Gaming in Autonomous Vehicles:
Rethinking the autonomous vehicle as a gaming platform

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Abstract

Autonomous vehicles (AV) are around the corner. Free from the constraint of driving, passengers will undoubtedly seek new forms of distraction. Autonomous vehicles will be part of a complex network of computers that collect and process more information than ever before. This opens a whole new range of possibilities in the field of game design. This dissertation explores the future of gaming in autonomous vehicles. The first part of this paper studies the current in-car entertainment industry and examples of innovative use of Augmented Reality on-board vehicles. We then proceed to study a particular game developed by Holoride, its potential as well as its limitations. Having done so, the paper will identify a gap in the field of research; gaming in autonomous vehicles. The study uses the analytical framework of Platform Studies to break down the hardware features of the autonomous vehicles that will later shape the AV game design. These features are mouvement, smart windows, vehicle-to-everything (V2X) and computer vision. We will also stress the importance of understanding different patterns of usage. Indeed, where and when the games are played may greatly impact the possibilities of game design. Having done so, five possible AV game genres are detailed with the following methodology; description, required hardware, communication and controls, game mechanics, predicted patterns of usage and target audience and finally an example of a game. These five genres are AV location-based games, Collaboration games, Interface-Oriented games, AR construction games and time-constrained games. Finally, this dissertation identifies concerns that may prevent the advent of AV game design and suggests paths for further study. These concerns are bandwidth priority issues related to 5G, the importance of good User Experience (UX) and issues of Privacy and Data Protection. By the end of this paper, we aim to redefine the autonomous vehicle as tomorrow's gaming platform.

Keywords:
Game Design, In-car Entertainment (ICE), Autonomous Vehicles, Computer Vision, GPS, Motion Sensors, Platform Studies, Innovation, Smart City, Intelligent Transport System, Augmented Reality, Voice Recognition, Google maps AP

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Background

American car manufacturer, General Motors was the first to exhibit autonomous vehicles to the mainstream market in 1939 (Futurama, 2020). The exhibit planned to envision what driving would be like 20 years ahead. It contained an automated highway system and illustrated how the United States could be connected in a widespread network of highways and freeways. In the 1950s and 1960s, GM partnered with RCA Labs to experiment using an electronic guide system that could autonomously glide down an automatic highway. This approach was expected to be commercialised by the 1970s, but ultimately funding for these projects ended up being withdrawn. Another interesting experiment was the Stanford Cart, a buggy equipped with a video camera and remote control that had basic image processing capabilities and successfully navigated a room with several obstacles (Futurama, 2020). These early attempts represented the first steps toward autonomous driving as the vehicles increasingly gained capabilities. The last seven decades saw steady advancements in autonomous driving technology leading up to the influx of companies and start-ups building self-driving systems in the last 10 years (Futurama, 2020). However, despite the continuous technological advancements and optimistic predictions, self-driving cars are still not the main means of transport on our roads today. Three issues seem to slow self-driving car's progression and all are related. The first is the number of accidents that have occurred involving self-driving cars, like the 2019's deadly crash involving an autonomous Volvo XC90 and a pedestrian in Tempe, Ariz (Geiger, 2019). As a consequence, the public's mistrust and fear of self-driving vehicles is high. A study carried out in the United States in 2019 found that 47% of U.S. drivers would not feel safe in a self-driving car (Geiger, 2019). However, experts suggest that the advent of 5G will make autonomous vehicles faster, safer and more reliable. This is mostly due to the elimination of latency that is said to have caused the previous accidents. Communication will be faster, hence the vehicle will be safer (Geiger, 2019). However, the third problem concerns the ethical considerations surrounding the vehicle's programming. These can not be settled by the advent of 5G. Indeed, the vehicle will only ever execute what programmers have hard coded-it to do in any given situation. This poses complex moral dilemmas to programmers when having to choose how the car must act in the event of an unavoidable collision. Must the vehicle save the driver and spare the greater number of pedestrians, or must it always prioritize its passengers' safety? There are five levels of autonomous vehicles ranging from level 1, the simple break assistance to Level 5, the fully autonomous vehicle that requires no supervision (Granath, 2020). Many vehicles on the road today contain some level of automation, but the previously cited concerns must be settled before the world is ready to launch into Level 5.

Methodology

For this research paper, we will assume that such considerations will be settled by thorough governmental research and legislation and that autonomous vehicles will eventually make their way to mainstream transportation, gradually overtaking today's human-driven cars. The aim of this paper is not to predict when self-driving cars will be democratised or how. Rather, this paper aims at exploring the ways in which passengers of this new mode of transport will use their spare time onboard these vehicles. Hence, the game propositions made in this paper are thought to work on Level 5 and above autonomous vehicles- ones which do not require any human supervision The underlying assumption of this paper is that, free from the constraint of driving, passengers will seek forms of distraction to occupy their journey. We will focus on gaming as the main form of entertainment as we will identify a gap in research in this field. A study conducted in the United States found that, on average, Americans spend 18 days a year driving their cars (Chan, 2017). This paper aims at exploring some of the possibilities that the autonomous vehicle can provide to occupy this commuting time. The paper also studies the unique potential that the vehicle provides to avoid implementing existing entertainment into this new gaming environment. By the end of this paper, we aim to rethink the autonomous vehicle as a gaming platform, suggest a framework of five-game genres that can be designed for autonomous vehicles and provide an insight on the limitations that game designers might face in the near future. To do so, the paper will be divided into four parts. First, we will review the current in-car entertainment industry, conduct a case study of AUDI's start-up HOLORIDE and study what car manufacturers have launched in the in-car infotainment domain so far. We will look at examples of AR inside concept cars designed by Mercedes, Audi and Bose Automotive. Having done so, we will identify a gap in the field; gaming and AR in autonomous vehicles. This will lead us onto the second part of the paper. In the second part, we will proceed to examine the self-driving car's characteristics and assess what defines the user experience on-board this new vehicle to extract certain potential gaming mechanics. We will also detail the different types of communication that the autonomous vehicle can perform; V2V (vehicle-to-vehicle), V2I (vehicle-to-infrastructure), V2X (vehicle-to-everything). Here, we will also conduct an analysis of different patterns of car usage. Indeed, elements such as in-car time, frequency of usage and external environment (rural or urban) may greatly impact the types of games that can be designed and played. In the third part, we will use the information gathered above to provide five game genres that can be designed for in-car gaming and explain their core characteristics. These will be; AR location-based games, collaboration games, Interface-Oriented games, AR construction games and time-constrained games. Finally, the fourth part of this paper will expose concerns related to the future of autonomous vehicles and AV games design. These are 5G, bandwidth priority and security, the importance of good User Experience design and concerns over privacy and data protection.

