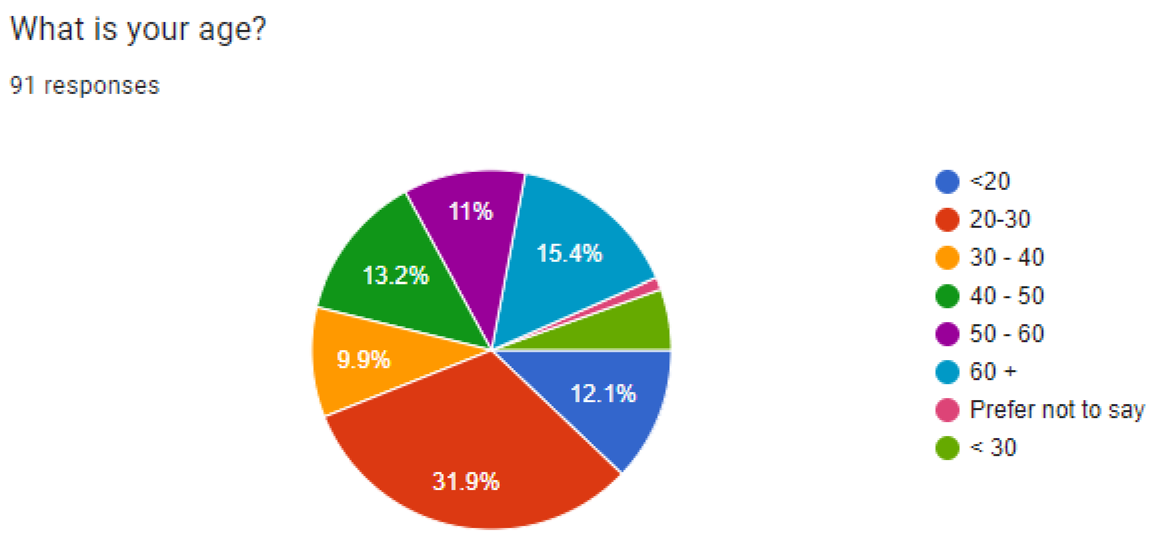

Figure 6 - Age Demographics of Survey

31 https://docs.google.com/document/d/1e1uiyK9ehufe21psOEok7ORvmZkchyzot5hEske7x18/edit#heading=h.bfi89spd0lmh

b) Survey Demographics

For our intended beachhead luxury car market the demographic we are most interested in receiving information from is the 30-60+ age range. Figure 6 shows that people aged 30+ made up 49.5% of our survey. We decided to target luxury cars as they would be most likely to implement new technology into their car screens, and have slightly larger margins than other car manufactures as stated in the background. Our largest group was the 20-30 year old range, and though they may not be in the market for our technology currently, we still value their responses as they will age and eventually become within our targeted demographic.

c) Types of Car Interfaces

We asked survey participants if they had driven cars with different types of interfaces to determine the prevalence of technology within cars.

