ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

A SERIOUS GAME USING VIRTUAL REALITY AND AUGMENTED REALITY IN A DRIVING LICENSE TEST

M.Sc. THESIS

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

EHLİYET SINAVLARINDA SANAL GERÇEKLİK VE ARTIRILMIŞ GERÇEKLİK KULLANAN CİDDİ OYUN

YÜKSEK LİSANS TEZİ

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TEMMUZ 2021

Tuğçe AVŞAR, a M.Sc. student of ITU Graduate School student ID 529171016, successfully defended the thesis entitled **"A SERIOUS GAME USING VIRTUAL REALITY AND AUGMENTED REALITY IN A DRIVING LICENSE TEST"**, which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Prof. Dr. Hatice KÖSE** Istanbul Technical University	.....
Jury Members :	**Prof. Dr. Leman Figen GÜL** Istanbul Technical University	.....
	Asst. Prof. Dr. Elif SÜRER Middle East Technical University	.....

Date of Submission : 8 June 2021
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To anyone who believes in the power of immersive technologies,

FOREWORD

This thesis is written as completion to the master Game and Interaction Technologies, at Istanbul Technical University. The master program is multi-disciplinary and focuses on making innovative and creative contributions to the field of game design, development, and interaction technologies. The subject of this thesis, an applied study that aims to develop a game that tests drivers in all conditions and situations that are not in normal tests but may also encounter. Thus, drivers can be more conscious, and also traffic accidents can be greatly reduced. This study is supported by the 2210-C Domestic Master Scholarship Program for Priority Areas of TUBITAK-BIDEB.

Due to my interest in immersive technologies and serious games, the project was jointly decided with Prof. Dr. Hatice Köse, a reputable professor from my postgraduate studies. We decided to develop a game to prepare the unconscious drivers for all situations encountered in traffic, due to the inadequacy of the license exams and educations. The hardest part of the research was to improve realistic car mechanics in the game to get the feeling that players are driving a real car. To take up this challenge, we added the Logitech G29 Steering Wheel Stand to our project. A practical experiment including application and measurement setup was carried out to study the effectiveness of the serious game and whether the game achieved its purpose.

I have experienced the research period as very interesting and instructive. I have been able to achieve a result I am very satisfied with. I would like to thank TUBITAK and TUBITAK-BIDEB to support my project. I wish to thank all participants; without their assistance, the analysis could not be possible. The greatest thanks go to my advisor Prof. Dr. Hatice Köse for her absolute interest, constant assistance, and guidance. Her valuable insights and directions gave me needful guidance to complete the research and write this thesis.

June 2021 Tuğçe AVŞAR

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ABBREVIATIONS

VR : Virtual Reality
AR : Augmented Reality
MR : Mixed Reality
XR : Extended Reality
AI : Artificial Intelligence
UX/UI : User Experience / User Interface
2D : Two Dimensional
3D : Three Dimensional
SDK : Software Development Kit
API : Application Programming Interface
PSVR : PlayStation VR
ITU : Istanbul Technical University
PC : Personal Computer
IT : Information Technology
SCI-FI : Science Fiction
IOS : iPhone Operating System
STS : Simple Traffic System
GEQ : Game Experience Questionnaire
ASD : Autism Spectrum Disorder
DoF : Degrees of Freedom
HMD : Head-Mounted Display
WHO : World Health Organization

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A SERIOUS GAME USING VIRTUAL REALITY AND AUGMENTED REALITY IN A DRIVING LICENSE TEST

SUMMARY

This research was conducted with the aim of reducing traffic accidents, which are among the top 10 causes of death, announced by the World Health Organization [1]. According to WHO data, 1.3 million people pass away and nearly 50 million people are injured as a result of traffic accidents worldwide every year [2]. To express this statistic in another way, it corresponds to the crash of approximately 20 Boeing 737-800 type passenger planes in the world every day and the death of all passengers. If this scenario were happening in air transportation in the world, it would not be acceptable, but unfortunately, these statistics are far from the scenario in road transportation. In Turkey, more than 7 thousand people die in traffic accidents and 300 thousand people are injured every year [3]. To put it more clearly, while 22 people die on the highways of our country, more than 820 people are injured every day. Traffic accidents lead to injury or death of one of our children, who are the future of our country, every 10 minutes [3]. Some of the injured remain disabled throughout their lives and a significant part of their lives are adversely affected.

Another striking statistic revealed by WHO is that the countries where 90% of the deaths in traffic accidents occur in the world are the countries with low-income and medium-income and the total number of registered vehicles is 54% of registered vehicles in the world [2]. Turkey, where the research was conducted, is one of these countries mentioned by WHO. In addition, the WHO report [2] also mentions the reasons why most accidents occur in these countries. Two of these reasons are poor planning in the highway networks and drivers who have a license without being adequately tested.

Although most of the drivers in Turkey pass the exams, they cannot drive or they lack information. The first main purposeof this research is to show that individuals who have a license gain the right to drive without having enough knowledge and experience. Before starting the research, a questionnaire was prepared in order to raise

awareness and to learn the opinions of drivers about driving license exams. Most of the drivers think that their driver's license exams and trainings are insufficient to get on the road as a driver. They said that most of the traffic accidents are caused by lack of information and not being able to master the rules. It is also thought that a VR game that will prepare the drivers for all kinds of scenarios will be much more successful for the preparation phase of the drivers and will be effective in reducing the number of accidents and raising awareness.

People get most of the information from their own eyes and, in most cases, perception is dominated by vision, visualization of information is important for efficient education systems [4]. In addition, thanks to immersive gaming technologies, players feel more fluid, fascinating and motivating than normal games [5]. For these reasons, it was thought that the use of immersive technologies would give the best results. It was decided to prepare two separate games for drivers and driver candidates. It was decided to make a game that will teach the information in the book over the phone with AR, an accessible and widespread technology. VR and steering wheel technologies were chosen for driving training that can be supported by more advanced systems.

The goal of AR serious game is to show that the knowledge that drivers learn from the book to pass the exam is not permanent, and to try to investigate how permanent this information is when visualized with augmented reality and serious gaming methodologies are used. In order to investigate this lack of information and customize the theme of the game, daily traffic signs that inform drivers about the road and are encountered every day were chosen as the subject. While conducting the research, the participants were selected from drivers with 1 - 6 years license due to their most up-to-date knowledge. Half of the traffic signs asked for the pre-test are the ones we encounter frequently in our daily life, and the other half are the signs that express dangerous areas but not frequently. According to the pre-test results, it was observed that the rate of not knowing the signs that we do not encounter frequently was high, and that even the most frequently encountered traffic signs were not known. Several research groups have used immersive technologies for learning purposes [6]. However, in many research processes, the pre-test questions were asked again as post-test questions, usually right after the experience, and the results were determined accordingly. In this research, the traffic signs that were asked in the pre-test were asked again in the active-duty part of the game and all the participants gave the correct

answers. Participants only answered questions about their experiences after the game. The fact that none of the participants made mistakes in the active duty in the game and when asked again a year later, they knew most of it correctly, showing that the information learned through AR serious game is much more permanent than the ones taught by traditional methods. The effect of visualization methods with AR was also reinforced by the participants describing the scenes in which the traffic signs were in the game one year later.

It is aimed to increase realism and make learning more effective by using the steering wheel in the VR serious game. The player is assigned as Uber driver in this game. The player is tasked with picking up the customer from the city and taking them to a nearby seaside town in the game. A practice phase has also been added for participants playing the game with VR or a steering wheel for the first time. After getting used to the game, the test phase is started. This phase begins in crowded city traffic with AI cars. Then, there are forested and mountainous roads between the city and the coastal area. The duration of your reaction to the obstacles that suddenly appear while you are walking on the forested straight road is measured. This is because in developed countries, reaction time is a prerequisite for driver candidates who want to have a driver's license. You are expected to dominate the car by adjusting your steering and speed on gravel roads in mountainous areas. At the end of the game, each player is given a score out of 100 for their driving experience. Participants are expected to score a minimum of 70 points as each has a driver's license.

In the VR test phase, the test was conducted with 16 people divided into 2 groups as gamers and non-gamers. Experienced drivers seem to score more at the end of the game. Those with higher scores among experienced drivers are those with out-of-town driving experience. This shows the importance of experience, which can be gained with the help of game before having a license. The most important point encountered in the game results is that two of the testers got less than 50 points. Considering that they have a license, it is seen that the conditions for traffic are insufficient. It is also seen that participants who think that they have improved themselves in the game are inexperienced or without out-of-town experience. It has been concluded that playing games with the steering wheel gives the impression of driving a real car. Regardless of whether they are a gamer or not, each participant thinks that if the game is expanded and different scenarios are added, it will help driver candidates to develop and gain

self-confidence and to be more experienced in traffic. When the results of the reaction tests are examined, it is seen that there is a slight decrease between the first and last reaction times. This shows that reaction times can be reduced with practice.

In future studies, it is aimed to add different scenarios for the VR game and vary according to weather conditions. In addition, it is aimed for the driver candidates to gain experience on real world roads by using Google Maps APIs instead of Terrain Generator asset. In addition, it is planned to conduct the tests to individuals who do not have a license. The VR game includes scene transitions due to performance. Testers cited these scene transitions as a distraction and a reality-distorting factor. In future studies, it is aimed to play the whole game in a single scene by making computer hardware improvement and scene optimization.

EHLİYET SINAVLARINDA SANAL GERÇEKLİK VE ARTIRILMIŞ GERÇEKLİK KULLANAN CİDDİ OYUN

ÖZET

Bu araştırma Dünya Sağlık Örgütü [1] tarafından açıklanan ölüme en çok sebep olan 10 ölüm nedeni arasında bulunan trafik kazalarının azaltmayı hedeflemek amacıyla yapılmıştır. Dünya Sağlık Örgütü verilerine göre dünya genelinde her yıl trafik kazaları sonucu 1,3 milyon kişi hayatını kaybetmekte ve yaklaşık 50 milyon kişi de yaralanmaktadır [2]. Bu istatistiği başka bir şekilde ifade etmek gerekirse, dünyada her gün yaklaşık 20 Boeing 737-800 tipi yolcu uçağının düşmesine ve tüm yolcuların ölümüne tekabül etmektedir. Dünyada hava taşımacılığında bu senaryo yaşansaydı kabul edilebilir bir durum olmazdı ama ne yazık ki bu istatistikler karayolu taşımacılığındaki senaryodan çok uzak ve gerçeğin ta kendisi. Türkiye'de her yıl trafik kazalarında 7 binden fazla kişi ölmekte ve 300 bin kişi yaralanmaktadır [55]. Daha açık bir şekilde ifade etmek gerekirse, ülkemizin karayollarında her gün 22 kişi hayatını kaybederken, 820'den fazla kişi de yaralanıyor. Trafik kazaları her 10 dakikada bir ülkemizin geleceği olan çocuklarımızdan birinin yaralanmasına veya ölümüne neden olmaktadır [55]. Yaralıların bir kısmı hayatları boyunca sakat kalmakta ve hayatlarının önemli bir kısmı olumsuz etkilenmektedir.

Dünya Sağlık Örgütü'nün ortaya koyduğu bir diğer çarpıcı istatistik ise dünyada trafik kazalarında ölümlerin %90'ının dünyadaki toplam kayıtlı araçların %54'üne sahip olan düşük ve orta gelirli ülkelerde olmasıdır [2]. Araştırmanın yapıldığı Türkiye, Dünya Sağlık Örgütü'nün bahsettiği bu ülkelerden biridir. Aynı raporda, bu kazaların nedenlerinden de bahsedilmektedir. Bunlardan ikisi düşük ve orta gelirli ülkelerde yeterince test yapılmadan ehliyet sahibi olan sürücüler ve karayolu ağlarındaki kötü planlamadır.

Türkiye'de sürücülerin büyük bölümü sınavlardan geçmesine rağmen trafiğe çıkamıyor veya bilgi konusunda eksiklikleri var. Araştırmaya başlamadan önce farkındalığı arttırmak ve sürücülerin ehliyet sınavları hakkında görüşlerini öğrenmek amacıyla anket hazırlanmıştır. Sürücülerin büyük bir bölümü ehliyet sınavlarının ve

eğitimlerinin ehliyet sahibi olarak trafiğe çıkılması konusunda yetersiz olduğunu düşünmektedir. Trafik kazalarının büyük bir bölümünün bilgi yetersizliğinden ve kurallara hakim olmamaktan kaynaklandığını söylemişlerdir. Ayrıca sürücüleri her türlü senaryoya hazırlayacak bir VR oyunun sürücülerin hazırlık evresi için çok daha başarılı olacağını ve kazaların sayısını azaltmakta ve bilinçlendirmekte etkili olacağını da düşünülmektedir.

İnsanlar bilginin çoğunu kendi gözlerinden alır ve çoğu durumda algıya görme hakimdir, bilginin görselleştirilmesi verimli eğitim sistemleri için önemlidir [4]. Bunun yanı sıra sarmalayan oyun teknolojileri sayesinde oyuncular normal oyunlardan daha akıcı, büyüleyici ve motive edici hissederler [5]. Bu nedenlerden dolayı sarmalayan teknolojilerin kullanılmasının en iyi sonucu vereceği düşünüldü. Sürücüler ve sürücü adayları için iki ayrı oyun hazırlanması kararlaştırıldı. Erişilebilir ve yaygın bir teknoloji olan AR ile kitaptaki bilgileri telefondan öğretecek bir oyun yapılmasına karar verildi. Daha gelişmiş sistemlerle desteklenebilecek sürüş eğitimleri için ise VR ve direksiyon seti teknolojileri seçildi.