Chapter I: In-car entertainment, industry overview and case study

1 - In-car entertainment overview

A review of the In-car entertainment industry (ICE) shows that there is no consensus over what qualifies as an ICE device. Indeed, some companies such as Argos, sell GPS, TV-DVD headrest screens under the umbrella term 'in-car entertainment' while HarperCollins dictionary defines In-Car Entertainment as: "an assembly of electronic components, such as a CD player, DVD player, or games console, forming a unit to provide entertainment in a car". For the purpose of this paper, we will move forward excluding tracking devices, park-assist devices and navigation systems from the 'ICE' category we are studying. Instead, we will consider 'entertainment' under the strict definition that qualifies entertainment as an art or production that creates diversion and amusement (Harper Collins, 2020). Perhaps the most iconic example of ICE are TV-DVD headrest monitors. These types of monitors witnessed a peak in the mid-to-late 1990s. These screens were seen as a high-end in-car accessory and were popularised by pop culture shows like MTV's 'Pimp My Ride'. However, TV-DVD headrest monitors never penetrated mainstream market. This was mainly due to the security hazard that they caused. Designed for passengers' use, the TV-DVD headrest monitors proved to be a distraction to the drivers and are said to have been the cause of several accidents. David Strayer, a cognitive scientist from the University of Utah who studies distracted driving explains in an article to TechNewsDaily: 'Some activities such as listening to the radio are passive, but others such as texting and checking Facebook are not. The mind can only do one thing at once when driving.' Furthermore, a study found that the choc of the impact of a child's head against the TV-DVD headrest monitor at 18mph in case of a collision was enough to cause death (Massey, 2007). For this reason, the installation of TV-DVD headrest monitors is illegal in many states in the United States such as New York. Also, issues of motion sickness greatly impeded the screen's popularity. Timothy C. Hain, a professor of neurology, otolaryngology, and physical therapy/human movement science at Northwestern University Medical School, and Charles M. Oman, director of the Man Vehicle Laboratory at Massachusetts Institute of Technology and leader of the neurovestibular research program at the NASA National Space Biomedical Research Institute, explain in an article of the Scientific American journal that motion sickness occurs when the peripheral vision perceives the body as still while the internal ear senses the body in motion. This disagreement causes spatial disorientation, nausea and sometimes vomiting. Additionally, the monitors' image resolution, as well as the use of DVDs have mostly become outdated. All of the above reasons caused the decline of TV-DVD headrest monitors. Audio, however, remains a popular form of ICE. Radio/MP3/Bluetooth players are among the must-have accessories of every vehicle. Interestingly, they enable activities that are not usually performed outside of the vehicle. For example, according to a study, half of all radio listeners only listen to the radio in their cars (Edison, 2018). The most popular radio shows are news broadcasts suggesting that users like to make profit of their commuting time by keeping up to date with the news. News broadcast radio would fall into the category of 'infotainment' (combination of information and entertainment) while music would fall into the category of ‘entertainment’ (Edison, 2018). These activities both fall under the realm of what psychologists Brock and Livingston call ‘Passive entertainment’ (Morrissey, 2014). *Passive entertainment* comes into opposition with *active entertainment*, otherwise called *interactive*. An example of this for audio devices would be, the radio *vs*. the voice assistant. Both rely on the same means of communication, audio. Yet, active entertainment creates a greater level of engagement on behalf of the user (Morrissey, 2014). While this was previously impossible due to legislation in many countries stating that It is illegal to display anything distracting while the driver is driving, autonomous vehicles can free drivers of this constraint and allow for all kinds of interaction. Many experts predict that ICE and infotainment will be a significant market in the near future. In fact, The global in-car infotainment market was predicted to be worth $35 billion by 2020. Intel believes that autonomous driving will spur a new passenger economy worth 7 trillion dollars (Martin, 2020).

1.2 Case Study: Holoride by Audi - Qualities and limitations

Another growing industry is the gaming industry. Within the entertainment industry, the gaming industry is forecasted to register a compound annual growth rate of 12% during the period of 2020-2025 (Mordor-Intelligence, 2020). However, little research has been done on gaming in autonomous vehicles - with the exception of the case study that is to follow. We will narrow this paper to focus on the potential of gaming in autonomous vehicles (P. Newswire, 2020). In 2016, Audi launched Holoride, a start-up that aims at ‘providing tomorrow’s in-car entertainment games’. Holoride’s mainpage read’s “Turning vehicles into moving theme parks”. In 2017, Holoride, partnered with Ford and Universal Studios to launch ‘Bride of Frankenstein’, a horror XR game. This game could be played inside a van (driven by a driver), using a VR headset and integrating the car’s motion to create an immersive experience. Arguably, ‘Bride of Frankenstein’ could be qualified as ‘an immersive experience’ rather than a game. It drives the passengers through a story, like a horror-theme park rollercoaster would take you through a haunted house. Except, here, the cart the user is in, reacts realtime to the vehicle’s movements. The user is sitting in the backseat of the van but their vision is entirely immersed into the universe inside the VR headset. Holoride makes this system work by using travel information of a route and time and combines it with the vehicle’s information from steering, stopping and acceleration, linking this all one-on-one to a selected virtual world. According to Holoride, real-time motion reaction greatly reduces the effects of motion-sickness. An Important element to note is that the 3D world into which the user is immersed in ‘Bride of Frankenstein’ does not use features outside of the vehicle such as the buildings, the road signs...etc. In other words, there is no Vehicle-to-Infrastructure (V2I) communication. It is an entirely unique world that is superimposed onto pre-existing terrain. This creates a certain number of limitations. First, the car must always follow a predefined circuit. This circuit is imposed by the triggers that occur at given times of the experience and must correspond to the car’s motion. Secondly, the car may only evolve in a restricted perimeter that has been used to superimpose the 3D modelled world onto. Third, aside from the point and shooting mechanic which allows passengers to fight off characters, the passengers are essentially passive as the car is driven by a driver. They can not influence the vehicle’s route or even choose their destination. The core of these restrictions stems from the fact that the game does not interact with the elements outside of the vehicle. Instead, it uses a VR headset. The choice of VR paired with motion, may heighten the level of immersion by completely shutting out the physical world, however the downside is that it restrains the scope of places and ways in which the games can be played. It also means the player can only play the game once before knowing the entire circuit.

Additionally, the work-load behind mapping an entire 3D modelled world is significantly high, time consuming and costly.

Passengers playing Bride of Frankenstein. Image credit: Holorid

1.3 - Alternatives and overview of current in-car AR systems

Procedural Content Generation for Games (PCG-G) could be an alternative to this. Procedural content generation (PCG) aims at generating game content automatically through the use of algorithms; thereby reducing the cost and labor required for game design and development (Amato, 2017). PCG-G advantages include smaller file size, larger amount of content and reduced predictability of the game. This type of technology is most famously used in Minecraft. However, the disadvantages of PCG-G include that games are more taxing on hardware, the terrain may feel repetitive due to the same basic algorithms used to generate the terrains, game designers may sacrifice quality over quantity, the computer is at risk of generating an unplayable world and finally, it is harder to script set game events. (Amato, 2017). Indeed, game events are pre-scripted events that are almost impossible to place inside a randomly and procedurally generated game. For this reason, some PCG-G use a combination of PCG and premade game development. Additionally, PCG-G would still require the use of a VR headset which is possibly the main obstacle to developing in-car games for mainstream use. Providing the current high cost of entry-level VR headsets, it unfortunately seems unlikely that passengers would have this type of hardware at hand in their vehicle. Instead, users would have to make a separate purchase. This would go against the idea of using the car's existing features as the gaming platform. Instead, another alternative, that this paper aims to explore, could be the use of Augmented Reality (AR). Augmented Reality is an enhanced version of reality created by the use of technology to overlay digital information on an image of something being viewed through a device such as smarglasses or a smartphone (Webster, 2020). While most people think of additive visual elements, AR can be visual, auditive and touch. AR can add but also subtract elements to reality. In the past twenty years, the car industry has made interesting use of AR designed to assist the driving experience. Here are five examples of innovative in-car AR systems. Reviewing these will provide valuable insight in where the industry is currently at that will later serve as a guideline to build gaming features.