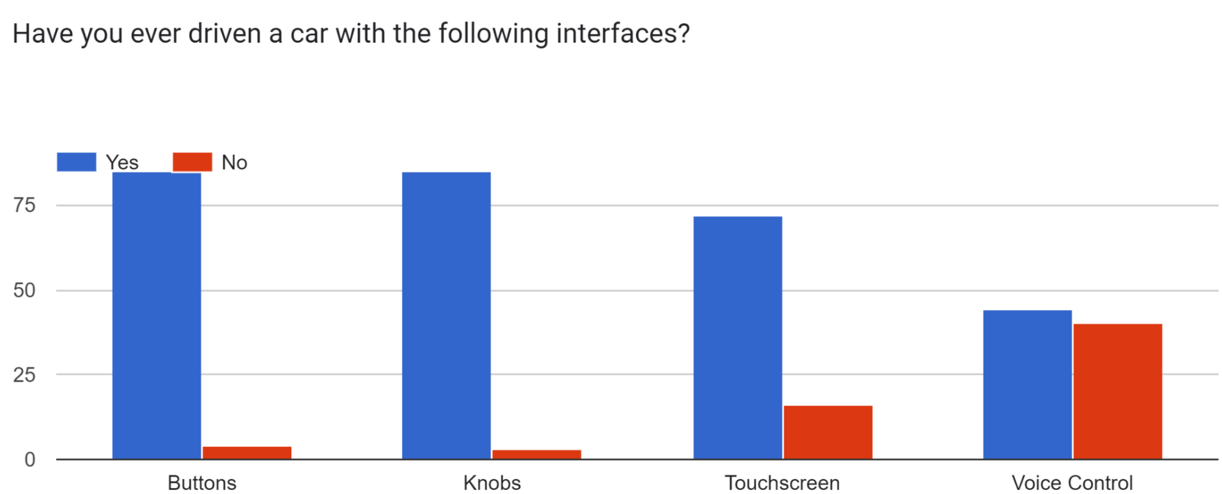

Figure 7 - Prevalence of Technology in Cars

Figure 7 demonstrates that 85% of participants had used cars that had buttons and knobs, while 72% of respondents had a car with touchscreens, and 44% of respondents had used a car with voice control. This suggests that buttons and knobs are currently used more than touch screen and voice control features due to the increased prevalence within older versions of cars themselves, though most participants have been introduced to cars with touchscreens.

d) Control Preferences for Simple and Complex Tasks

Figure 8 and Figure 9 asked the targeted participant's preference for different types of actions, and their preferred control method. Our research found that participant's control preferences varied depending on the type of task: simple or complex. Simple tasks include things like adjusting seats, climate, lights, and volume. Complex tasks included things such as navigation, sending texts, and anything that would take multiple steps and confirmation. Oftentimes, complex tasks are done before the car is in motion. Our survey aimed to capture this key difference by asking about both a simple and a complex task. This is important because when determining if ECDs are a good fit for this market, we need to consider their application. If the findings show that respondents prefer buttons for simple tasks, ECDs would allow us to implement buttons within screens and fill this need.

On a scale from 1 to 5, how easy is it to control the car's CLIMATE without taking your eyes off the road with the following interfaces while driving?

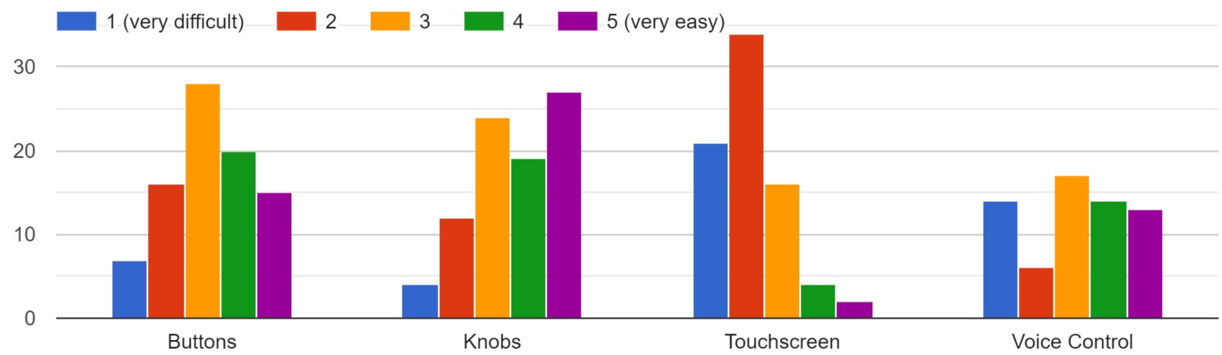

Figure 8 - Climate Control Preference

On a scale from 1 to 5, how much do you prefer to control the car's NAVIGATION without using the following interfaces while driving?