AR ciddi oyununun hedefi sürücülerin sınavı geçmek için kitaptan öğrendikleri bilgilerin kalıcı olmadığını göstermek ve bu bilgilerin artırılmış gerçeklik ile görselleştirildiğinde ve ciddi oyun metodolojileri kullanıldığında ne kadar kalıcı olduğunu araştırmaya çalışmaktır. Bu bilgi eksikliğini araştırmak ve oyunun baz aldığı konuyu özelleştirmek amacıyla, sürücülere yol hakkında bilgi veren ve her gün karşılaşılan trafik işaretleri konu olarak seçildi. Araştırma yapılırken katılımcılar en güncel bilgilerinden dolayı 1 - 6 yıllık ehliyet sahibi sürücülerden seçildi. Ön test için sorulan trafik işaretlerinin yarısı günlük hayatımızda sıkça karşılaştığımız, yarısı da tehlikeli bölgeleri ifade eden ancak sık karşılaşmadığımız işaretlerdir. Ön test sonucuna göre, sık karşılaşmadığımız işaretlerin bilinmeme oranının yüksek olduğunun tespit edilmesinin yanı sıra, en sık karşılaşılan trafik işaretlerinin bile bilinmediği görüldü. Birkaç araştırma grubu, sarmalayan teknolojileri öğrenme amacıyla kullanmıştır [6]. Ancak birçok araştırma sürecinde, ön test soruları genellikle deneyimin hemen ardından son test soruları olarak tekrardan sorulmuş ve sonuçlar buna göre tespit edilmiştir. Bu araştırmada ön testte sorulan trafik işaretleri oyundaki aktif görev bölümünde tekrar sorulmuştur ve bütün katılımcılar doğru cevapları vermişlerdir. Katılımcılar oyun sonrası sadece deneyimleriyle ilgili soruları cevapladı. Oyundaki aktif görevde hiçbir katılımcının hata yapmaması ve bir yıl sonra tekrar

sorulduğunda büyük bir bölümünü doğru bilmeleri, AR ciddi oyunuyla öğrenilen bilgilerin geleneksel yöntemlerle öğretilenlerden çok daha kalıcı olduğunu göstermektedir. AR ile görselleştirme yöntemlerinin etkisi, katılımcıların bir yıl sonra oyundaki trafik işaretlerini hangi sahnelerde olduğunu tarif etmeleriyle de pekiştirilmiştir.

VR ciddi oyununda direksiyon seti kullanılarak gerçekçiliğin arttırılması ve öğrenmenin daha etkin olması hedeflenmiştir. VR ciddi oyununda kullanıcı Uber sürücüsü görevine atanmıştır. Oyunda oyuncu müşteriyi şehirden alarak yakındaki bir sahil kasabasına götürmekle görevlidir. Oyunda ilk kez VR veya direksiyon setiyle oynayan kullanıcılar için alıştırma evresi de eklenmiştir. Oyuna alıştıktan sonra test evresine geçilmektedir. Test evresi AI arabaların olduğu kalabalık şehir trafiğinde başlamaktadır. Daha sonra şehir ile sahil bölgesi arasında ormanlık ve dağlık yollar bulunmaktadır. Ormanlık düz yolda ilerlerken aniden karşınıza çıkan engellere verdiğiniz tepkinizin süresi ölçülmektedir. Bunun nedeni gelişmiş ülkelerde reaksiyon süresinin ehliyet sahibi olmak isteyen sürücü adayları için ön şart olmasıdır. Dağlık bölgelerde çakıllı yollarda direksiyon hakimiyetini ve hızınızı ayarlayarak arabaya hakim olmanız beklenmektedir. Oyunun sonunda her kullanıcıya sürüş deneyimiyle ilgili 100 üzerinden puan verilmektedir. Test kullanıcıların her birinin ehliyete sahip olmasından dolayı minimum 70 puan almaları beklenmektedir.

VR test evresinde gamer olan ve olmayan olarak 2 gruba ayrılmış 16 kişi ile test yapılmıştır. Deneyimli sürücülerin oyunun sonunda daha fazla puan aldığı görülmektedir. Deneyimli sürücüler arasında daha yüksek puan almış olanlar ise şehir dışı sürüş deneyimi olanlardır. Bu da deneyimin önemini göstermektedir. Oyun yardımıyla ehliyet sahibi olmadan daha öncesinde deneyim kazandırılabilir. Oyun sonuçlarında karşılaşılan en önemli nokta ise test kullanıcılarından ikisinin 50 puandan daha az almış olmasıdır. Ehliyet sahibi oldukları göz önüne alındığında trafiğe çıkma koşullarının yetersiz olduğu görülmektedir. Oyunda kendini geliştirdiğini düşünen kullanıcılar deneyimsiz veya şehir dışı deneyimi olmayan kullanıcılar olduğu görülmektedir. Direksiyon setiyle oyun oynamanın gerçek araba kullanıyormuş izlenimi yarattığı sonuna varılmıştır. Gamer olup olmadığı fark etmeksizin her katılımcı oyunun genişletilmesi ve farklı senaryolar eklenmesi durumunda sürücü adayları için gelişimlerine ve özgüven kazanmalarına ve trafiğe çok daha tecrübeli çıkabilmelerine yardımcı olacağını düşünmektedir. Reaksiyon testleri sonuçlarına

bakıldığında ise ilk ve son reaksiyon süreleri arasında küçükte olsa bir azalma olduğu görülmektedir. Bu da reaksiyon sürelerinin alıştırma ile azaltılabileceğini göstermektedir.

Gelecek çalışmalarda, VR oyunu için farklı senaryolar eklenmesi ve hava koşullarına göre farklılık göstermesi hedeflenmektedir. Buna ek olarak, Terrain Generator varlıkları yerine Google Maps APIs kullanılarak sürücü adaylarının gerçek dünya yollarında deneyim kazanması hedeflenmektedir. Ayrıca yapılacak testlerin ehliyet sahibi olmayan bireylere yapılması planlanmaktadır. VR oyunu performans dolayısıyla sahne geçişleri içermektedir. Test kullanıcı bu sahne geçişlerini dikkat dağıtıcı ve gerçekliği bozucu bir etken olarak belirtmişlerdir. Gelecek çalışmalarda bilgisayar donanım iyileştirmesi ve sahne optimizasyonu yaparak tek sahnede bütün oyunun oynatılması hedeflenmektedir.

1. INTRODUCTION

People spend most of their daily lives in traffic. Many people spend the day in the driver's seat or passenger seat, not even realizing that their lives are in danger. As a result of traffic accidents, not only drivers but also passengers lose their lives with a great rate. Although we did not leave our homes due to the pandemic in Turkey in 2020, nearly half a million recorded accidents occurred [7]. The biggest cause of accidents is non-compliance with the rules and lack of knowledge. Many new drivers, on the other hand, cannot go out on the road because they do not feel ready, even though they have a driver's license.

The genre of the game prepared for the research was chosen as serious game. This is because the primary purpose of serious games is effective learning [5]. Such games are used in areas like defense, education, scientific discovery, health, crisis management, engineering, and politics. They often involve a simulation of real-world events or processes designed to solve a problem. The simulation aims at problem-based learning by putting the player in the role of a problem solver, responding to realistic scenarios. AR technology changes the look of reality by adding device-generated virtual elements on top of real environmental elements. In this way, information about the real world surrounding the player and digital information can become interactive and provide powerful tools in many daily activities [8]. VR games, on the other hand, are effective in drawing the player into the game more effectively and tricking the brain. Thanks to immersive gaming technologies, the player feels more fluid, fascinating and motivating than normal games [5].

In this research, it was decided to consider the serious game in two parts. It was divided into two different games, an AR serious game about the information learned by reading the driving book can be accessed and run on their phone or tablet, and a VR serious game that will train more confident drivers and prepare them for any traffic scenario before real traffic. Thanks to the combination of AR and serious gaming concepts, an efficient learning alternative can be provided for the user by changing the perception of the real environment and providing the opportunity to interact with the content to

be learned in a more active and interesting way [9]. People get most of the information from their own eyes and, in most cases, perception is dominated by vision, visualization of information is important for efficient education systems [4]. It is aimed to prepare the drivers for all kinds of scenarios by creating the impression that there is a driver in the real vehicle, together with the VR and steering wheel. Steering wheel pedal set has been included in the game so that the driver can have a real driver experience in the second phase of the VR serious game. Considering that this game can be played in driving courses, it is kept wider in terms of hardware.

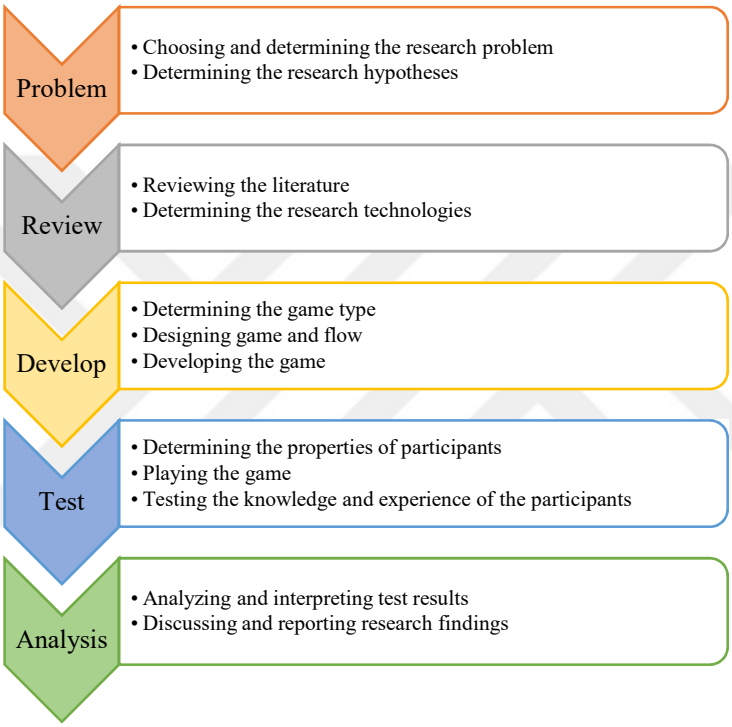

Figure 1.1 : The flow chart of research procedure.

As seen in Figure 1.1, the plan to be followed while planning the research is divided into 5 main groups, which are problem identification, literature review, development, testing and analysis.

While choosing the problem, the inadequacy of the traffic exams, which I know from my own experience, and the reduction of traffic accidents due to this were considered. As a result of the researches, it was seen that traffic injuries are one of the top 10 causes of death by the World Health Organization [1]. Therefore, as awareness on this issue increases and the permanence of information increases, drivers will be able to act with more self-confidence and knowing the rules in traffic. Since it is thought that traffic accidents will decrease due to this, it was decided to prepare a study on this subject. In

later research, it was seen that driving license were obtained through different procedures in many countries. For example, while there is no reaction test in driver's license exams in Turkey, some countries like England require a reaction test. The most important reason why the reaction test is a must is that it is a factor that affects the number of traffic accidents because of how quickly the driver reacts to the problem that comes across. However, the biggest shortcoming in each country was that drivers weren't prepared for all scenarios before getting their licenses. While conducting the research, it was decided to make a game that would both teach the traffic rules and prepare the drivers for all kinds of scenarios in order to prepare the drivers for traffic.

While determining the technological aspect of the research and the genre of the game, it was decided to divide into two main phases. The first phase of the research is the game design in which the information in the book is easy to access and visualized. The second phase is a second game design that will prepare the driver candidates for every condition in traffic. While choosing the game type, serious games have been chosen so that the player takes the game seriously and thinks it is for educational purposes, not entertainment. In the first phase, augmented reality technology was chosen to visualize some of the information in the book and make it easy for everyone to access. Today, almost everyone's phone can run augmented reality applications. In the second phase, it was planned to use it in driving courses and the choice of technology was chosen more advanced. VR and steering wheel systems are used.

The first main purpose of the research is to show that individuals who have a license gain the right to drive without having enough knowledge and experience. For this, it is expected to get a minimum of 5 points out of 10 in the pre-tests of the AR game. While 5 points indicate that the player has average knowledge, if it is taken below 5 points, it will be proven that the player's knowledge is exceedingly inadequate. In order to test the knowledge learned through traditional methods, tests will be conducted with drivers who have had less than 6 years of license and whose knowledge we think is fresh. It is thought that the game made with AR will be interesting and entertaining. The hypothesis that AR is effective and permanent on learning will be strengthened. At the same time, an evaluation will be made at the end of the game for the points that the players will get and the mistakes they will make in the VR game. At the end of this evaluation, it is expected to get at least 70 points out of 100 points. However, it is thought that there will be individuals with a driver's license under 70

points. In this case, the hypothesis that drivers who have a license but who are incompetent are in traffic and that the risk of causing an accident is high will be proven.