1.3.1. Valeo XtraVue by General Motors

General Motors’ Valeo XtraVue Trailer camera system is an example of subtractive AR. The camera system allows the driver to see through the back camera view of their vehicle thanks to a camera that is placed at the back of the trailer (Wayland, 2019). Valeo XtraVue Trailer by General Motors gives the driver a view of their blind spots.

Valeo XtraValue by General Motors. Photo credit: General Motors

1.3.2. Head-Up-Displays: WayRay, Mercedes, Audi & Bose Automotive

The most common use of in-car AR is additive AR in the form of ‘Head Up Displays’ (HUD). Like many technological advancements, HUDs were first experienced on military fighter jets before the hardware trickled down to the civilian automotive industry (Glon, 2020). Today, HUDs are increasingly common in all types of new cars from the Peugeot 3008, to the BMW 7 Series. HUDs can display navigation information such as speed, instructions, but are usually not contextually placed. However, foreshadowing the rise of autonomous driving, companies such as WayRay aim at making the entire windscreen an immersive AR view that displays contextually placed information. With WayRay’s fully immersive AR windscreen, the user can navigate the city, learn about points of interest and still continue to keep an eye on the road in case of a hazardous situation.

Photo credit: WayRay AR system

In 2012, Mercedes revealed their augmented-reality based interface that lets the user navigate through the car's infotainment system through simple hand mouvements, the Dynamic and Intuitive Control Experience (DICE). The system was displayed in a concept cockpit in which built-in motion sensors detect the driver's movements. Users who tried the experience reported that points of interest appeared on the windscreen when the car drove past certain buildings, restaurants or monuments. Friends driving past with another DICE system show up on the windscreen as an icon with their info and face. The system was also capable of registering a track that was played in a club that the car drove past. The song's name was displayed on the windscreen and the user could choose to save it to their Media tab. Although the system was only at its early stage of development when displayed at the CES (Consumer Electronics Show) in 2012, Mercedes representatives said it is likely that such devices will be available in future vehicles (Howley, 2012) .

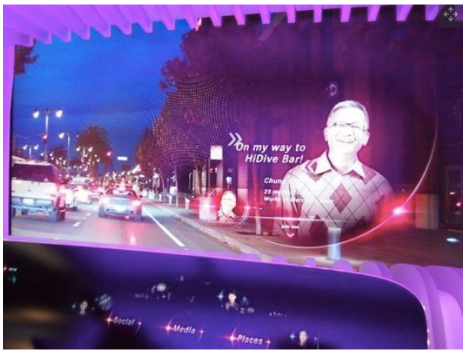


Photo Credit: Mercedes DICE (CES 2012)

Audi AI:ME concept car, CES 2020/ Copyright: Audi AG

More recently, Audi unveiled their concept autonomous car, AI:ME at CES 2020. AI:ME is designed as a 'third living space, after the home and the workplace. Ai:ME features an eye tracking system that can facilitate food orders from driven past restaurants, or display information relative to points of interest the driver looks at (DesignBoom, 2020). Bose Automotive's SmatDrive uses similar eye and face tracking to follow where the passengers are looking. However, the difference with previous AR displays is that Bose' SmartDrive requires passengers to wear smart glasses with speaker/microphone built-in to the branches. This way, each passenger is free to look and learn about by hearing information through their glasses instead of seeing it displayed on the windscreen. The advantage of this is it allows for several people to use the system at once and maintain a level of privacy as only the user can hear the information they choose.

Image credit: Bose Automotive

The advantages of Heads Up Displays is that the passenger can maintain eye contact with the road. In case of a hazardous situation, the driver of an autonomous vehicle can take back control of the vehicle. HUDs are therefore a useful transitory system for autonomous vehicles ranging from Level 3 to Level 5 that require driver vigilance. Another advantage is that, by contextually displaying the information, the user maintains a sense of motion and therefore bypasses concerns of motion sickness. We have looked at an example of what is currently being done in the in-car gaming industry with Holoride's Bride of Frankenstein experience. We then reviewed what type of systems are being designed for the future of in-car AR. However, we noticed that Holoride's Bride of Frankenstein game was partly limited by its use of VR and that the current progress of in-car AR systems were designed for infotainment more than for gaming purposes. We have thereby identified the gap that the next part will attempt to explore. What type of games can be designed to be played in autonomous vehicles that can rely on existing technology to make the most out of this new platform?