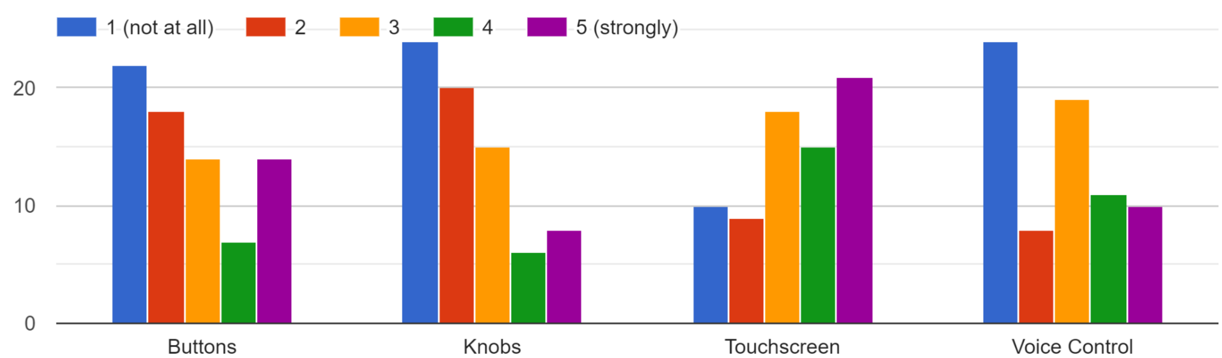

Figure 9 - Navigation Control Preference

e) Control Preferences for Simple and Complex Tasks

According to our data from Figure 8, the average scores for Climate were Buttons: 3.22, Knobs: 3.6, Touchscreens: 2.14, and Voice control: 3.12. Likewise, according to Figure 9, The average scores for Navigation were Buttons: 2.62, Knobs: 2.35, Touchscreens: 3.41, and Voice control: 2.68. Participants preferred touchscreens for navigation 20-30% more than other control methods. During the interview portion of our data collection we found that respondents preferred touchscreens for complex tasks because they can do them while the car is stationary, it is similar to a computer/phone, and there is not a feasible way to do it with buttons.

In general, simple tasks were preferred by Voice Control, Buttons and Knobs, while Touchscreens were strongly preferred for complex tasks like navigation. This demonstrated our hypothesis that on average respondents prefer different control methods for different tasks.

Overall, the findings from this section supports our hypothesis that people prefer different control methods for different tasks. Multiple responses mentioned that muscle memory is an important part of getting used to simple control systems. As for the second question, data indicated analog methods were preferable, but didn't know how to implement that with a complicated task. Lots of respondents said they like the way that touchscreens interface similar to a computer, and that they see navigation as a visual task, as similar to having a physical map. Some respondents mentioned that voice can be incredibly unreliable as there is always background noise, though others mentioned that it is convenient when it works. The biggest reasoning for why respondents gave high and low ratings was the speed that the task could be completed.

f) Perceptions of Safety and Distraction

To understand users' perceptions of safety and distraction, we asked how safe or distracted they felt while using different interfaces. The goal is to understand how users perceive different technology with regards to their health. People may perceive different technology as safe or unsafe, but be more or less distracted by them. This is especially true as distraction is so closely correlated to safety in visual tasks such as driving. In general users tend to have similar reasoning behind both of these answers, and so we expect the results to be similar in terms of the qualitative data.

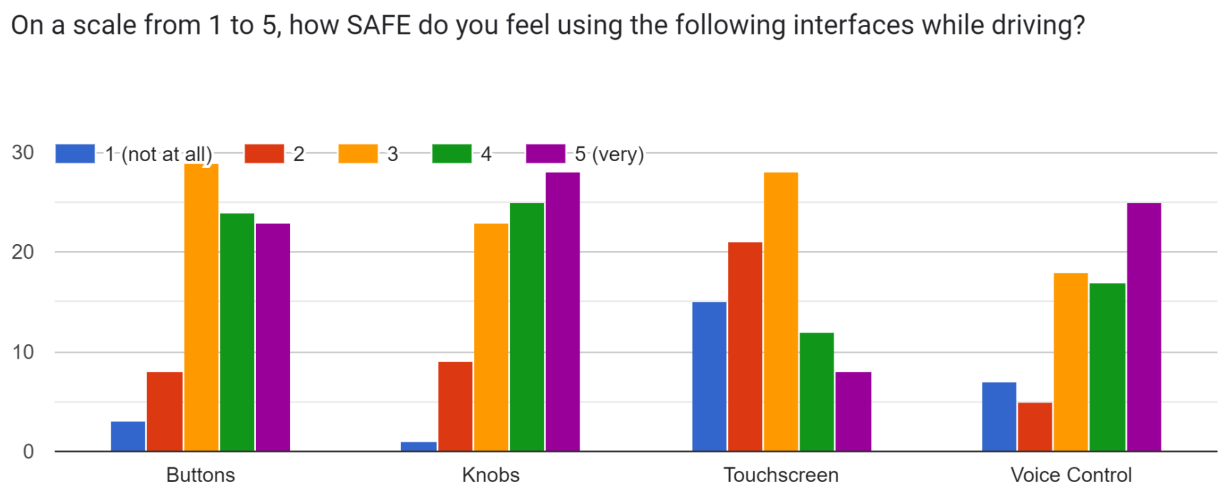

Figure 10 - Perception of Safety Using Different Control Methods

In Figure 10 the average scores for Safety were Buttons: 3.63, Knobs: 3.79, Touchscreens: 2.74 and Voice control: 3.68. This means that on average respondents found themselves to feel about 20% more safe on average when they used a button, knob or voice control compared to a touchscreen.