Although it is known that reaction times are very important to prevent accidents, there is no such criterion for obtaining a driver's license in Turkey. A reaction test will be conducted within the VR game for licensed individuals. It is known that reaction times decrease with practice. It is also aimed to test the reaction improvement status for driver candidates with the help of this serious game. VR game tests are primarily intended to be tested for licensed gamers and non-gamers. It is thought that the game will be tested on driver candidates in future studies after the feedback about the car physics and the game. Gamers and non-gamers are expected to find the game interesting and prefer the expanded version of the game to prepare for the driving license exams. While the gamer group is expected to find the game interesting and useful, it is thought that the approach of non-gamers to the game may be more hesitant. In the tests planned with the drivers, it is thought that the experienced drivers will find the game insufficient in terms of self-development. However, inexperienced drivers are expected to think that they are improving themselves with the game. Inexperienced or game drivers are expected to prefer VR when asked whether they would like to practice with the VR game if they have to get their license again.

1.1 Purpose of Thesis

This research was conducted with the aim of reducing traffic accidents, which are among the top 10 causes of death, announced by the World Health Organization. According to striking statistic revealed by WHO report [2] is that the countries where 90% of the deaths in traffic accidents occur in the world are the countries with low-income and medium-income and the total number of registered vehicles is 54% of the number of registered vehicles in the world. Turkey, where the research was conducted, is one of these countries mentioned by WHO. In addition, the WHO report also mentions the reasons why most accidents occur in these countries. Two of these reasons are poor planning in the highway networks and drivers who have a license without being adequately tested. The first main purpose of the research is to show that individuals who have a license gain the right to drive without having enough knowledge and experience.

In many European countries such as Austria, Germany and UK, which are high-income countries mentioned in the WHO report, the psycho-motor skills of the drivers are examined first with tests called ‘psychological assessment’, then scales regarding their attitudes and behaviors related to traffic are applied, and finally an interview is made with the person. As a result of these three evaluations, a decision is made about whether the person has safe driving skills [10] [11]. In developed countries, it is not enough to just pass the driver’s exams in order to have a driving license. It is aimed to set these standard procedures and to evaluate reaction time and candidate's behavior with the serious game in low-income and middle-income countries. However, behavioral evaluation was not taken into account in this thesis, which is the first part of this research. It will be added in future studies.

It is aimed to use the game not only during the driver's license exams, but also to practice a lot during the preparation phase. Thus, it is aimed that driver candidates are more consciously prepared for situations that they are not likely to encounter in traditional exams, but they may encounter in real traffic life. At the end of the game, it is to investigate whether they want to have a license with virtual games, where they can be better prepared for all scenarios, or with the traditional exam method. In addition, it is aimed to increase the permanence of the information learned from the book by turning it into a AR serious game to visualize.

1.2 Hypothesis

It is thought that with these thesis games, it will be shown that the knowledge of drivers who have licenses is not permanent and that most of them are not ready to go into traffic. It is also known that there are many drivers in our country who cannot drive even though they have a driver's license. It is thought that these drivers, who cannot drive, will feel more self-confident with the game. It is expected that even the knowledge of drivers who have just given the test exam are not permanent, although the information asked is that they encounter most often from the information in the book. It is expected that this information is more permanence with the AR serious game. In the VR serious game, the gamer group is expected to get used to the game faster. While more experienced drivers are expected to have higher game scores, these drivers are expected to feel that they haven't improved their driving skills with the game. Regardless of the gamer group or the non-gamer group, both groups are

expected to think that VR gaming would be a good practice to be a driver. In addition, it is expected that some driver will make mistakes due to the navigation errors that will be added to the game due to accidents as a result of navigation and wayfinding. In reaction tests, which are not performed in Turkey, it is expected that drivers with slow reaction times will be encountered. A slight improvement is expected between the first and the last of the reaction times. Drivers are also expected to find it fun and motivating to play with VR and the steering wheel.

2. LITERATURE REVIEW

2.1 Immersive Technologies

Immersive technology is used to describe technology that aims to replicate the physical world via the use of a digital or virtual world by generating a sensory environment, hence producing a sense of immersion. Immersive Technology is any technology that utilizes the 360-degree area to expand or create a new world. As a result, viewers may see the material in any orientation.

In immersive technologies, users are completely immersed in a 3D digital world and feel like they are a part of this world. These technologies, which have the potential to provide ideal environments to concretize abstract concepts, have become one of the topics of interest to educational technology researchers today. Recent research on its use in education claims that this technology may contribute positively to students' learning outcomes in the future.

Immersive technology is used in a variety of fields, including retail and e-commerce [12], art [13], entertainment and video games, military, education [14] [15], and medical [16]. It is also gaining traction in the non-profit sector, particularly in fields such as disaster relief and conservation, due to its ability to immerse users in situations that elicit more of a real-world experience than a static image, thereby creating a stronger emotional connection with the situation being viewed. As virtual reality gets more prevalent, it is likely to infect other sectors.

Through Cisco's research [17], six differentiators are identified in Figure 2.1. These differentiators enable immersive technology to create experiences that are superior to those available on a phone or in two dimensions. Experiences and applications can incorporate all of these differentiators or just one. The first distinguishing factor concerns things, contents, and goods. Applications or games in which the user or player is focused on a three-dimensional item, such as an automobile or a product. Samples of this differentiator are product design applications, health and scientific applications or games. The second of these differentiators is about immersive

environments and simulations. Applications or games that transport users to digitally produced settings and circumstances, or to locales that are otherwise unavailable due to expense or safety concerns. This is applicable to military, educational, architectural, and IoT applications. The third of these distinguishing factors is related to visuals. Visualizations can be used to visualize data, networks, or molecules. It enables the physical and manipulable representation of abstract data. Additionally, it has the ability to provide a new visual dimension for comprehending complicated data sets or statistical reports that are far more difficult to comprehend in 2D. Thus, this is applicable to financial, information technology, and big data applications. Another distinguishing feature is the use of overlays and annotations. It is used to superimpose two-dimensional data and augmentations on real-world objects. This technology is used in a variety of industries, including manufacturing, oil & gas, and healthcare. Another point of differentiation is social presence. It enables the advancement of real-time collaboration by allowing employees to work alongside one another as if they were co-located, but being physically scattered. It makes use of science fiction to illustrate ideas such as the Jedi Council in the Star Wars films. The final distinguishing factor is natural user interfaces. It enables new modes of interaction with apps and information by combining 3D controllers, hand tracking, and speech interfaces with chatbots and artificial intelligence. It is used in science fiction films including Minority Report, Iron Man, and Avatar.

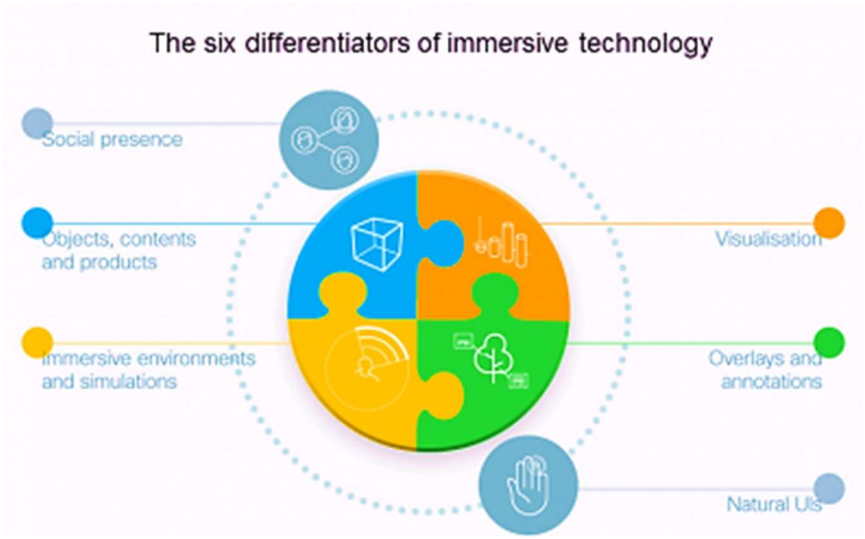

Figure 2.1 : The six differentiators of immersive technology **[17]**.

Immersive technologies with fancy names that are extending our reality. The different types of Immersive Technology are 360, VR, AR, MR, and XR.

2.1.1 Extended reality

Extended reality (XR) is a catch-all phrase that refers to the complete range of immersive technologies (VR, AR, MR). As seen in Figure 2.2, XR is supported by three pillars, with 'X' serving as a variable for reality kinds. This concept incorporates the three processes, and it is their growth and confluence that has resulted in the emergence of XR. It is a broad term that encompasses anything from "totally real" to "totally virtual." Numerous businesses worldwide, including those in the gaming industry, healthcare, engineering, entertainment, real estate, retail, and the military, are already capitalizing on the technology.

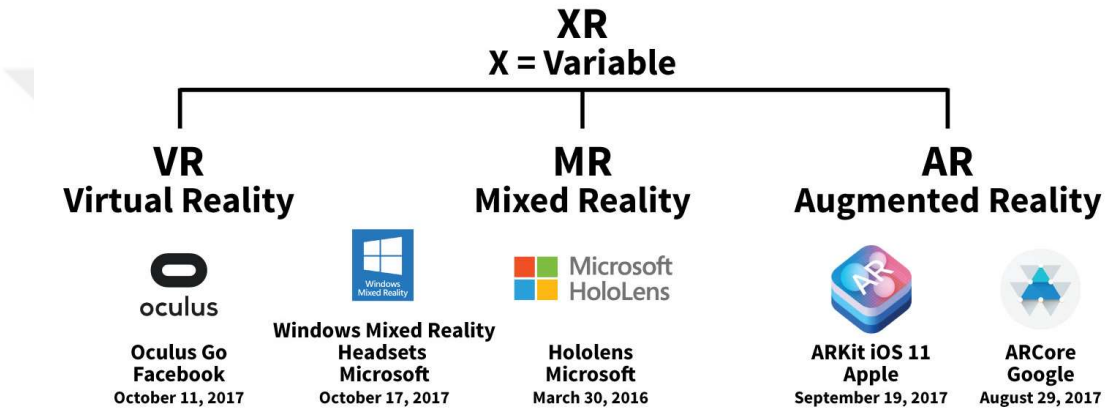

Figure 2.2 : XR spectrum.

Figure 2.3 : The differences between VR, AR, and MR **[18]**.

While they are all fascinating technologies with the same goal of connecting the virtual and physical worlds, they each have unique properties. As seen inTable 2.1, the key difference between VR and AR is that VR users enjoy a totally virtual experience, whereas AR users have virtual features added to their real-world experience. MR users can engage with the new virtual elements throughout their real-world experiences.

Another difference is that, whereas VR and AR have grown considerably more accessible to ordinary users over the last decade, and we continue to see new adaptations on a daily basis, MR is still mostly used by major organizations. While the majority of virtual reality and augmented reality applications run on smartphones, MR requires additional processing power.

Table 2.1 : Comparison of immersive technologies.

Comparison factors	VR	AR	MR
Is the user aware of the real world?	NO	YES	YES
Can the user interact with the real and virtual world in real-time?	NO	YES	YES
Can real and virtual contents interact with each other in real-time?	NO	NO	YES
The main environment	Virtual	Real	Real

2.1.2 Augmented reality

As seen in Figure 2.3, augmented reality (AR) is a sort of immersive technology in which digital visuals are superimposed on the actual environment. This implies that users of augmented reality are not totally cut off from the outside world. Rather than that, augmented reality expands reality. Caudel and Mizell [19] used the phrase augmented reality to refer to a heads-up, see-through display they created. According to Caudel and Mizell, this technology is utilized to augment the user's visual field. As a result, this technology is referred to as augmented reality. According to Azuma [20], augmented reality is a system that possesses three characteristics: the capacity to mix actual and virtual items, real-time interaction, and the utilization of three-dimensional objects. It is critical to remember that augmented reality encompasses more than the visual sense; it has the ability to encompass all senses, including sound, touch, and smell [21].

AR gives an interactive experience of the actual world by bridging the divide between the virtual and real worlds. It adds computer-generated information such as images, music, and video to actual world items. There are essentially three sorts of displays that may be used to interact with augmented reality systems: portable, head-worn, and spatial [22]. The many types of screens and hardware used to enhance reality each have their own set of advantages and disadvantages.

From its early days in large enterprises, augmented reality has now made its way to our cellphones. The mobile augmented reality world is exploding in popularity, as smartphones now include suitable hardware and sufficient computing power to run AR-based applications. Snapchat Filters is an excellent example of augmented reality [23]. Snapchat Filters allow you to superimpose digital photos of a dog, kitten, or movie celebrity onto your face. Another well-known example is Pokemon Go, which allows players to go around their area with their mobile phones in search of Pokemon that are superimposed over the surrounding environment [24]. Even businesses like Ikea [25] have their own augmented reality applications that allow users to select a product (such as a piece of furniture) and digitally place it in their homes, as seen in Figure 2.4. Essentially, it enables consumers to test a product prior to making a purchase.

There are primarily two forms of augmented reality: marker-based and markerless. A trigger sign or marker is necessary in marker-based augmented reality applications to initiate the augmented experience. Additionally, the device must not be rotated away from the marker in order for the augmented item to remain visible. The marker can be a QR code-like structure or any other distinctive design that an augmented reality software can identify and, once identified, the app begins displaying the augmented content over it. Markerless augmented reality is a more sophisticated form of the marker-based augmented reality technology. It displays the augmented content by utilizing the device's camera, GPS, and other sensors such as the accelerometer and compass. Unlike marker-based augmented reality, the augmented item maintains its position even when the smartphone is turned away. Additionally, markerless AR comes in three flavors: location-based AR, such as Pokemon Go, projection-based AR, such as Cicret Bracelets, and superimposition-based AR, such as the Marshall app in Figure 2.5, which allows users to preview which color will look great before actually painting the wall.