1.4 Analyzing the Autonomous Vehicle through the lense of Platform Studies

In order to understand which features work best at assisting game design inside an autonomous vehicle, we ought to examine the broader possibilities that the car can offer and try to draw parallels with existing gaming platforms. To answer this question we turn to platform studies. Platform studies is a branch of game theory that investigates the underlying computing systems and how they shape, enable, constrain and support the creative work being done on them (Bogost, 2017) Looking at existing types of gaming platforms will help better understand what features will define the autonomous vehicle as a gaming platform. It is perhaps useful to think of three different categories of gaming platforms: PC, Console, Smartphone/Tablet (Muresan, 2020). Today, mobile gaming is the most popular gaming platform. Around 39 percent of the entire gaming population prefers smartphones or tablets to play their favorite games (Muresan, 2020). It is also the most recent of the three platform types. Indeed, the mobile-dominant gaming market only truly emerged at the launch of the first smartphone. The advantages of mobile gaming include, portability, low cost of hardware and game purchase and the possibility to use features already present on the device such as network access, GPS and camera. The disadvantages of mobile gaming include lower graphics and high battery consumption. The implications of these characteristics are that games created for mobile gaming have short play time sessions, reach a broad audience and are simple to play. Puzzle games are the most popular mobile game genre. According to a study conducted by Verto's data, 38 million monthly unique users play puzzle games such as Sudoko or Crosswords. Matching puzzle games are the second most popular genre with 30 million monthly active unique users. The leader in this category is Candy Crush. Augmented Reality games come in the third position with 29 million active monthly unique users. AR mobile games are typically games such as Ingress or Pokemon Go. Pokemon Go was a tremendous success with over 2 billion dollars net worth and over 800 million downloads. A study of user behaviour showed that Pokemon Go players were ready to go to great trouble in order to collect Pokemons (Geriomenko, 2019). Harvard Professor Shoshana Zuboff explains how Niantic, the Google-backed start-up that launched Pokemon Go, led a real life marketing experiment with this game to evaluate how well they could 'guide' users to different locations. Some of these locations included stores, ice-cream shops...etc. The owners of these stores paid Niantic to place pokemon's in or around their stores hoping this would attract more customers to spend time and money in their business. The results were very encouraging. Despite it not being an entirely new concept, the fact that Pokemon GO relied on a pre-existing popular franchise, that tapped into the collective nostalgia of many smartphone owners and on the features already present in the mobile made for its unique success (Varghese, 2019). This example illustrates how important the mobile's in-built hardware is in allowing features of the game. In this case, GPS, camera and portability of the console allow Pokemon Go to be played. Console-dominant gaming platforms is the second most popular gaming platform. Today, 23 percent of the entire gaming population prefers console or handheld devices such as the Nintendo Switch to play their favorite games (Muresan, 2020). The global gaming console market is dominated by gaming console manufacturers such as Nintendo, Sony and Microsoft. Some of the popular products from these tech giants that are very popular among players are the Xbox One, Playstation 4 and Ninentendo's Wii. Advantages of console gaming include high graphics, large screens, multiplayer friendly games, the possibility to add hardware (Kinect etc…) and easy-to-use controllers. The disadvantages of console gaming include no spatial mobility (Wii, Kinect and allows mobility inside a given space but the console itself can not be moved) and the high cost of the games and hardware. The implications of these features are that games designed for consoles are made for long-time play sessions. They are also commonly played in common living areas such as a living room. This implies that many games are multiplayer friendly. Most, if not all consoles come with several controllers. The most popular console gaming genres include e-Sports games (Fifa series, Rocket League, Overwatch...etc), Fighter Games (Street Fighter, Tekken, Dragon Ball Z...etc), RPG games (Red Dead Redemption II, GTA series, Final Fantasy series...etc). Popular games on console also include all the Wii series. Nintendo Wii's easy game mechanics and playful multiplayer mode made it a popular console for families. In their book, Codename Revolution: The Nintendo Wii Platform, Steven E. Jones & George K. Thiruvathukal explain how the Nintendo Wii shifted the attention from what's happening on the screen to what's happening in the physical space. The playful console system signaled a turn from the fully immersive and time-consuming MMORPG and FPS games. The home console hosts fun and simple games enjoyed by families. Finally, PC-gaming platforms are played by 15 percent of the entire gaming population (Muresan, 2020). Players use their laptops, desktops, mouse, keyboard and sometimes additional features such as joystick to play their favorite games. Advantages of PC-gaming platforms include powerful hardware and high graphics. This is facilitated by the PCs inbuilt network connexion. The disadvantages of PC-gaming include no mobility, costly hardware and game cost purchase and the necessity to purchase additional hardware, mainly controllers, for the best experience in certain games. The implications of the PC's features on the game design are that PC games tend to have long play sessions, they tend to not be designed for more than one player to use the platform at a time, however online multiplayer mode is common. PC games tend to be more complex and targeted towards an audience of regular gamers, as opposed to 'casual gamers' that the Nintendo Wii would target for example. Popular games include FPS (First-person-shooter such as Call of Duty), MOBA (Multiplayer Online Battle Game, such as League of Legends) or Construction and Life Simulation Games (Minecraft, The Sims or SimCity). To summarise, it appears that each console exists for the purpose of supporting games that can not be played at their best on a different console. Each console has a particular set of features that characterise and drive the games that will best be designed for this platform. Ian Bogost and Nick Monfort, founders of Platform studies, summarise this idea as such :

"By choosing a platform, new media creators simplify development and delivery in many ways. Their work is supported and constrained by what this platform can do. Sometimes the influence is obvious. A monochrome platform can't display color, a video game console without a keyboard can't accept typed input. But there are more subtle ways that platforms interact with creative production, due to the idioms of programming that a language supports or due to transistor-level decisions made in video and audio hardware."

- Ian Bogost & Nick Monfort, Platform Studies: Frequently asked Questioned Answers, (Bogost, Al, 2020)

Could we consider creating a fourth category of gaming platforms in which we could include the Autonomous Vehicle? If we are to consider autonomous vehicles to be tomorrow's next gaming console, what features and games can be played with it that can not be played with any other existing gaming console? In order to extract this information, we must first break down what the autonomous vehicle's key technical features are and then attempt to associate these with potential gaming mechanics.

Chapter II : Characteristics of the autonomous vehicle, game-mechanics and technology review

The autonomous vehicle is quite different to most other gaming platforms. Unlike the PC-dominant or console-dominant platform, the autonomous vehicle's primary function is not entertainment. Rather, quite like the mobile-dominant platform, the autonomous vehicle acts as a host that can be used to integrate gaming features. The implication is that the user will first use the vehicle to complete its primary function and will only optionally engage with the entertaining content. The primary function of any transport vehicle is to get their passenger from point A to point B. Once this statement has been acknowledged, there are two options for AV game designers. The first option is that game designers decide games must work around the constraint of the itinerary. This category could be called 'itinerary priority' games. The games must therefore not impact the distance, length nor itinerary of the trip. The second option is that game designers decide that the vehicle may modify the itinerary to play the game. If we pursue the parallel with mobile-dominant consoles, this would make sense. As we have previously stated in this paper, Pokemon Go has proven that users are ready to go out of their way to complete tasks in the game. Therefore, this might, indeed, apply to AV players too. This category could be called 'playmode priority' games. We will later provide examples fitting for each of these options. The first part of this chapter will identify the four core characteristics of the autonomous vehicle and link these to computer systems, softwares and hardware that might facilitate game mechanics. These are; movement, windows, communication and vision. Similarly to what we have done in the last section of the previous chapter, We will try to identify what the autonomous vehicle possesses that can later serve as a basis for a gaming mechanic.

2.1 SmartGlass Technology and Interactive Windows

We've previously looked at ways in which the car industry is beginning to use windows as AR canvases for contextually display of info-tainment. The next level would be to make these windows touchable displays in which users could not only see the AR elements displayed but also interact with them via an intuitive touching mechanic. In 2012, General Motors commissioned a group of graduate students from the Bezalel Academy for Art and Design in Israel, to turn car windows into interactive displays (Crawley, 2012). The students were given free control over the project to create without concerns of costs or mass production requirements. In an article published in Venture Beat in 2012, journalist David Crawley summarizes the projects from 'Windows of Opportunity' as such:

> *" Otto, an animated character projected over passing scenery that responds to real-time car performance, weather and landscape. With Otto, passengers can learn about their environment in fun, playful ways.*

Foofu, an app that allows passengers to create, explore and discover through finger drawing on window steam.
Spindow, an app that provides its users a peek into other users' windows around the globe in real time.
Pond, an app that allows passengers to stream and share music with other cars on the road, downloads favorite tracks, and share messages with other passengers on the road."

These projects were prototypes. Back in 2012, the technology required for these games to be played was not yet sufficiently advanced to allow for implementation. In order for these games to work in real-time in autonomous vehicles, two elements are required. First, the SmartGlass technology that allows passenger interaction with the glass. This was possible back in 2012 and students indeed used the motion and optical sensor technology developed by EyeClick to turn the window glass into a 'multi-touch and gesture sensitive surface.' (Crawley, 2012). SmartGlass technology is capable of variable states of translucence and transparency, and can reflect projected images. The second requirement is strong V2X communication.