On a scale from 1 to 5, how DISTRACTED do you feel using the following interfaces while driving?

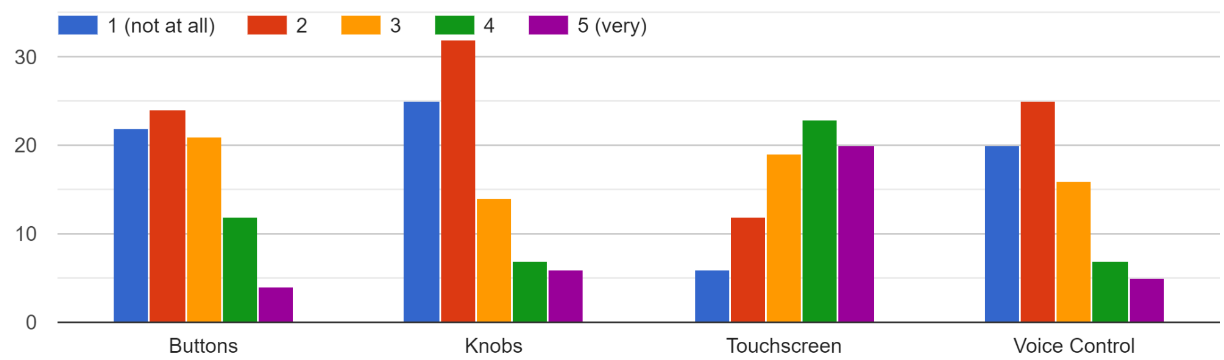

Figure 11 - Perception of Distraction Using Different Control Methods

The average scores for Distraction in Figure 11 were Buttons: 2.45, Knobs: 2.27, Touchscreens: 3.48 and Voice control: 2.36. In general, respondents felt 10%-20% more distracted using touch screens than other devices. This helps to strengthen the inverse correlation between safety and distraction. This means that respondents generally felt pretty safe using multiple forms of control, with a slight preference leaning towards knobs buttons and voice control. The inverse pattern can be clearly seen when looking at how distracted users felt. Participants seem to feel the most unsafe and distracted using touchscreen, and slightly less safe and more distracted using voice control than knobs and buttons, which performed about equally. This supports our hypothesis that touchscreens can be distracting and unsafe.

g) Qualitative Insights from Survey Responses:

Some of the qualitative data also supports this position as well. Survey participants cited muscle memory and the ability to use simple controls without looking away from the road as reasons for their preferences. In the case of navigation many preferred touchscreens due to their similarity to computers and the visual nature of the task. However, some respondents mentioned voice control being unreliable due to the background noise, although it was convenient when it worked.

h) Qualitative Data from Interviews:

We conducted many interviews with industry experts, end users, market advisors, and others over the course of this IQP. Participants helped us to gain insight as to which questions to ask in our survey, market information and direction, and novel solutions. In our interviews many parallel themes to our background and survey were discussed. Most of the general consensus from industry experts was about how touchscreens will continue to be an apparent part of the automotive industry, and many of the key stakeholders will be the main barrier to entry into the market. There were notable remarks about differentiating user experience and about how most people enjoy analog control mechanics such as buttons, though they are becoming less apparent. From our end user interviews we found that most people think that this is a really cool idea, and think that it would add to the safety of the vehicle. Most users also reported feeling distracted by touchscreens in their responses. Other feedback from professors and users mentioned the many other markets that this technology could be applicable to. All of this data aligns with our survey data, and information from outside sources. This further supports our hypothesis about ECD technology and its fit in this field.

i) Comparison with Consumer Reports Findings:

Our results were consistent with those from Consumer Reports, a company that surveys over 73,000 individuals annually to gather opinions on car infotainment systems. Their research also found a strong correlation between user satisfaction and simplicity within the controls of the infotainment system. Kelly Funkhouser, a program manager for vehicle interface testing says that the best systems are all designed to minimize distraction. She further states that "In most cars, it's intuitive to feel around for those controls without taking your eyes off the road."[32] Our smaller scale survey results closely align with the larger pool of results from Consumer Reports, emphasizing the importance of reducing the time drivers spend with their eyes off the road as a key factor in user satisfaction with car controls.

j) Key Insights

Our survey results indicate that respondents have different control preferences for simple and complex tasks, with a general preference for buttons, knobs, and voice control for simple tasks and touchscreens for complex tasks. Participants perceived touchscreens as less safe, and more distracting compared to other control methods. These findings are consistent with larger-scale surveys conducted by Consumer Reports, which emphasize the importance of minimizing distractions for user satisfaction in car infotainment systems.