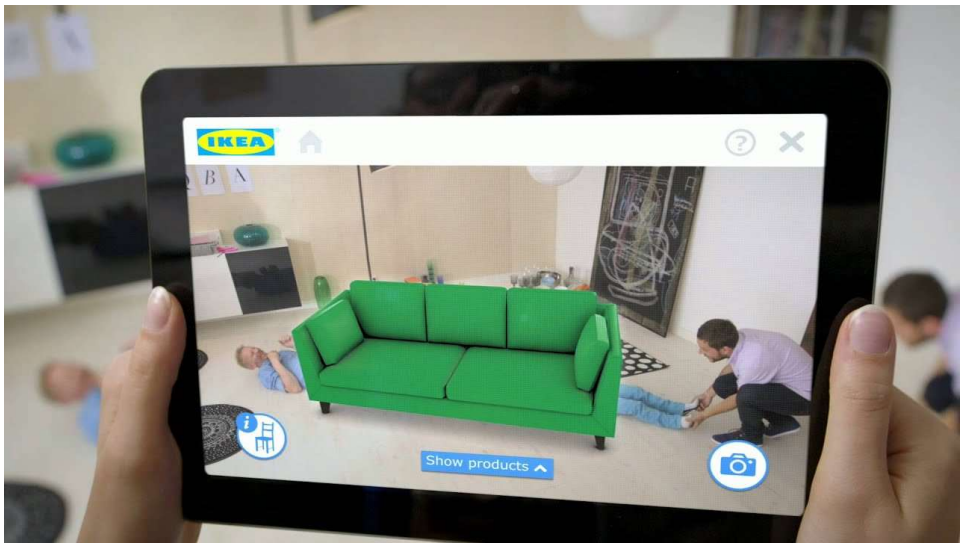

Figure 2.4 : Ikea AR app.

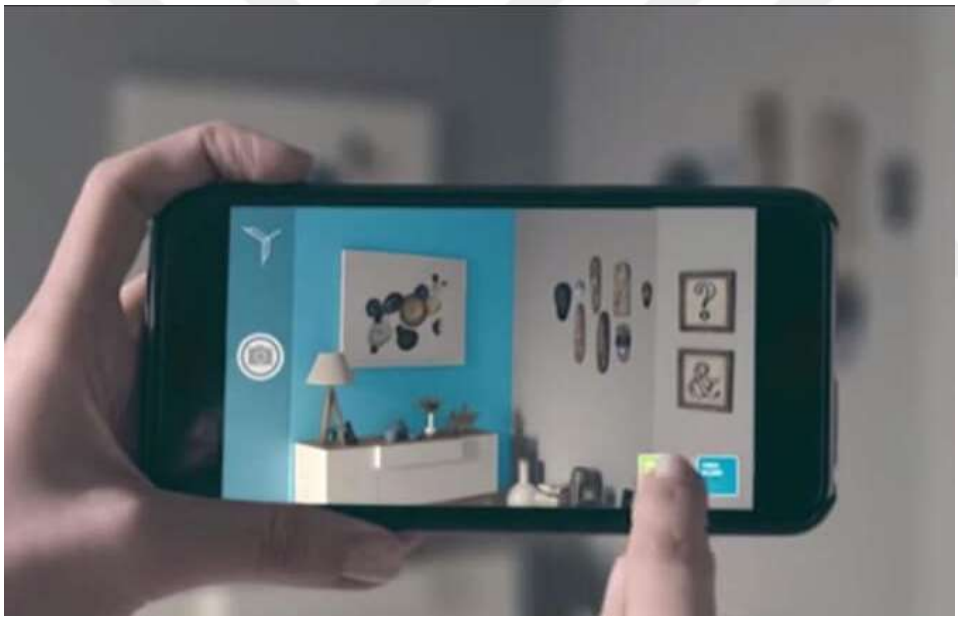

Figure 2.5 : Marshall AR app.

2.1.2.1 Popular augmented reality software development kits

In this section, the popular SDKs used to build AR applications and games are examined. There are four popular SDKs, which are: ARKit, ARCore, ARFoundation, and Vuforia. The AR serious game in this thesis was made using ARFoundation. The reason why I choose it will be explained in the ARFoundation section.

ARKit

ARKit [26] is the AR development framework for IOS devices. It enables you to integrate the camera and motion abilities of an iOS smartphone into your app or game in order to create augmented reality experiences. ARKit simplifies the process of creating an augmented reality experience by combining device motion tracking, camera scene capture, powerful scene processing, and display conveniences. With these technologies, developers may create a variety of augmented reality experiences by utilizing the front or back camera of an iOS smartphone.

ARKit adds a depth API, allowing developers to access detailed depth data collected by iOS devices. Location anchors make use of the higher-resolution data in Apple Maps to position augmented reality experiences in an iOS device's applications or games at a precise location in the world. Additionally, there are several features, such as [26]:

- World tracking
- Geotracking
- Motion tracking
- Image tracking
- Object detection
- Orientation tracking
- Positional tracking
- Environmental understanding
- Light estimation
- Multiple face tracking
- People occlusion

ARCore

ARCore [27] is a software development kit for Android devices developed by Google. It is Google's platform for developing augmented reality experiences. ARCore enables your phone to detect its environment, comprehend the world, and interact with data by utilizing a variety of APIs. ARCore is compatible with a broad range of certified Android smartphones running Android 7.0 (Nougat) or later. ARCore is fundamentally

engaged in two tasks: monitoring the mobile device's position as it travels and developing its own understanding of the actual environment.

It offers a depth API, which enables access to the comprehensive depth data collected by Android devices. Additionally, it is used to locate augmented reality experiences at a specific location in the world via Android smartphone apps or games. Additionally, there are several features, such as [27]:

- Motion tracking
- Image tracking
- Object detection
- Orientation tracking
- Positional tracking
- Depth understanding
- Environmental understanding
- Light estimation
- Sharing

ARFoundation

ARFoundation developed by Unity [28], allows developers to work with AR platforms in a multi-platform way. It is basically an abstraction layer for ARCore and ARKit. As seen in Figure 2.6, the AR Foundation usually supports ARCore and ARKit capabilities, as well as devices running Android 7.0 or later and iOS 11.0 or later. Additional support is provided by the framework, which enables developers to directly use native ARCore and ARKit functionalities via their respective Unity packages.

The augmented reality foundation consists of a collection of MonoBehaviors and APIs for interacting with devices that cover the following concepts:

- Vertical and horizontal plane detection
- Feature point detection
- Light estimation
- Hit testing

- AR Anchors
- Image Tracking
- 3D object tracking
- Environment Probes
- World Maps
- Face Tracking
- Cloud Anchors
- AR Remote
- Lightweight Render Pipeline

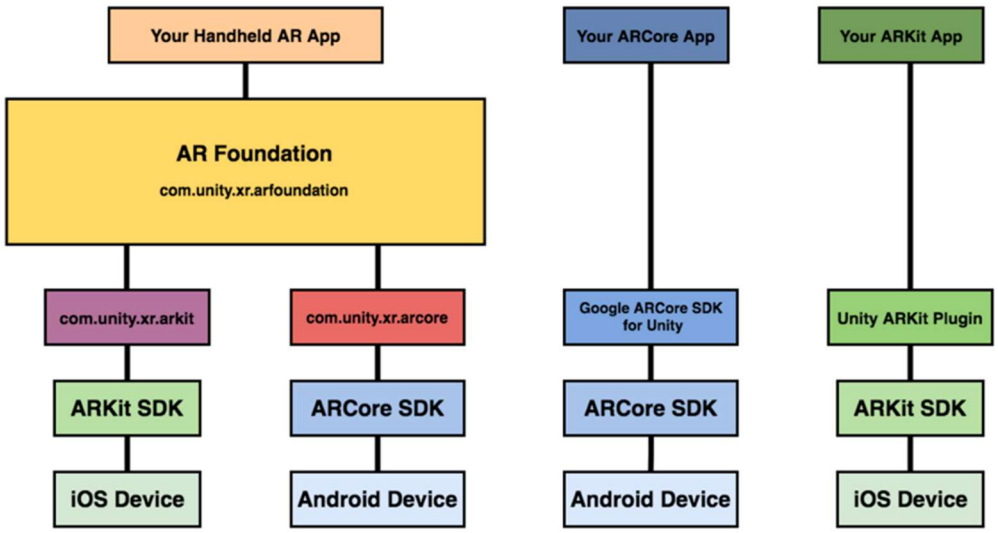

Figure 2.6 : Comparing ARCore, ARKit, and ARFoundation.

Vuforia

Vuforia [29] is an augmented reality platform that is primarily used for object and image tracking in augmented reality development. As seen in Figure 2.7, Vuforia enables developers to submit models, pictures, object scans, and other support target kinds for its computer vision algorithms to recognize. The platform, however, is confined to detecting items from supplied recognition targets. As such, Vuforia

performs best when used in conjunction with ARCore, ARKit, or the AR Foundation via the Vuforia Engine library.

Vuforia from PTC is an excellent development system for business-oriented projects, particularly those involving the manufacture of augmented reality products [29]. The versatile development engine of the application has already been utilized to create novel processes in a variety of sectors. Additionally, technologies such as Vuforia Expert Capture and Vuforia Chalk make it simple to build augmented reality instructions and collaborative sessions, further increasing worker performance.

Vuforia applications are best solution in industry such heavy-duty for:

- Augmenting work instructions in the factory
- Real-world training proven to improve skills and reduce downtime
- Field service that helps ensure more service tickets are completed during the first visit
- Tools to help customers envision using products in their own facilities.

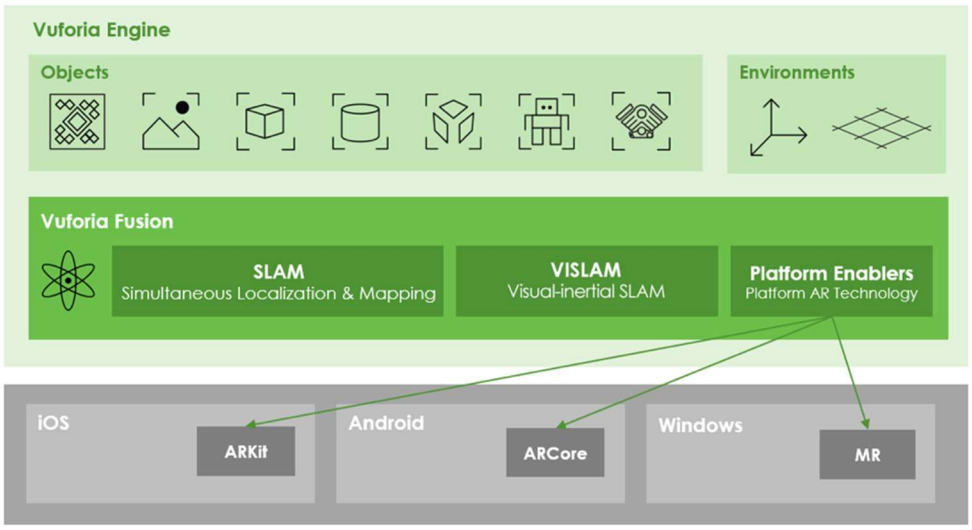

Figure 2.7 : Vuforia Engine.

2.1.2.2 Comparing popular augmented reality software development kits

The previous section examined four different platforms from industry leaders. There is no unambiguous winner. All four platforms are more than capable of providing you with the essential tools for developing augmented reality experiences. Finally, your choice is entirely dependent on your unique requirements and circumstances - various

platforms are better suited to different types of projects. Additionally, Apple is continually improving and adding new capabilities to ARKit, which makes it a favorite choice among developers. However, ARCore is a free technology that benefits from cross-platform interoperability. Vuforia is more expensive, but it has the benefit of combining and using the capabilities of ARKit and ARCore, as well as being cross-platform.

While AR Foundation is not compatible with all devices that enable augmented reality, it is an excellent choice for adding functionality shared by ARCore and ARKit. In light of the comparison in Table 2.2, the AR Foundation was selected for usage in this augmented reality serious game. Rather than establishing two distinct projects for iOS and Android, I would be able to create a single platform-independent app this way. The AR Foundation enables us to leverage both the ARKit and ARCore frameworks, as well as Unity3D's rich capabilities and asset marketplace.

Table 2.2 : Comparison of features of major toolkits for mobile AR.

Comparison factors	ARCore	ARKit	AR Foundation	Vuforia
Devices	Android 7.0+ and IOS 11.0+	IOS 11.0+	Android 7.0+ and IOS 11.0+	Android 6.0+ and IOS 9.0+
Features	Points, plane detection, pose, light estimation, anchors, trackables, image tracking, face tracking, object occlusion, cloud anchors	Points, plane detection, AR world map, light estimation, anchors, face tracking, motion capture, people occlusion, collaborative sessions	Provides features included in ARCore and ARKit	Predefined images, models, objects, 3D scans

2.1.3 Virtual reality

Virtual reality (VR) is a term that refers to the use of computer modeling and simulation to enable a person to engage with a three-dimensional (3-D) visual or other sensory world that has been created artificially. VR applications immerse the user in a

computer-generated environment that resembles reality by utilizing interactive devices that transmit and receive data and are worn as goggles, headsets, gloves, or body suits. In a typical virtual reality experience, a user wearing a helmet equipped with a stereoscopic screen views animated visuals of a simulated environment. The illusion of "being there" , or presence, is created using motion sensors that detect the user's motions and modify the view on the screen in real time (at the instant the user moves). Note that this is an effect, not an illusion. Thus, a user can walk around a simulated suite of rooms, encountering various vistas and perspectives that are convincingly tied to his own head turns and steps. The user can even pick up and control objects he sees in the virtual environment while wearing data gloves outfitted with force-feedback devices that offer the feeling of touch. If the objects in the environment interact with you then the effect of spatial presence is greatly heightened.