2.2 Motion detection: Sensor Fusion & IMU

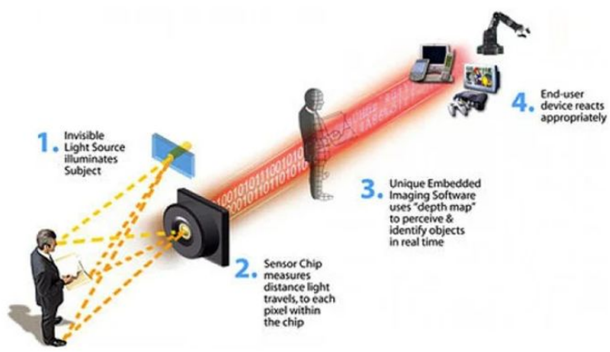
There are two types of motion detection characteristics related to the AV. The first is motion sensors that check where the car is, and the other are motion sensors that check where other objects are in relation to the car. For AV engineers, determining this data is key to assuring safety on board the vehicles. Respecting the road signs, speed limitation and avoiding collisions are their main focus. Interestingly, the hardware onboard that monitors the car's motion is similar to the hardware used in motion-based games. Motion sensor technologies in video games have peeked since Nintendo released the Wii. The motion sensors typically employed in the newest games are 3-axis accelerometers—three-dimensional motion sensors with electrical outputs corresponding to acceleration components in the *x*, *y*, and *z* directions (Goodrich, 2014). An accelerometer is an electromechanical device used to measure acceleration forces. Such forces may be static, like the continuous force of gravity or, as is the case with autonomous vehicles or mobile devices, dynamic to sense movement or vibrations (Goodrich, 2013). Acceleration is the measurement of the change in velocity, or speed divided by time. A dynamic accelerometer measures gravitational pull to determine the angle at which a device is tilted with respect to the Earth. By sensing the amount of acceleration, users analyze how the device is moving. Accelerometers allow the user to understand the surroundings of an item better. With this small device, you can determine if an object is moving uphill, whether it will fall over if it tilts any more, or whether it's flying horizontally or angling downward. For example, smartphones rotate their display between portrait and landscape mode depending on how you tilt the phone. Accelerometers are used in cars as the industry method way of detecting car crashes and deploying airbags almost instantaneously. They are used in autonomous vehicles and are deemed as important as cameras and radars to operate the vehicle safely (Horton, 2017). Autonomous vehicle industry refers to these as IMU's (Inertial Measurement Unit). IMU are typically 9-axis accelerometers that directly measure a vehicle's three linear acceleration components and three rotational rate components. Used for gaming, these will therefore provide a potentially richer experience than the current most performant motion-detection accelerometers of gaming platforms. However, accelerometers alone are not sufficient to provide a safe autonomous driving experience. A self-driving car requires many different sensing technologies. For example, it typically needs Lidar to create a precise 3D image of the local surroundings, radar in a different part of the spectrum for ranging targets, cameras to read signs and detect colors, high-definition maps for localization, and more. Unlike the IMU, each of these technologies interacts with the external environment to send data back to the car's software stack for localisation, perception, and control. Using IMU's alone would thereby appear to be the best solution for designing in-car games that do not interact with the external environment, such as Holoride's Bride of Frankenstein. However, pairing the IMU device with other technology like GPS, Lidar, Radar or Camera would provide the opportunity to add the interaction with external environment elements, otherwise known as V2X (Vehicle-to-Everything) which we detail in section [2.4]. This technique combines several elements of motion sensor technologies called 'Sensor Fusion'. Sensor Fusion and IMUs are then linked to the computer system and send data registered to a software that analyzes this information and reacts accordingly. In the case of autonomous vehicle engineering, this will typically involve avoiding obstacles or adjusting the speed. The implications in terms of game design include the possibility to rely on these features to create games that are sensitive to speed, orientation, inclination of the vehicle as well as games sensitive to the vehicle's position relative to external elements such as other vehicles, pedestrians, road signs or buildings.

2.3 Computer Vision

Computer vision is the field of study that works at allowing computers to gain high-level understanding of the content within digital images or videos (Technopedia, 2020). Computer vision works in combination with artificial intelligence as the computer is required to interpret what it 'sees'. In the autonomous vehicle, there is 'inward looking' computer vision and 'outward looking' computer vision. Inward looking computer vision focuses on what is happening inside the vehicle. This was the case for the examples we studied previously, Bose Automotive, Mercedes DICE and Audi's AI:ME systems. These use face and eye tracking to detect the passengers' movements. Because autonomous vehicle's Level 3 and 4 still require human attention, these systems are useful to detect emotions such as stress, sleepiness or even alcohol consumption. Outward vision focuses on what occurs outside of the vehicle. This type of computer is a combination of LIDaR, RGB Camera, Thermal cameras and HDR camera. We will look at the systems that will prove most relevant in the process of AV design, LIDaR and RGB Camera.

2.3.1 LIDaR

A LIDaR is a device placed on top of the vehicle that spins and casts laser beams 360° around the vehicle. It has a receptor that measures the distance of objects by measuring the time the casted beam takes to bounce back. Thanks to this system, LIDaR devices can produce a 3D reconstruction of the surroundings that allows vision of depth of field and elevation (Singh, 2020). For games that require a visual interaction with the landscape, the car must be able to 'envision' the depth of field and height of obstacles that the elements on the window must interact with. For a game such as *Otto,* the SmartGlass technology should be paired with a LIDaR technology. These games would be best suited for games played by passengers looking sideways at the skyline. The computer could thereby operate an edge detection to detect the sky and the skyline and create collisions between the player's character and the elements that were detected below the skyline. A more evolved version of these 'Skyline' games might involve a Spiderman-like possibility to move the character below the skyline. The second requirement of computer vision is a powerful imaging software that uses a depth map and perceives and identifies objects in real-time. At a smaller scale, Xbox's Kinect uses similar technology.



Depth perception using the infrared camera

Copyright : How does the Kinect Work By Robert Cong & Ryan Winters

2.3.1 - RGB Camera, Object Recognition, Tracking and Machine Learning

Computer vision and machine learning come together in hand in hand. Machine as a subset of Artificial Intelligence (Fullscale, 2019). For example, RGB cameras on autonomous vehicles enable the car to record and analyze objects in the digital images of its surroundings that help better understand it. However, it is the powerful algorithms of machine learning techniques that process and help make sense of the information recorded in the scene. Today, RGB cameras combined with powerful algorithms are capable of achieving object recognition and motion tracking (Liu, 2018). Machine Learning essentially trains the computer to recognize objects in a scene by feeding it with images, defining these and classifying them. Key points of the objects are recorded so that the computer can later compare and match corresponding objects against what those stored in the database. This technique is better known as scale-invariant feature transform (SIFT) (Fullscale, 2019). However, another approach exists that does not require specifically defined features but rather is inspired by the convolutional neural network system. This approach is better known as Deep Learning. Deep Learning is an artificial neural network that tries to reproduce the biological neural network (Fullscale, 2019). Together, computer vision, sensor fusion and machine learning allow the vehicle to collect data that can then be processed to provide information on where the car is, where other cars are, where pedestrians are, and how to act on the road. These types of communications are better known as V2X (vehicle-to-everything) communications.