[32] (Barry, 2022)

Conclusion / Recommendation

Our project explores the need of drivers to improve safety standards and overall experience with the ever-growing presence of touchscreens in their vehicles. To address this need, we investigated ECDs as a potential solution. However, several assumptions had to be made to reach the conclusion that they are a viable solution.

- End users value the physical feedback from buttons and knobs and would want that integrated into touchscreens.
- End users are willing to adopt this new technology into their day-to-day behavior.
- Car companies are willing to make these kinds of innovations in their cockpits

Testing these hypotheses meant we needed to conduct further research. We did so by conducting additional interviews where we got end users, field experts, and representatives from car companies to share stories of their experiences. This, coupled with the various data tabulated from the survey, helped us further understand the specific needs in this market and whether or not there is a product-market fit.

- End users feel unsafe and distracted when using touch screens while driving, creating safety risks as they must avert their gaze from the road.
- End users strongly prefer the feedback provided from buttons and dials as it allows them to improve driving safety while performing tasks that would otherwise pose a risk.
- Car companies will continue to implement touch screens into the infotainment systems of their cars.

- The competitive landscape of car companies who seek to differentiate from their competitors are willing to adopt haptic technology into their infotainment systems.

Based on these key findings from our research, we can conclude that the integration of ECDs into car touchscreens is a potential viable solution to improve driver safety and decrease potential distractions while driving.

Since the findings from this study are promising we would continue with the development of the integrated ECD system into car displays and our value proposition through the following steps:

- Value Proposition
    - Further interviews along the value chain and customer discovery
    - Solidify value proposition by participating in Value Creation Workshops and Pitch Forums
- Prototyping
    - Create single electrode and finding the relevant voltage and frequency values
    - Create a dense array of electrodes and tune so that the feeling of a button can be accurately simulated
    - Integrate an array with a touchscreen
- Interface ECDs into automobile touchscreens
    - Integrating the value proposition and functional prototype into vehicles through a functioning device

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Appendices

Appendix A: Interview Notes (General Questions)

What are hoping to get out of these interviews

- Car Companies
    - How are they driving the market, and what do they look for in terms of touch screen features, how are their margins, what are they willing to do for their customers to sell/risk.
- Screen Manufacturers
    - How do they meet the needs of car companies, how do they set themselves apart feature wise from the other manufacturing competition, what are their margins, risk, manufacturing costs/resources for integration.
- Market Analysts
    - Key insights in the market (timing, key players, niches etc.), best places to target, feasibility, and into how our technology would be able to be integrated and the effects of that.
- End Users
    - As they are part of the driving force behind the motives of the car companies, we are hoping to confirm whether or not we are meeting a need they have.

In general: A better understanding of the market, its changes, and receptivity to novel ideas that fit a user need, and how our idea would or would not be able to play into the market based on cost risk analysis.

Questions for Car companies

1) What is your current margin on the HUD displays within cars?
    a) We need to know how wide the margin is to see if we can realistically implement an idea
2) How would you address the distraction caused by using the touch screens?
    a) Do companies even care about safety
3) How would you improve the touch screens?
    a) Have they already considered other avenues, is there competition
4) How open are you to adding features to the touch screens?
    a) Seeing market receptivity to change
5) What are the biggest ways you would improve user safety and satisfaction?

a) What are they already doing to address what we want to solve

Questions for Screen manufactures

1) What are the current margins on your screen technology
    a) We need to know how wide the margin is to see if we can realistically implement an idea
2) What do car companies tell them?
3) How does that relationship work?
   Do they do joint design work etc or responding to an RFP?
4) Competition questions are good.
5) Who is the best customer?
6) Is there room for them to bring something to the car company or do they just charge for nuts and bolts?
7) Does the accident rate of distractions from screens matter to you and what steps are you taking?
8) How do your manufacturing cycles work with different car models/production cycles?
    a) How does our idea work implementing it into the timing cycles/ deal cycles
9) How open to risk is the market?
    a) We want to know if they would be willing to take a chance on a new feature or not
10) What categories of features do car companies look for in screens?
    a) Is haptic or audio feedback stuff they look for or not competition
11) Based on the hardware manufactures you buy from. If the chip/component selection has "extra" resources, and we can implement them. How receptive would you be to integrating our system?
    a) We need to know exactly how much of stuff they use to see if we can squeeze in to not burden the price margin
12) What safety features do you implement to keep people from looking at screens while driving
    a) Do they care about safety