Many people use the term "virtual" to refer to something that is not real, while "reality" refers to the real world. As a result, an oxymoron is created [30]. However, the correct meaning of virtual is "to have the effect of being such without actually being such". "Reality" is defined as "the property of being real," while "real" is defined as "to have tangible existence". By these definitions, "virtual reality" implies "to have the effect of tangible presence without actually having it," which is precisely what a competent virtual reality system accomplishes. There is no obligation for the virtual environment to be identical to the physical one. VR needs to not only look real but feel real. Virtual reality software development tools can make that happen.

Virtual reality's key need is that the scene be re-rendered from your current point of view as you move [30]. The frame rate at which a scene must be re-rendered is application-dependent. The other criteria is that interactive items in the environment respond immediately to your requests. How long a delay can be tolerated is application-dependent. Prolonged delays result in a significant reduction in the ability to control virtual objects.

The most instantly recognizable component of virtual reality is the head-mounted display (HMD). Human beings are visual creatures, and the primary distinction between immersive Virtual Reality systems and standard user interfaces is frequently display technology. Oculus Rift, Samsung Gear VR, HTC Vive, Google Daydream View, and Google Cardboard are all notable instances of VR headsets. These headsets block out the outside environment and provide video to each eye, enabling depth

perception. This technology is then strengthened by head and body tracking to establish a connection between the virtual and real worlds.

DoF is an abbreviation for degrees of freedom [31]. This is a term that refers to motion about or along an axis. In virtual reality, the term "DoF" refers to a tracked axis. The term "tracking" refers to the capability of hardware to detect changes in angle or distance on the axis. 3-DoF refers to orientation tracking or rotational movement [31]. This means that the three rotational axes around which an object can be rotated are tracked. This is possible with mobile virtual reality headsets and standalone virtual reality headsets such as the new Oculus Go. When you turn your head while wearing a headset, it detects the angle shift of these axes and allows you to gaze around the surroundings. 6-DoF refers to tracking of both the headset's position and orientation [31]. Movement can be tracked along three axes: x, y, and z, and any combination of these three axes can be used to depict motion; this is referred to as a vector. If you were to take a step forward while wearing a headset, for example, external hardware would detect the headset moving in the x axis. If you jumped immediately, the headset would shift vertically in the y axis. The difference between three degrees of freedom and six degrees of freedom is shown in Figure 2.8.

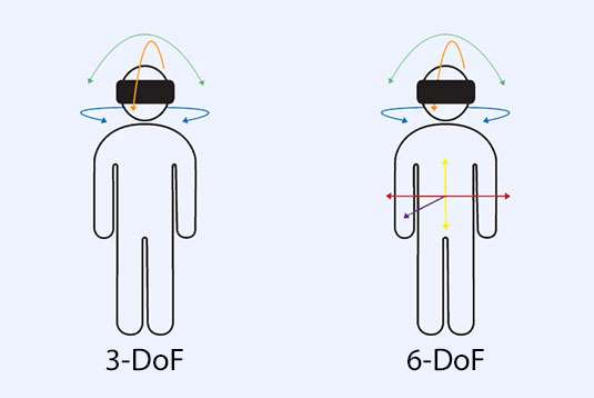

Figure 2.8 : The difference between 3-DoF (rotational movement) and 6-DoF (rotational and translational movement) with a VR headset **[32]**.

Examples of 3-DoF VR headsets:

- Google Cardboard
- Oculus Go
- Merge VR

- Samsung Gear VR
- Google Daydream

Examples of 6-DoF VR headsets:

- Oculus Rift
- Oculus Quest 2
- HTC Vive
- Windows Mixed Reality

2.1.3.1 Mobile virtual reality SDKs

Virtual reality, which immerses users in a computer-generated digital environment, requires an expensive, powerful PC to function. From Steve Jobs to Mark Zuckerberg, all of the greats think that for a technology to have a meaningful influence, it must reach the widest potential audience [33]. So, there are more economical choices available, such as the Gear VR and Google Daydream View, which function by connecting your phone to a low-cost headpiece. Mobile VR developers may save far more money than makers of room-scale VR applications, provide an immersive experience to users, and reach the biggest potential audience. Desktop VR outperforms mobile VR, particularly for business VR applications and VR arcades.

Mobile headsets are shells equipped with lenses that you insert your smartphone into. The lenses divide the screen into two pictures for the eyes, thereby transforming your smartphone into a virtual reality gadget. Due to the fact that all processing occurs on your phone, there is no need to attach any cables to the headset. However, because phones are not meant for VR, they are unable to deliver the greatest visual experiences and are weak in comparison to PC or game console-based VR. Additionally, mobile VR does not presently provide positional tracking. 3-DoF is used in mobile VR devices.

GoogleVR SDK

The GoogleVR SDK makes it simple to port your 3D project to Android and iOS VR. Google provides two virtual reality platforms for mobile devices: Daydream and Cardboard. Daydream [34] is a high-quality mobile virtual reality platform that is suited for immersive, longer-form experiences. Daydream Standalone [35] is a strong,

immersive mobile VR experience that does not require a phone. Cardboard's low-cost, lightweight technology makes it ideal for brief VR encounters [36].

Daydream has the following characteristics [34]:

- Mobile VR with high resolution and minimal latency.
- Affordably priced gear, including a comfortable headgear and a standardized controller that is easy for people to use and expressive for developers.
- Effective tools for developing and fine-tuning virtual reality experiences in the development environment of your choosing.

Cardboard has the following characteristics [36]:

- Support for Android and iOS devices.
- Viewers that are affordable and offer one-button input and gaze-based user interfaces.
- SDKs that make it simple to create VR experiences in your preferred development environment.

Daydream Standalone has the following features [35]:

- Increased CPU and cooling performance, which translates into more powerful applications that run without any heat or performance difficulties.
- WorldSense enables accurate six-degree-of-freedom inside-out tracking with sub-cm resolution.
- High-resolution, VR-optimized panels with a wider field of view.

Oculus Mobile SDK

Oculus Mobile SDK [37] comprises tools and libraries for both C/C++ development for Oculus, as well as for Samsung Gear VR. Unity and Unreal both include built-in support for developing Oculus Android VR applications.

The contents of the Oculus Mobile SDK [37]:

- VrApi enables the integration of third-party engines (not required for Unity or Unreal).

- Native application framework for rapidly prototyping and developing high-performance virtual reality apps.
- Native project examples and source code to serve as a reference model for developing your own virtual reality apps.
- Native development-related tools and resources.

2.1.3.2 PC, console and standalone virtual reality SDKs

These high end headsets are 6-DoF headsets and allow users to move in a mapped out area. At a higher price range, PC headsets deliver a more immersive experience. The majority of these headsets are tethered through wires that connect the headset to an external piece of hardware that provides power. The dedicated display, together with integrated motion sensors and an external camera tracker, significantly increases image and sound quality while also offering head tracking.

A standalone VR headset, or all-in-one VR headset, has everything necessary to convince you that you're in another world. It is a single piece of integrated hardware, similar to a phone or tablet. Enjoy high-quality VR anywhere you choose, without the need for wires, a phone, or a computer. Standalones are completely wireless. It's critical to remember, however, that not all wireless virtual reality headsets are self-contained. Certain systems transmit data wirelessly from nearby computers or consoles, while others rely on cable packs that attach to clothes or slip into a pocket.

OpenVR SDK

OpenXR is a royalty-free open standard developed by the Khronos Group for developing high-performance virtual reality applications that operate on a variety of platforms [38]. OpenXR enables applications and engines to operate on any system that exposes the OpenXR APIs, including WebXR. Unreal Engine, Unity, Godot, and Blender are all capable of developing OpenXR applications. OpenXR aims to simplify the development of augmented and virtual reality software by enabling applications to run on a broader range of hardware platforms without having to port or rewrite their code, thereby providing platform vendors supporting OpenXR with access to a broader range of applications (see in Figure 2.9). Which means that anyone working on XR technologies, from large organizations to indie developers and artists, now has a common standard called OpenXR. This standard will be followed by hardware vendors who will write drivers to support OpenXR apps, OS platform developers who will

support apps written in OpenXR standards, and engines that will support OpenXR export.

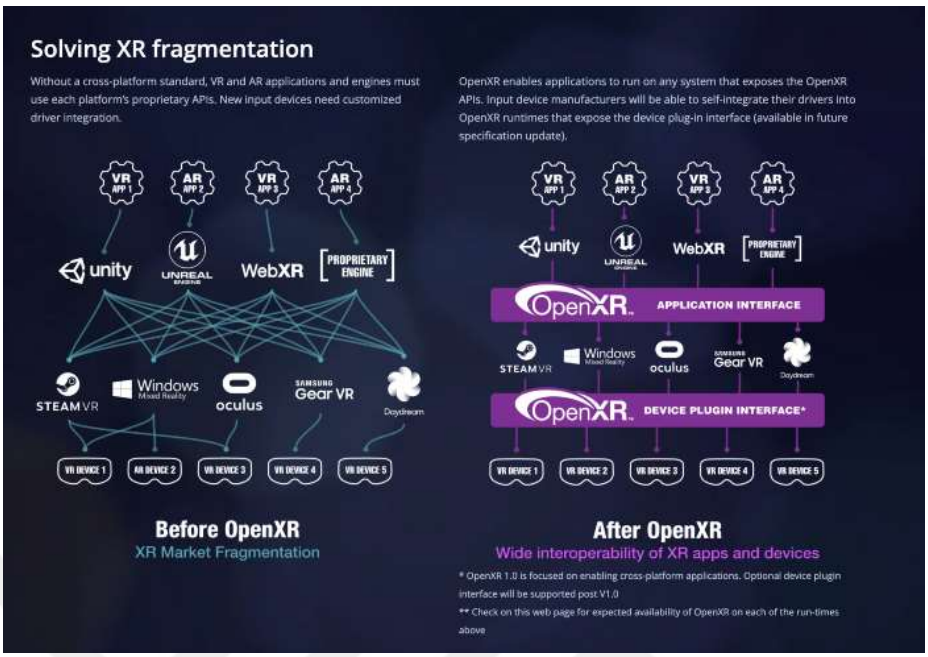

Figure 2.9 : XR app development process before and after OpenXR.

Oculus VR SDK

Oculus SDK [39] is considered to be the best VR SDK for Oculus headsets since it includes various engine-specific kits, samples, assets as well as audio packages in order to help build VR apps very quickly and easily in your preferred development environment. This VR dev kit brings along lots of features and handles many issues of VR content like optical distortion and rendering techniques. There is a great deal of value within the full Oculus Integration Package, including the Oculus Avatar SDK, Platform Services, utilities and more. For many devs, a more streamlined package would include: The core VR folder, Audiomanager, Platform, OculusProjectConfig.asset, and the Spatializer.

PSVR SDK

The PSVR SDK [40] enables developers to create apps and games for the Sony PlayStation VR. It comes along with features like 360-degree vision, gorgeous images, fantastic audio, and a camera. These are just some of the ways it helps you to fully immerse yourself in its hyper-real 3D environment, along with the impressive VR games it comes with. To build applications and games for Sony PlayStation VR and

gain access to the PSVR development kit, developers must first register as developers. To register and obtain this Sony SDK, you must pay.

2.1.4 Mixed reality

As the name indicates, Mixed Reality combines augmented and virtual reality [41]. Another possible explanation is because it is also referred to as Hybrid Reality as it combines real-world and digital aspects. The term Mixed Reality was introduced in a 1994 paper by Paul Milgram and Fumio Kishino, "A Taxonomy of Mixed Reality Visual Displays". While MR is primarily a technology for blending the physical and virtual worlds, the greatest benefit is in having realistic interactions between the users and digital items.

MR equipment should be utilized while working with a digital device to get an all-encompassing immersive experience. In the grand scheme of things, Microsoft's HoloLens is one of these kinds of gadgets. By utilizing these transparent MR devices and other interactive tools, such as gaze, voice, or gesture detection, users may react to digital things based on their activities. In addition to the actual and virtual environments, they may engage with both at the same time. Users may also utilize their own motions, gazing or blinking, and a variety of other input methods, instead of relying solely on remote control devices, smart glasses, or smartphones. Additionally, these interactions and the believable simulations enhance the user's overall MR experience, making it feel more like an actual setting. This is the newest immersive technology available from these three realities, and it is also the least used. Although it does have a significant impact on our everyday lives, it is not yet incorporated into many things we do on a daily basis.

Immersive communication experiences enabled by MR technology enable more efficient collaboration between individuals. Employees may don headphones and begin collaborating immediately without being cut off from the outside world. The finest example for this is Skype for Microsoft HoloLens [42]. Mixed reality technology enables industrial processes to run more smoothly by offering real-time guidance to employees. Workers may see holographic instructions directly in front of their eyes, ensuring that they are always aware of their responsibilities. This significantly decreases the possibility of human mistake and enhances quality. Additionally, MR is advantageous for maintenance and repairs, especially in industries that need

knowledge and accuracy. Manufacturers have already begun conducting field trials of mixed reality technologies. Renault Trucks used MR to monitor and manage quality at one of its manufacturing facilities [43].