2.4 - V2X: Vehicle-to-Everything Communication

Currently the debate between DSRC (Dedicated Short Range Communication) and C-V2X (Cellular Vehicle-to-Everything) revolves around the choice of whether to use Wifi or 5G as the network to navigate autonomous vehicles. As we previously mentioned, 5G could mean lower latency and greater bandwidth needed for smart traffic systems and safer autonomous vehicles. Indeed the vehicle's safety relies on its ability to react fast enough to prevent any accident. While many countries are still debating which standard to use, in October

2019, China made the decision to opt for C-V2X and gave a dedicated bandwidth spectrum on which to operate. Many experts believe this will eventually be the standard (Little, 2019). V2X communication includes communication between a vehicle and another vehicle (V2V), vehicle and a pedestrian (V2P), vehicle and roadside infrastructure (V2I) and vehicle to network (V2N). In terms of game design, 5G represents an unprecedented number of potential interactions between all elements connected to the internet of things (IoT). This vast network of communication would form the Intelligent Transport System (ITS). In terms of game design, communication with the SmartCity allows location-based games and communication with other vehicles allows collaboration games.

2.4.1 - Vehicle-to-Infrastructure (V2I): What is it & How does it work ?

Vehicle-to-infrastructure is a communication system that allows bi-directional sharing of data between vehicles and the components that support a country's road system (Rouse, 2017). Such components include overhead Radio Frequency Identification Device (RFID), traffic lights, lane markers, streetlights, parking spaces, signage and many more (Rouse, 2017). As Margaret Rouse explains in an article published in 2017 in TechTarget, "*In an intelligent transportation system (ITS), V2I sensors can capture infrastructure data and provide travelers with real-time advisories about such things as road conditions, traffic congestion, accidents, construction zones and parking availability. Likewise, traffic management supervision systems can use infrastructure and vehicle data to set variable speed limits and adjust traffic signal phase and timing (SPaT) to increase fuel economy and traffic flow. The hardware, software and firmware that makes communication between vehicles and roadway infrastructure is an important part of all driverless car initiatives."* Applications of V2I can currently range from adjusting a car's speed to signaling a free car parking space.

2.4.2 - Vehicle-to-vehicle Communication: What is it and how does it work ?

The American National Highway Traffic Safety Administration (NHTSA) defines Vehicle-to-vehicle (V2V) communication as a mode of communication that enables vehicles to wirelessly exchange information about their speed, location, and heading. The technology behind V2V communication allows vehicles to broadcast and receive omni-directional messages (up to 10 times per second), creating a 360-degree "awareness" of other vehicles in proximity (NHTSA, 2019). In case of a predicted incident, like a car driving too close to another or a predicted collision, vehicles can adjust their speed or send an audio message to the other car for the driver to make adjustments. This type of direct communication between vehicles opens great multiplayer gaming potential for AV which we shall explore in the third chapter.

2.4.3 - Vehicle-to-Pedestrian: What it is and how it works ?

Vehicle-to-Pedestrian is the communication of data between vehicles and all other road users that qualify as vulnerable road users (VRUs). These include pedestrians but also cyclists, motorcyclists and electric scooter users. Currently, V2P communication's prime objective is to avoid collision and crashes between vehicles and pedestrians. This is done by bi-directional sharing of vehicles and VRU's GPS+Sensor information used to predict and prevent collisions. Similar to V2V communication, safety messages may be sent or action might occur on the part of the AV to avoid the collision (Parag Sewalkar and Jochen Seitz, 2017).

2.4.4 - Vehicle-to-Network: What it is and how it works ?

Vehicle-to-Network is the system which allows communication between the vehicle and application server and cloud to allow long distance updates on information such as traffic or stream content in-vehicle. Unlike V2V and V2I who rely on DSRC that communicates information at a maximum range of 300 meters, V2N uses cellular connection, meaning the vehicle can anticipate congestion and passengers can be made aware of what is happening at a distance in real-time (Mpricial, 2020). This communication allows GPS applications to remember and contextually locate where the car is. This type of communication will be particularly interesting for designing location-based AV games.

2.5 - Patterns of Usage: Time and Environment

A key feature of AV game design are patterns of usage. Where, when, how long and how often people use their vehicle greatly impacts the games people will play. A long drive on the highway may not offer the same gaming experience than a short drive through an urban landscape. The environment and the time of travel are two key elements that the AV game designers should take into consideration. One way to approach the issue might be to suggest designing games that reproduce the features of other platforms that are used for similar amounts of time. For instance, a longer in-car travel might call for more complexe, time-consuming games similar to games designed for PC gaming or console gaming. On the other hand, a shorter in-car travel might call for less complexe games similar to games designed for mobile gaming. Furthermore, the number of smart objects connected to the IoT in urban space is most likely to be higher than it will be in rural environments. Therefore, it appears that games designed to be played in urban spaces will more likely have a stronger emphasis on interaction with other smart objects and users (pedestrians, other vehicles, road signs, infrastructure,...etc). On the other hand, games designed to be played in the rural space will more likely be focused on landscape, skyline and activities such as drawing. To summarize this chapter, we have seen that current AV technology onboard the vehicle allows the car to; communicate with its environment, with pedestrians, and is easily localised thanks to communication with the network. We also saw that technology enabling direct, touchable interaction on the windows already exists and that solutions could be put into place to use these as the prime interface of displaying and interacting with elements outside of the vehicle. It appears we have thereby identified the key technical hardware and software features of the autonomous vehicle that can serve as a basis to AV game design.

Chapter IV - Five types of AV games

In light of what we have previously discussed, here are five categories of potential AV game genres. We will operate with the following methodology for detailing each genre; description, required hardware, communication and controls, main game mechanics, predicted pattern of usage and target audience and examples of application.

3.1 - AV Location-Based Games

3.1.1 - Description

As we mentioned in the first paragraph of chapter II, AV Location-based games will most likely be subdivided into two categories. The first, 'itinerary priority' games use location but do not change the travel path for the game's purpose. The second, 'playmode-priority' games place the game before the constraints of route. Itinerary priority games should use the points of interest at display around the vehicle's route. This works well with games that involve spotting and collecting certain elements in the scene around the car. 'ISpy with my little eye…' is a game traditionally played in cars in which a passenger sees something outside of the car and other passengers compete to guess it first.

3.1.2 - Required hardware and communication

Thanks to computer vision, Audio systems, motion tracking systems like mercedes' DICE and SmartGlass technology, the car can detect and identify an object and then ask the passengers to compete to spot it first. On the other hand, an example of 'playmode-priority' game involves an interactive story that is generated with its branches matching the route's intersections. Thanks to GPS and accelerometers, the car can calculate the different ways to arrive at the same destination. It would then offer decision branches at crossroads and would take the direction of the choice's order of proposition. For example, if the user is given the choice between option A and B at some point of the story and chooses option A, the car will take a right turn at the next intersection. If the player had chosen option B, the car would have taken a left turn at the next intersection. In case of an intersection containing more than two directions, The first option will be the most right direction and the last will be the most left direction. This type of game would be a combination of existing interactive narrative software such as Twine and GPS technology. It would require the use of an Audio system, V2I communication, computer vision and an interface on the Smartglass that allows users to make the choices.

3.1.3 - Game mechanics

The main game mechanics for AV location-based games are listening, speaking, touching and taping.

3.1.4 - Predicted patterns of usage and target audience

The predicted pattern of usage for AV location-based games is most likely to be for medium to long-time play sessions. In the case of playmode-priority games, the story could last as long as the player wishes to make it last. If the player has a view of the GPS navigation route, it is easier for them to end the game faster by making the choices that will lead them faster to the end destination. For itinerary priority mode, the predicted pattern of usage is more likely to be in urban environments as these present a greater number of elements to identify than a rural landscape - however, the density of the urban landscape might make it harder to spot elements before the vehicle has already past them. Games such as ISpy are geared towards children due to their simplicity while games such the Interactive location-based game that are more complexe, will be geared towards older public 18-55, who have a previous gaming experience. While these games are designed to be single-player, V2V allows collaboration in games such as AV ISpy for competing to find and collect certain elements before other players.