Questions for Market Analysts

1) How do different price points in cars (high to low end) change margin prices on screens
    a) What section of each market do we care about? Land rover vs toyota
2) How do the cycles work in terms of the timeline for manufacturing to deal to selling time
    a) How does our idea work implementing it into the timing cycles/ deal cycles
3) How receptive is the market to change?
    a) We want to know if they would be willing to take a chance on a new feature or not

4) Which car companies drive most of the change to the screen market?
    a) Knowing which car companies drive innovation also tells us which manufacturers to target
5) Are there any solutions to user distractions due to touchscreens in cars?
    a) Do they care about safety
6) Would haptic feedback be worth the estimated price increase?
    a) Can they care about safety if its within a reasonable price range

Questions for End Users

1) Do you feel safe using the touch screen in your car?
    a) The answer to this will help us gauge how important the need is and how urgent they feel about it.
2) Do you feel that the touch screen is a distraction?
    a) This would test our hypothesis as to whether this is an important safety factor with touch screens.
3) How much do you value the physical feedback that a hardware button/knob gives?
    a) This would test our hypothesis as to whether our specific technology, which can return the feedback, is valuable to the end user.
4) Would you prefer if there was additional feedback from using the screen?
    a) This further solidifies whether more feedback would be welcome specifically regarding car screens.

Questions for Professors

1) What direction do you think technology in touch screens is going?
2) What is your opinion on touch screens in cars?

They are fine. Not really any different from buttons. Mentioned iPad and how that is similar. If can add feeling of button that would be great if cost is low. Mentioned Tesla and how they do not use radar because it is expensive.

3) Does your car have a touch screen?

Yes, they all have touch screens. All the newer ones. Agrees they are a distraction. Carplay is not very good.

4) Based on our technology, how realistic do you think it would be to implement into car touch screens?

Does not really know how we would do it as haptics are very hard. Everyone has different properties of their skin.

5) Do you know anyone that is relevant to the car touch screen market? Would you be willing to make an introduction?

No one in touch screens or anything like that. Does not know anyone in the car market or manufacturing.

Appendix B: Interview Notes/Summaries[33]

Interview Notes Summary 1

Pros

- Good for car company - reduce costs of button and switches
- More control/interface with new features and can update cars more easily
- Users are used to screens so this is a natural extensions

Cons

- Control apps designed for user engagement, driving is exactly the opposite
- Basic functions we use all the time, and not making them accessible is a proven recipe for accidents - Harder to use coupled with motion
- Navigation in particular, nested menus and nuanced climate controls
- When you are moving even then its harder to press and not as smart as you think
- Adding extra unnecessary complications

Interview Notes Summary 2

- All different, depends on their values (market receptibility)
- Mazda example vs BMW and Lexus
    - Audio controls also take cognitive load
    - Kids like to mess with audio control
- Software will accelerate as they can OTA updates
- Major mover is TESLA - similar to apple doesn't like buttons (highest profit margins per car) everyone is trying to match them and being radical
- Caution and rigorous testing (especially older companies)

Interview Notes Summary 3

- When prompted with information best through touch
- Thinks audio would cover most things visual wont
- Thinks 3d touch is cool
- Is reassurance of pressing a button

Interview Notes Summary 4

- Thinks car idea would be cool
- Topographic maps for data and such
- Vehicles in general, especially aviation
- Directions

[33] There were many more notes than this but due to the confidentiality of this paper, we have just written a few examples of some notes we took during interviews

- Online shopping would be crazy with clothes
- VR/AR gaming
-

Interview Notes Summary 5

- Very receptive to tech want to differentiate customer experience
- Organized geographically manufactured per geography
- Safety is important but to manufacturer's specifications microvision and resolution at price point vendor is ultimately responsible
- Congratulations you've targeted the right market, accessing that market is going to be really hard.