2.2 Serious Game

Serious games are those that serve a purpose other than enjoyment. They are utilized to aid in the process of learning and behavior modification. Serious gaming is employed in a variety of different fields, including education, healthcare, marketing, and a variety of other businesses and sectors. Serious games use instructional tactics, expertise, and structures, as well as gaming components, to impart certain skills, information, and attitudes. They are meant to address a variety of issues and provide both challenges and rewards. While there is nothing wrong with traditional ways, games provide us with a new means of transferring information and knowledge. Additionally, it is beneficial as a tool for the following reasons:

- **Increased engagement and immersion:** Because games are constructed in such a way, they always push the player to continue playing through the use of incentives, plot advancement, and other feedback mechanisms.
- **A secure environment in which to experiment:** In the real world, your actions have repercussions; occasionally, these repercussions include destroyed property or injured sentiments. Games establish a secure, virtual environment in which players can explore freely without fear of causing harm.
- **Positivity enhances learning:** It's entertaining! According to studies, pupils who utilize games to learn report experiencing more pleasant feelings. This results in a more enjoyable learning experience as compared to traditional and video-based methods of instruction.

2.2.1 Serious game samples

Knowledge transmission occurs in a variety of ways. At school, we are taught, we study literature in our spare time, and we exchange information with others. Occasionally, it is about less intriguing themes, and it becomes tough to maintain your attention. In this case, a serious game may be the answer. This is the case with Blok Out, a mixed-reality tour of Leeuwarden's 'Blokhuispoort' [44]. In Leeuwarden, the

Blokhuispoort is a museum with different activities. However, this site is steeped with history. Blok Out enables visitors to learn more about the Blokhuispoort and the people who were formerly imprisoned there. The serious game attempts to broaden your historical horizons as you explore the Blokhuispoort. You embark on a journey with the game's protagonist, Barend, the old key keeper of the Blokhuispoort. Barend has been rendered memoryless. By resurrecting the ancient jail, you restore Barend's memories. Throughout the mission, you'll need to solve a variety of puzzles and riddles. The game, which is recommended for youngsters aged eight and up, may be played on a smartphone.

It is critical to practice frequently when learning a new skill. A simulation is appropriate for some abilities. Consider a novice pilot who must master all of the cockpit's buttons. To effectively teach this, the cockpit and flight experience must be as realistic as feasible. Additionally, there are instances where the realism of the training environment is irrelevant as long as the proper action is taken. In this situation, a serious game is a viable option, as they are frequently more enjoyable to play, resulting in a superior outcome. They chose to employ a serious game for surgeons in training at the University Medical Center Groningen (UMCG). These surgeons must practice an average of 200 hours per year to maintain proficiency in their motor abilities. Previously, surgeons practiced using a simulator, but the UMCG discovered that the simulator was being used inefficiently. As a result, the UMCG created Underground [45], a serious game. Sari, the hero of the game, is tasked with rescuing her robot friend Sw4nk from the mines. The game provides an enjoyable and demanding environment for trainee surgeons to improve their motor abilities.

Changing behavior is challenging. According to research [46], it takes an average of 66 days to acquire new behaviors. A person must be exposed to the new behavior during this time period. This requires motivation. Games have engaging characters, an innovative gaming world, and multiplayer competitiveness. These features contribute to the enjoyment of gaming and, more significantly, the desire to continue playing. A healthy lifestyle is a behavioral modification that we all contemplate at some time. And we are all aware of how difficult it is to initiate and sustain change. The creators of the serious game Greenhabit [47] recognized this as well. Greenhabit is a game that makes maintaining a healthy lifestyle enjoyable. Greenhabit challenges players everyday on topics such as healthy diet, exercise, relaxation, positive thinking, and the

social environment. Players have 12 weeks to accomplish as many daily tasks as feasible. Naturally, this earns you points and badges, but it also earns you actual incentives, such as a free vegetable box from the neighborhood grocer. Players are exposed to behavioral modification for a longer length of time through the serious game. Additionally, because you only have to accomplish one challenge every day, altering your lifestyle becomes easier.

2.3 Game Engines

Game engines are critical for developing VR apps. Utilizing a game engine enables you to centralize all of your assets and provides a sophisticated editor for 3D objects. They work in conjunction with artist and designer tools to assist you in creating lifelike graphics and experiences. A virtual reality game engine, or VR game engine, provides a framework for game creators to create a virtual reality video game experience. A VR game engine frequently includes a virtual reality SDK that enables developers to create, produce, and test their games in virtual reality. These tools enable developers to design and edit three-dimensional characters as well as completely immersive three-dimensional experiences. Similar to game engine software, virtual reality game engines enable developers to focus on building an engaging product for the end user rather than wasting time connecting all the components of a gaming system. VR game engines fall under the same category as game engines, but are distinguished by the fact that they directly or indirectly support VR operating systems and hardware. Developers may use VR game engines to create games for a variety of platforms, including gaming consoles and smartphones. While certain virtual reality game engines are capable of creating augmented reality experiences, they should not be mistaken with augmented reality game engines, which enable developers to build augmented reality video game experiences that superimpose 3D objects on the actual environment.

2.3.1 Unity

Unity [48] is a widely used game creation platform that has been used to produce successful games such as Pokémon Go, Hearthstone, and Rimworld. It has a real-time gaming engine, high-fidelity visuals, and a plethora of integration options that can be used with a variety of VR headsets. This makes it a premier choice for developers who

want to produce VR apps and experiences. When using the Unity game engine, you have the option of using virtual reality mode so you can have a better idea of how your virtual world would look on your own headset.

It is widely known that Unity [48] is focused on game creation for mobile devices. However, it may also be used to build virtual reality solutions. Numerous organizations across several sectors have utilized it to build training and simulation, because it works well with all common VR platforms. With Unity, you'll get:

- A highly capable 3D editor.
- A variety of built-in design and artistic tools are supported as well as support for CAD design and drawing tools.
- Some of the collaboration capabilities that can streamline your workflow are shown below.

2.3.2 Unreal engine

Unreal Engine [49] is one of the most advanced real-time gaming engines and three-dimensional development tools available today. This is a very effective solution for developers that are trying to produce hyper-realistic interactive VR experiences on a large scale for multiple VR headsets. With Unreal Engine [49], teams get access to an advanced collection of VR software development tools. This will work with a wide range of VR technology. With Unreal Engine, you receive:

- You have access to C++ and/or Python scripts, so you may tailor the tool to your specific needs.
- The versatile editor is bolstered with a framework that allows for online multiplayer functionality.
- When you want to construct your own prototype quickly, use Blueprint visual programming.

2.3.3 CryEngine

CryEngine [50] is a well-known name in the world of game development. On the other hand, it is also a strong VR software development tool. It is compatible with a wide range of systems. CryEngine is designed with the goal of delivering the following features:

- Characters who have very stunning designs.
- Virtual reality program that can be utilized with their sandbox tools.
- Built-in audio solutions allow you to construct a completely immersive experience.

3. AN AUGMENTED REALITY SERIOUS GAME – TRAFFIC GUARD

3.1 Background and Motivation

Several studies have been demonstrate that AR technologies combined with serious educational games can significantly improve user learning. It has been demonstrated that AR games are used in the field of education and are effective in increasing knowledge. The AR virtual laboratory educational game and learning process in the field of chemistry was described as interesting, accepted, and immersive [51]. As a result of the data of another AR-based study on the composition of chemical substances, the researchers concluded that AR has a significant complementary learning effect and is more effective for low-achieving students than high-achieving students [52]. AR games on many different topics have been developed and tested in education.

Apart from the field of education, immersive technologies are used in the professionalization of novices in the industry [53]. Hands-on training for new workers to gain maintenance and assembly skills is important to a variety of industries. Simulating the training in order to stay away from the damages or dangers that may arise during the applied training is as important for the employees as it is beneficial for the companies. AR training applications have also been made, allowing the technician to interact with real-world objects and simultaneously access virtual information for guidance. As a result of these studies, it was observed that the number of errors that AR-trained technicians could not resolve was significantly less than that of conventionally-trained technicians [4]. The most important reason for this is that the AR game has the possibility to prepare the technician for all kinds of possible scenarios.

It has been found that games with immersive technology motivate players to try harder [54] and have a greater potential for motivation compared to a non-immersive game [5]. In the light of these researches, like the applications used to prepare technicians for many types of possible scenarios, it was thought that this research could prepare

the drivers for all kinds of scenarios and could make the information about the traffic more interesting and permanent with two separate games to be prepared as AR and VR. The most interesting part of the studies comparing the permanence of knowledge with traditional education was drawing conclusions based on the test made immediately after the education. Therefore, after the pre-test was conducted and the gaming experience was carried out in January 2020, it was decided to wait for a year before the players' knowledge was tested and to make a comparison about permanence without taking into account external factors.

3.2 Game Design

Before starting the game development, it was decided to choose a specific topic to further customize the topic during the design process. Traffic signs that we frequently encounter in our daily life and that give important information about the road were selected. Turkey, the researcher's own country, was chosen for this study. For scenarios where drivers can learn these signs and test themselves, the role to be given to the player in the serious game was to be the traffic guard of the city. In order to become the protector of the city, the player first had to go through the training phase and then start active duty. Therefore, the name of the game was given 'Traffic Guard' and a logo was designed as seen in Figure 3.1.

Figure 3.1 : The app icon of the Traffic Guard game.

The most crucial component underlying serious games, as indicated in section 2.2, is putting the player in a problem-solving position. When creating an AR game about traffic rules, this serious game feature is taken into consideration. In this game, the player is assigned to the position of traffic guard. As a result, the player is tasked with securing traffic and resolving traffic issues. Because of the player's role, the AR game is called 'Traffic Guard.' A training phase is assigned in the first stage, which teaches

traffic rules and signs in preparation for becoming a guard. The purpose of the traffic sign that the player clicked while walking about the city is explained at this point. Guards who successfully finish training are deployed to active duty. The second stage is the stage of testing the player. In this stage, the player investigates traffic complaints from various regions of the city on the spot, posts the necessary traffic signals to remedy the situation, and fixes the problem. As a result, it puts the knowledge gained in the first step into practice.

While naming the city created, the designer opted to merge city names from both the virtual world and the real world in order to convey the sense that the game is both a virtual world and a world related to the actual world. While thinking about virtual world city names, the designer was inspired by the city of Los Santos, which is well-known among both players and non-players of "Grand Theft Auto: San Andreas." Because this thesis topic is based on the current road traffic rules in Turkey, Istanbul was picked as one of the real-world cities. As a result, the city in the Traffic Guard game became known as 'Los Stambols.' Low-poly modeling was employed in the game's design to avoid any performance issues that can arise while playing on mobile phones. The city was designed using the 'City Adventure' asset [55], and traffic signs were created using 3D modeling. City Adventure [55] is a user-friendly build-it-yourself asset that includes all of the required components for creating high-quality modular town-related games. The reason this asset was picked is because it is ideal for mobile and AR. Figure 3.2 depicts a variety of building types, including an airport, a railway station, housing areas, garden houses, factories, banks, hotels, cafes, garages, gas stations, apartment buildings, post offices, pharmacies, skyscrapers, stadiums, tram stations. Aside from buildings, the asset includes a variety of vehicle types, including motorcycles, bicycles, buses, trucks, vans, trams, and automobiles.

Figure 3.2 : Los Stambols.

At the beginning of the game, the player can choose which mission to try. The task options are " Visual Guide" based on discovery learning and "Begin Active Duty" based on testing knowledge by earning points (see Figure 3.3).

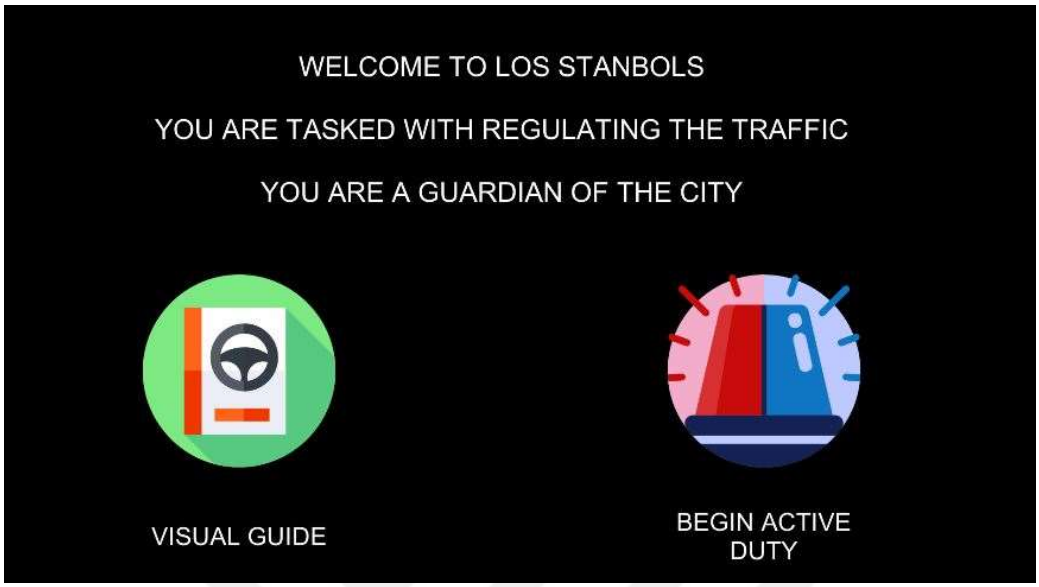

Figure 3.3 : Welcome Page on Traffic Guard game.