3.1.5 - Examples

Identification games (ISpy), Interactive narrative location-based games (INLBG).

3.2 - Collaboration Games

3.2.1 - Description

Collaboration games are games whose main feature relies on the interaction with other players onboard other vehicles or nearby pedestrians who play and connect to the network thanks to their cellular mobile device.

3.2.2 - Required hardware, communication and Controls

The features required to operate these games are V2V communication, V2P communication, SmartGlass, Audio systems, microphones, Sensor Fusion, GPS. The controls will be present in the form on an interface displayed on the window. Some games may only require voice interaction. Microphones and speakers systems are therefore a requirement of many collaboration games.

3.2.3 - Game mechanics

The game mechanics involved in collaboration games include interaction with the windows such as touching, circling, taping as well as listening and speaking.

3.2.4 - Predicted usage patterns and target audience

The predicted pattern of usage of this type of game is on long distances during which a given number of vehicles who choose to play together stay within a range of 300 meters (corresponding to the DRSC maximal V2V distance) of each other for a sufficient amount of time to allow a game session. Highway roads are the area most suited for such travel arrangements between vehicles. However, thanks to the Intelligent Transport System, with an itinerary entered and communication between cars, vehicles with similar itineraries could in fact choose to connect and play together for portions of their shared route.

3.2.5 - Examples

Examples of V2V or V2P collaboration games could include Blindtests or Quizzes. Passengers could choose songs and play these in the connected vehicles while the remaining vehicles compete to find the song's name first. Other types of V2V collaboration games could be similar to the game invented by Bezalel Academy students in which cars teamed up send virtual snowballs on eachother.

3.3 - Interface-oriented games

3.3.1 - Description

Interface-oriented games (IOG), are games which place the window's interface as the central component of the game. IOGs are divided into two categories. The first interface-oriented category is collision games. Collision games display a character on the SmartGlass. The second is Studio games. Sudio games use the window as a creative canvas to draw and paint on.

3.3.2 - Required Hardware, communication and controls

Thanks to LIDaR technology and computer vision, depth of field can achieve collision detection in 3D. Therefore, a simple 2D collision detection is possible, but so is a more complexe 3D collision detection in which the player would make his character jump and hang on to elements of the skyline that they drive past, like a Spiderman character. The controls for IOG are the windows and the user's fingers.

3.3.3 - Game mechanics

For collision games, the game mechanics include tapping and swiping to move the character across the scenery to avoid obstacles. The player, looking out through the side windows, taps on the window to the places where it wants its character to land, or send its web. For Studio games the mechanics include drawing, erasing and swiping.

3.3.4 - Predicted Usage patterns and target audience

Due to the high density of the urban landscape, collision games might be harder and more taxing on the hardware to play in a city. However, rural landscapes and long straight roads such as highways are ideal to play collision games. Studio games however, do not require a particular setting as they do not require interaction with the external elements. These games are open to a wide range of players due to their basic game mechanics and straightforward interface. These players can range from children to adults and may include casual players as well as more experienced gamers.

3.3.5 - Examples

An example of a collision game would be a 2D version of Spiderman. A Spiderman character is displayed on the side window and this character can be controlled by tapping and swiping on the window to avoid obstacles. The player, looking out through the side windows, taps on the window to the places where it wants its character to land, or send its webs. An example of a studio game could be an open canvas displayed on the window and a virtual toolbox containing different digital brushes, pencils colours to let players express their creativity.

3.4 - AR Construction Games

3.4.1 - Description

AR construction games allow players to choose elements from the world they drive past and resize these to integrate them into their personalized AR landscape. Users can choose any element from a lamppost, to a tree, a gate, a building or even a cloud. The AR landscape would appear on a central flat surface present inside the vehicle.

3.4.2 - Required hardware, communication and controls

The users must wear AR glasses to play this game and see their landscape appear on the flat surface in front of them. The main controls are the players' fingers and the SmartGlass that the player touches to select the chosen elements. Computer Vision technology is also central to AR construction games. This type of game requires a powerful GPU and an algorithm capable of instantly converting a recognised object into a 3D model. While this technology has not yet been commercialised, one way around this issue would be to have a preexisting bank of 3D models that can be matched to the object recognition system. For example, if the player selects a tree - the object recognition information will then be fetched from the car's computer vision system and algorithm to identify it as a tree. Once it has been successfully matched, the game displays a set number of trees that have been modelled and lets the player choose from one of these.

3.4.3 - Game Mechanics

The main game mechanics of AR construction games are circling, selecting, resizing and placing.

3.4.4 - Predicted patterns of usage and target audience

Players may want to save their landscape to avoid having to start from scratch the next time they travel in a different vehicle. For this reason AR construction games may be connected to a server that remembers user session information. Players can therefore store their elements on a virtual space, access these and even trade them with other players thanks to V2V. The target audience would be similar to players of PC Life simulation games, business simulation games and city-building games.

3.4.5 - Examples

An example of an AR construction game could be an AR SimCity. Players begin with a blank landscape in front of them. They can then select and place elements within their landscape as they drive. Players can share their landscape online to inspire or gain likes from other users.

3.5 - Time-Constrained Games

3.5.1 - Description

Time-constrained games are games that work around the user's itinerary. The game begins once the player has entered the destination and the car calculates the travel time. These games mostly operate on a countdown basis, meaning the player succeeds if they accomplish the given task before reaching the destination. The tasks' difficulty is adjusted according to the trip's length. A shorter trip will call for an easier task to accomplish.

3.5.2 - Required hardware, communication and controls

Time-constrained games require Audio and microphone systems and GPS. The controls will be voice operated while the choice of destination may be entered on the car's in-built navigation system.

3.5.3 - Game Mechanics

The main game mechanics of time-constrained games are listening and speaking.

3.5.4 - Predicted patterns of usage and target audience

The predicted patterns of usage of time constrained games are for short-to-medium trips.

3.5.5 - Examples

A typical example of a time-constrained game could be an enigma game. Once the player enters the destination in the GPS, the vehicle reads out an enigma to solve and launches a countdown that ends once the destination has been reached. The player succeeds if they solve the enigma before arriving at the destination. To summarize, we outlined five potential AV game genres; AV location-based games, Collaboration games, Interface-Oriented games, AR construction games and time-constrained games. It is important to clarify that this framework is not definitif and only aims at providing a framework of analysis for future game designers. Indeed, it is hard to make clear categories in which one game fits only. Some might argue that certain games would better fit into two categories or more, such as ISpy, that could be seen as a time-constrained game. Nevertheless, the point of this section was to summarize the findings of chapter II and make suggestions and give examples for future game possibilities and research. In the next and final chapter, we will outline the current limitations of this research paper and potential obstacles that future AV game designers might face.

Chapter V - Limitations

There are a number of concerns that might slow the advent of AV game design and this section aims at identifying these in the hope that future research might address these issues to overcome blockages. The concerns will be discussed in the following order; 5G, bandwidth priority and passenger security, hierarchy of information and the Importance of good User Experience design and Privacy and Data protection regulation.