3.3 UI/UX

The UI and UX designs of a mobile game are elements that help make a difference by creating a unique value proposition to the game. A perfect balance of user interface (UI) and user experience (UX) helps them stay on your app for longer as well as get more users for the mobile app. UI/UX designs have evolved throughout the research so that users can do things easily and find the feature they are looking for easily. The screen designs have been tried to be simple and understandable so that players enjoy interacting in a convenient and easy way and can focus on the game. A significant portion of the research was devoted to usability assessment, as the app needs to be easy to learn and understand for most users to enjoy the benefits of the app.

As a first step, a short information text about the name of the city and their role in the game was added to the player as seen on the welcome screen in Figure 3.3. It was added as a result of users expressing their wishes for short information about the story of the game on the login screen during A/B tests. Another problem noticed during the A/B tests was that the process of returning to the main screen and re-entering the desired part of the game was extremely distracting and tiring when the city design was misplaced and wanted to be placed again. That’s why it was decided to transfer the

touch placement process to a button. It was decided to change the icon according to the meaning of the button, as seen in Figure 3.4, for its placement and to search for a place again, and the placement and removal of the city depended on the button.

There were no effects to show the location of their markers in the active-duty section. During the A/B tests, it has been made more remarkable with the particle effect, as users have difficulty in finding the focus and understanding that they will interact with the part.

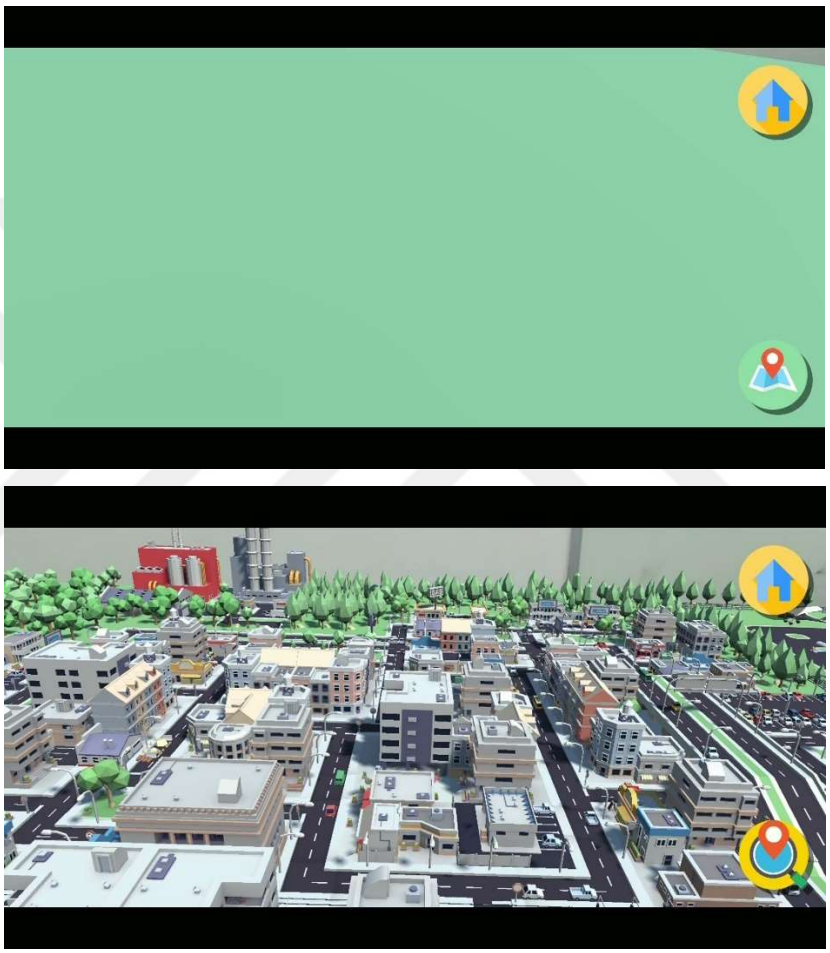

Figure 3.4 : The change of placement icons.

3.4 ARFoundation Setup

It was my biggest goal for the game to work and be accessible on all kinds of phones. Because of researcher's experience, it was certain that this game would be developed in the Unity3D game engine. In which AR technologies should be used, improvements were made with Vuforia first. At the time of working with Vuforia, it was not available as a package in Unity and was not advanced enough. In order to avoid two separate

development processes with ARCore and ARKit, AR Foundation was chosen, which provides the opportunity to use both SDKs from a single code.

Setting up and employing ARFoundation requires importing the ARFoundation package from the Unity Package Manager as shown in Figure 3.5. Also, either ARKit and ARCore packages are critical to include when building an AR game and pushing builds to both your Android and IOS devices. Importing ARKit and ARCore packages depends on your target deployment platform. If you want to deploy to IOS, you have to install ARKit. If you want to deploy to Android, you have to install ARCore.

In addition, AR Foundation requires configuring your Scene appropriately with two GameObjects and their related scripts: AR Session and AR Session Origin. ARSession controls the lifecycle of an AR session. It keeps getting updates from the subsystem to check if the session is still alive. ARSessionOrigin keeps your virtual objects in the correct position in AR environments. Firstly, the Main Camera is deleted from your Scene, because of using a special AR Camera. AR Session controls the lifecycle of an AR experience, enabling or disabling AR on the target platform. Also, AR Session component can be on any game object. If the Scene does not contain an AR Session, the game will not be able to track features in its environment. An AR session is a global construct. An ARSession component manages this global session, so multiple ARSession components will all try to manage the same global session. Also, some devices do not support AR experiences. Because of detecting whether AR is supported, AR Session component has a static coroutine that you can use as in the example code below. To determine whether the device is supported or whether the AR software is installed or whether the session is working, ‘ARSession.state’ is used. Also, when the current state of the session changes, an event called as ARSession.stateChanged is triggered.

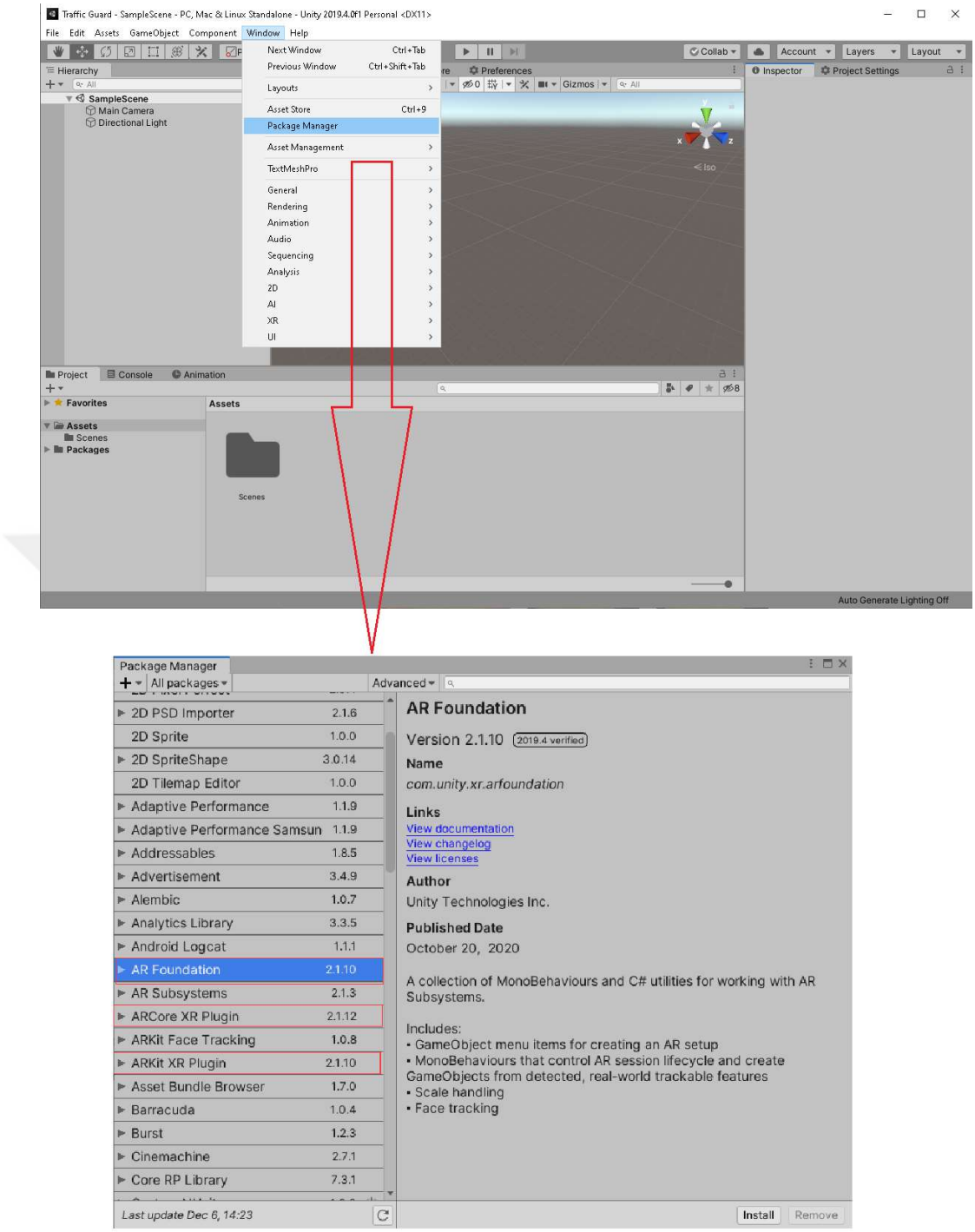

Figure 3.5 : Importing the AR Foundation Package.

Before start developing, some settings need to be modified to get AR Foundation up and running. In Project Settings, Plug-in Providers of XR Plug-in Management need to be configured as seen in Figure 3.6. For IOS, ARKit provider must be checked. For Android, ARCore provider must be checked.

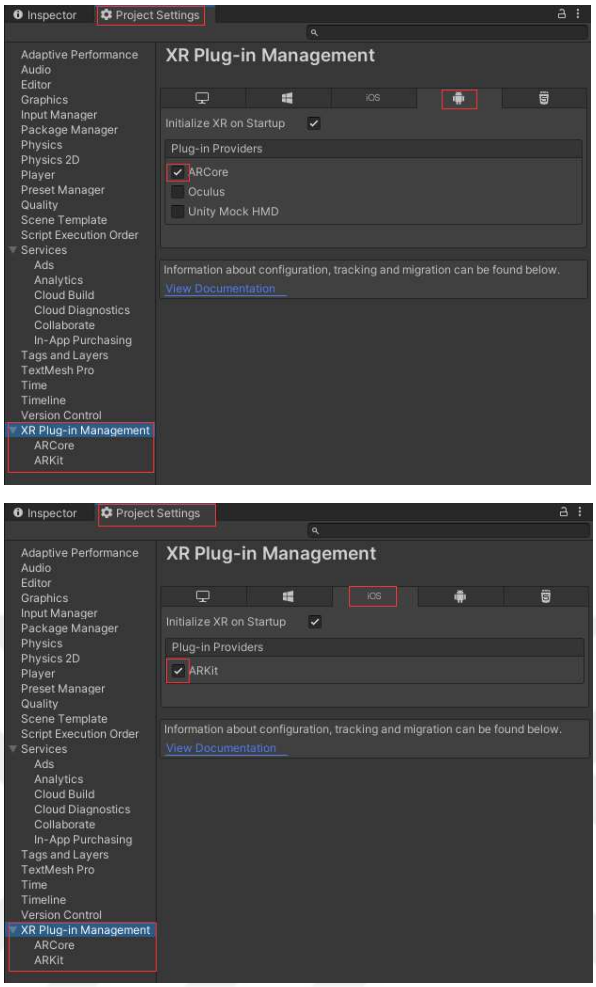

Figure 3.6 : Settings in Plug-in Providers of XR Plug-in Management.

AR Session Origin purposes to transform trackable features into their final position, orientation, and scale in the Scene. The ARSessionOrigin performs the appropriate transformation into Unity space. In order to instantiate gameobjects in the correct place, AR Foundation needs to know where the session origin should be in the Unity scene. ARCamera should be a child of the ARSessionOrigin because the camera is driven by the session and the camera and trackables will move together in this setup. Then the project deployment target in build settings should be changed. After successfully set up, AR Foundation is ready to run the game mechanics.

3.5 Mission Options

3.5.1 Visual guide level

In this part of the game, the first goal was to design a life-size city in a large area and place information so that the player can learn about the signs they encounter while walking around this city. The biggest disadvantage of this situation was that each user preparing for the tester did not have a large area. That's why the playground was designed to sit on a large table. The virtual city has the appearance of a real city with features such as an airport, railway, factories, cultural center, parking lot, intersections, and where traffic is lively.