4.1 5G, Bandwidth priority and passenger security

Despite general enthusiasm towards the deployment of the 5th generation cellular network (5G) a certain number of issues are currently slowly 5G deployment. First is the requirement to install an important number of antennas on road signs, traffic lights, buildings...etc. This is due to the fact that 5G uses shorter wavelengths to transfer data than 4G. This means that 5G can transfer larger amounts of data at once but it also means that the range is shorter than 4G's current range. 5G wavelengths can be blocked by trees, buildings and walls. This means that while cities are more likely to invest in costly 5G deployment equipment, rural areas might not be so fast to make the transition. The second concern stems from the potential congestion of the 5G network. Despite 5G been praised for its broad bandwidth, allowing for a significantly more important number of users to connect to the network at one given time without causing saturation and slowing it down, experts still forecast that 5G will one day, eventually become saturated and the need for transition to 6G will then arise. This is especially understandable as an IST requires all cars, pedestrians and infrastructures to be connected to the 5G network and will potentially overtake a large portion of the 5G bandwidth. It is not impossible to imagine that to avoid such a scenario from happening, government regulations decide to limit the use of 5G networks in autonomous vehicles for safety and navigation purposes to avoid saturation. In which case, Autonomous vehicles could no longer rely on the vehicle's in-built functionalities.

4.2 - Hierarchy of information and the importance of good UX design

A modern vehicle is packed with computers and sensors all sending information back to the head unit and a high-end vehicle can contain over one hundred different electronic control units (ECUs) (Shouten, 2019). These ECUs serve to later display useful information to the user. As a user designer (UX) designer, the challenge will arise from the need to find intelligent ways to handle these hundreds of different signals and display information in a user friendly way. As we've studied in this paper, with the arrival of autonomous vehicles this amount of information is likely to increase drastically. AV game design will only increase this amount of information displayed. It is important that designers anticipate the need of a clear information hierarchy to avoid any game interaction interface to cluster the passenger's experience with overwhelming information. Furthermore, in terms of designing commands to play games on-board AV vehicles, the challenge is as big as inventing a brand new way of interacting with the vehicle without impacting on safety and navigation commands already built-in. Designers will have to think of ways to bring together several interfaces to create a seamless experience. What audio commands does the user give to the speech recognition system, what will the touchable window interface look like and how will these all work together are AV UX designer's next challenges. A possibility would be to create a centralised switch button system that the user can activate to go from infotainment displays to game displays. The second concern surrounds location tracking

4.3 - Data Protection and Privacy concerns

Although the following concerns apply to autonomous vehicles in general, AV game designers should be prepared to overcome the same obstacles in relation to data protection and privacy law when designing games. This is especially true with regards to V2V, V2P and location-based games. These types of games multiply the number of cellular connections, thereby increasing the risk of cyberattack and data breaches. In an informative article written by Norton Rose Fulbright organisation and published in *Compliance and risk management, Regulatory response* journal entitled 'The Privacy and implications of Autonomous Vehicles', the writer explains that there are three main areas of concerns surrounding privacy and autonomous vehicles. The first is the recording of owner and passenger information. Autonomous vehicles may record passenger and owner information for a range of reasons going from vehicle access authorisation to personalisation of the on-board experience or in the case of games such as AR construction games discussed above, to remember a passenger's session progress. This data qualifies as sensitive information as it may enable to identify a user to a high degree of certainty. While data protection laws across the globe differ widely, in the European Union, the General Data Protection Regulations clearly state that any company recording sensitive information that may allow a user to be personally identified is responsible for putting high security measures in place to protect this information against any data breaches. However, as mentioned above, multiplying the number of connections also increases the network's vulnerability to cyber-attacks. Unfortunately, it appears that the deployment of certain technological systems often occurs before the insurance that the system is one hundred percent secure. For example, researchers from the University of Michigan found that some new connected systems of wireless traffic lights control were vulnerable to cyberattacks. The weaknesses reportedly enabled the use of encrypted wireless signals to control the traffic lights at a distance using a simple laptop computer operating with a wireless card operating on the same frequency as the wireless traffic lights (Stern, 2014). This example shows how important the protection of the networks is. Cyberattacks on any of the parts of the ITS could potentially result in fatalities. The second concern surrounds location tracking. Location tracking operated via GPS and V2N is useful to record information on route, congestion, speed or preferred itinerary over time. However, this information combined with user specific information could, once more, be potentially harmful in the hands of ill-intentioned people. Concerns over the use of this information by marketing companies are also rising. Indeed, with the combination of user information and patterns of location, companies may be able to deduce sensitive information on the user like where they live, work, go out to better target their advertising campaigns. Finally, the third concern stems from the principle of sensor data (Norton R. Fulbright, 2017). As we previously explained, the autonomous vehicle functions by collectecting, storing and analyzing its surroundings. This is done thanks to sensor fusion, machine learning and computer vision. The imagery collected by the vehicles that serve for navigation including video footage public roads on pedestrians may be subject to dispute over invasion of privacy. Similar concerns are expressed surrounding the use of voice recognition. We come to understand that autonomous vehicles will act as the final stone of a truly connected world. Travelling will be safer and more efficient. As a consequence, the amount of data produced and collected will be greater than ever before. Bearing in mind that data has recently surpassed oil in value, it is to be expected that companies will attempt to commodify their large databases selling this data to third party organisations. This could have unprecedented impacts on privacy. When building tomorrow's AV games, it is important to keep these concerns in mind - arguable, for ethical reasons but most importantly, to avoid costly legal procedures later down the line. Consent and compliance forms for each of the games that collect and store sensitive information is crucial.

Conclusion

To conclude, in this paper we have reviewed the current in-car entertainment industry. We carried a case study of Holoride's VR game the bride of Frankenstein. This game proved to be limited by its use of VR that disables from using the car's full potential. As an alternative, we approached the use of AR in vehicles. We analyzed different examples of innovative use of AR in the car industry, from substractive AR to audio AR systems to full AR on-window displays. However, we came to understand that little to no research had been done on applying this technology for gaming in autonomous vehicles. From there, we conducted a comparative approach of the three most popular gaming consoles in order to better understand how a platforms' hardware shapes the types of games that are played on it. We suggested creating a fourth category of gaming platforms, the autonomous vehicle. To follow this path we moved onto breaking down the core hardware and software features of the autonomous vehicle. These were mouvement, windows, computer vision, communication and patterns of usage. We understood how each of these worked and explained how these would later be used as a basis for game design. The third chapter gave a framework of five possible AV game genres. These were, AV location-based games, Collaboration games, Interface-Oriented games, AR construction games and Time-constrained games. For each of these, the methodology used gave a description, listed the required hardware, communication and controls, gave the core game mechanics, predicted the patterns of usage and target audience and provided one or two examples. Finally, the fourth chapter of this paper outlined three concerns that might prevent the advent of AV gaming in the near future in the hope that research will investigate and overcome these issues. These were concerns over the saturation of the 5G bandwidth frequency due to the high volumes of data, the challenges of inventing intelligent and clear User Experience codes for in-car gaming and concerns over Privacy and Data Protection relative to the high volume of collected data.

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