By finding the traffic signs in the city, the player is shown helpful information, as shown in Figure 3.7, where they can learn what they do, what penalties will be incurred if they are not followed, and what to do when they see the sign. The player is expected to explore the city and discover the traffic signs in the city at this stage and learn all of them in the on-site plot, thus starting active duty. The player is expected to mark the signs that the player has received information in the city with the confirmation button. Considering that the game is a serious game, although the first aim is not entertainment, the fun element in this part of the game is that it resembles a kind of puzzle game in which you have to find all the signs in the city. Active duty cannot be started unless the learning phase is completed.

Figure 3.7 : Traffic sign information panel.

3.5.2 Active duty level

In Active Duty, the players were given information regarding a problem that occurred in a given part of the city, and it was expected to be chosen the correct traffic sign for placing in that area. Figure 3.8 presents an example case. In this case, it was mentioned that the train hit five cars in the last three months at the railway crossing with no barriers (uncontrolled), causing casualties. For the solution of the problem, a traffic sign that informs the drivers is needed. The signs that were not taught in the training stage were included in this stage, creating a challenge for the players. The location of the sign, which was expected to be placed in the area where the accidents took place, was presented in a way that would attract the attention of the players. For this purpose, a siren-like effect similar to the ones used in police cars was used. When the players clicked where the mark should be placed, they were given three options and these options included signs that the players did not learn during the training phase. However, two of the three options were chosen from the signs that the players were taught during the learning phase and were not suitable for being put on the scene so that they would decide to place the sign that they were not familiar with. This allowed them to choose the option they had not seen before in the learning phase by eliminating the other two options. After the correct sign was selected, the information screen about the traffic sign, like the ones in the visual guide section, appeared.

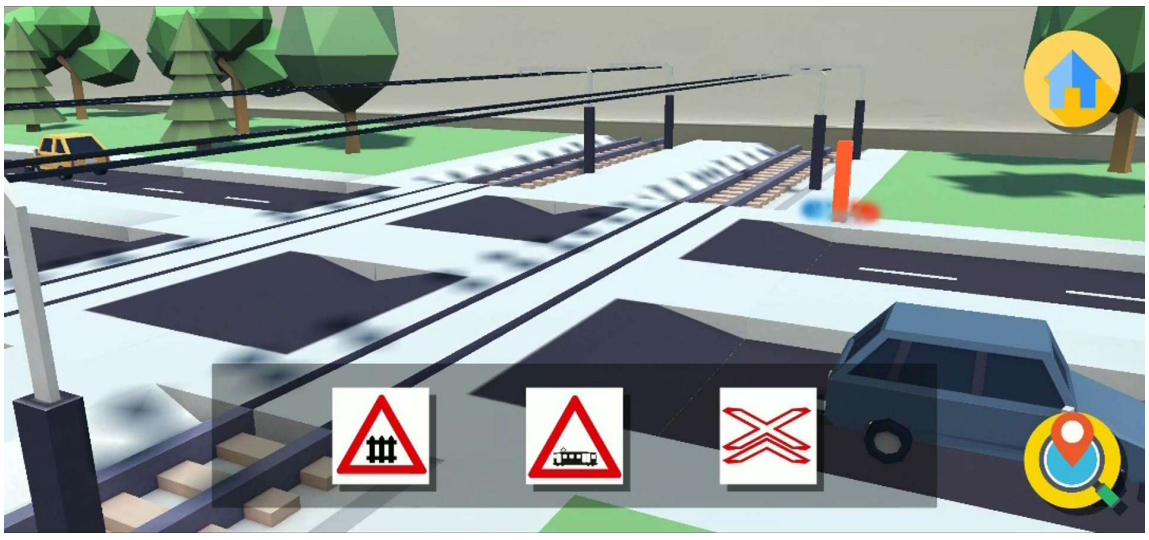

Figure 3.8 : Sample case for active duty.

3.6 Experiments

The test phase consisted of 4 stages: pre-test, playing AR serious game, experience test, and post-test.

3.6.1 Participants

Five individuals with having a driving license, three males and two females, with a mean age of 25.8 years, participated in this testing phase. All participants have a valid driving license for at least one year. The average year of participants' driving license is 4.8 years. The reason for the selection of participants with a driving license is to show that although they passed the traffic rules exam, they don't know a lot of important signs. Also, they can compare the traditional process and AR serious game because of performing the traditional procedure before. Participants' gaming habits are not the same. In this project, the researcher wonders if this augmented reality-based serious game motivates participants with no gaming habits.

3.6.2 Pre-test

In the preliminary test phase of the study, ten questions about the traffic signs and two questions about personal information were asked to the participants (see in Figure 3.9). Half of the traffic signs asked were the signs frequently encountered in daily life. The participants were expected to know at least five of them. The correct answers were given 1 point and the wrong answers were not given any points. Thus, the average expected to be at least 5 out of 10; however, the results were not as high as expected.

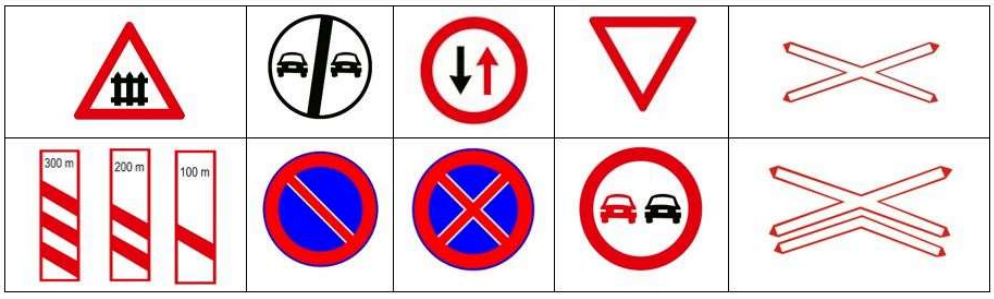

Figure 3.9 : Questionary of the pre-test.

When calculating the scores, the answer was considered correct if the participant knew the exact meaning of the sign. Table 3.1 shows that the respondents had an accurate

answer rate of 34% and an average score of 3.4. To raise the average and make the research more efficient, it was decided to give a score of 0.5 to participants who do not know the exact meaning of the traffic sign but know what it is about. For instance, the first question of the test was the controlled railway passing sign indicates that the railway is controlled by a barrier or similar system on both sides and that a lightened or vocal stop warning would be observed. Participants who could not give this answer and did not know the characteristics of the sign but knew that the sign was related to the railway were given half a point. Thus, the answer table was updated as seen in Table 3.2 to calculate the new average according to the answers to the questions. The new average was calculated as 4.4 points. However, as a result of the efforts to improve the results, it was observed that the participants who were expected to have the most up-to-date information fell below the expected average.

Table 3.1 : The degree of accuracy of answers in pre-test.

Participant	Questions									
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
A										
B										
C										
D										
E										

(Green: True – 1 point / Red: Wrong or Unanswered – 0 point)

Table 3.2 : The regulated degree of accuracy of answers in pre-test.

Participant	Questions									
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
A										
B										
C										
D										
E										

(Green: True – 1 point / Yellow: Near – 0.5 point / Red: Wrong or Unanswered – 0 point)

3.6.3 Experience test

At the end of the game, a short three-question questionnaire in Figure 3.10 was given to the players to evaluate the experience. The survey consisted of 3 questions and they were asked to be answered on a scale from 0 to 5. "0" meant "I strongly disagree" and 5 stood for "I strongly agree." The questions were prepared to examine the participants' attention in the game, their sense of knowledge, and whether they would like to prepare for their driver's test with the AR game instead of conventional methods if they went through the learning process for the re-exam. Participants who selected 4 or 5 formed the "agreeing group", participants who chose 2 or 3 were included in the "neutral group", and participants who chose 0 or 1 were the "disagreeing group". The results based on the categorization are presented in Figure 3.11.

Q1. While I was playing, my attention was totally centered on game

Q2. Through the game, I could learn a little bit more about traffic signs

Q3. If I would take the traffic license exam again, I will choose the method of learning with AR serious game

Figure 3.10 : Questionary of the experience test.

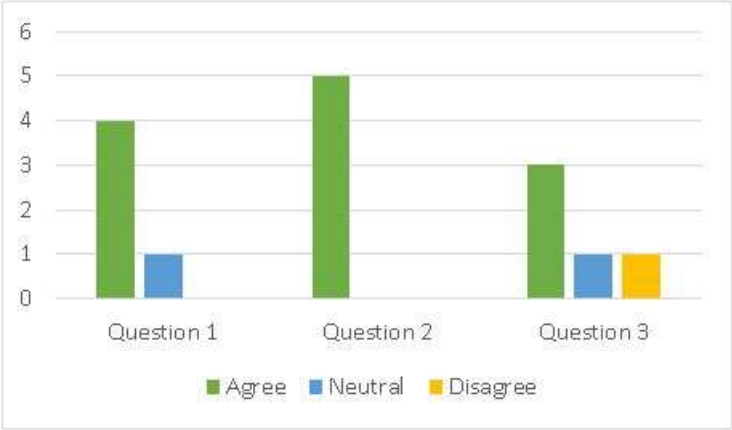

Figure 3.11 : The results based on the categorization of the experience test.

3.6.4 Post-test

To test the permanence of the information learned in the game, the questions and traffic signed that were asked in the pre-test were asked again a year later. The accuracy of the answers to the questions is shown in Table 3.3. The questions whose accuracy rate

was 4,4 were answered correctly. The participants knew what all the signs meant. At the end of the test, when participants were asked if they remembered any signs in the game, it was seen that they remembered the problems they had solved in detail. In addition, one of the most notable pieces of feedback from the participants was that they indicated that they became more sensitive to traffic signs they encountered after the game.

Table 3.3 : The degree of accuracy of answers in post-test.

Participant	Questions									
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
A										
B										
C										
D										
E										

(Green: True – 1 point / Yellow: Near – 0.5 point / Red: Wrong or Unanswered – 0 point)

3.7 Results

The starting point of this study was the drivers' lack of knowledge and it was evidenced by preliminary test results. While an average score of at least 5 out of 10 was expected, drivers who scored 4.4 as the result of improvements were found to lack information about traffic signs. When the questions about the experience were examined, it was seen that the players mainly focused on the game, proving that immersive games help players bring their attention and focus to the game. It was also indicated that all participants agreed that they have gained information about traffic signs thanks to the game. The examination of the answers given to the first two questions showed that the combination of AR and serious games had positive effects on learning. The majority of the participants reported that they would choose to prepare with AR if they were to take the re-exam. During participant selection, participants who are not the same in terms of gaming experiences were deliberately chosen. One interesting answer given to the last question was that the participant, who did not have much game experience, admitted that the gaming experience enhanced his knowledge and that he found the game interesting, but he would choose traditional methods if he had to prepare for the exam again. This suggests that no matter how strong the educational aspect of AR

games might be, participants without gaming experience are likely not to prefer AR gaming.

It was observed that the scores of the post-test, which was conducted one year after the experience increased considerably compared to those of the first test. It was detected that knowledge was permanent although a year passed after the learning, proving that learning through AR gaming is more efficient than learning through traditional methods. That the participants were able to remember enough about the game to describe parts of the game suggested that AR technologies used for visualization make significant contributions to learning. In line with the results obtained in this experiment, it was determined that augmented reality was an effective learning tool when combined with serious games.

A control group that does not have a driver's license can be added to the research design the information provided in the game can be expanded in the following stages or future studies.

4. A VR BASED SERIOUS GAME – UBER DRIVER

According to WHO (World Health Organization) data, 1.3 million people pass away and nearly 50 million people are injured as a result of traffic accidents worldwide every year [2]. To express this statistic in another way, it corresponds to the crash of approximately 20 Boeing 737-800 type passenger planes in the world every day and the death of all passengers. If this scenario were happening in air transportation in the world, it would not be acceptable, but unfortunately, these statistics are far from the scenario in road transportation. In Turkey, more than 7 thousand people die in traffic accidents and 300 thousand people are injured every year [3]. To put it more clearly, while 22 people die on the highways of our country, more than 820 people are injured every day. Traffic accidents lead to injury or death of one of our children, who are the future of our country, every 10 minutes [3]. Some of the injured remain disabled throughout their lives and a significant part of their lives are adversely affected.

Another striking statistic revealed by WHO is that the countries where 90% of the deaths in traffic accidents occur in the world are the countries with low-income and medium-income and the total number of registered vehicles is 54% of registered vehicles in the world [2]. One of the biggest reasons for these accidents may be drivers who have a license without being adequately tested in low-income and middle-income countries. Another major reason is poor planning in the highway networks.

In many European countries such as Austria and Germany, the psycho-motor skills of the drivers are examined first with tests called ‘psychological assessment’, then scales regarding their attitudes and behaviors related to traffic are applied, and finally an interview is made with the person. As a result of these three evaluations, a decision is made about whether the person has safe driving skills [10] [11]. In developed countries, it is not enough to just pass the driver’s exams in order to have a driver’s license.

In this part of the research, it is to test whether individuals who have a driving license are prepared for situations that they do not encounter in exams but are possible to

encounter in real life, and to measure their reaction times. At the end of the test, it is to investigate whether they want to have a license with virtual games or with the traditional exam method, where they can be better prepared for all scenarios.

4.1 Background and Motivation

The development of computer technology has significantly influenced the spread of research in simulators. Driving simulators are devices in which the driver steers the car using the same control elements as in a real car (accelerator pedal, brake, steering wheel), but where vehicle traffic is implemented in a virtual world on a large screen [56]. Although these devices create the perception of reality, these devices is not as effective as virtual reality in creating the real impression because you know that you are looking at a screen. One of the indisputable advantages of simulators is the possibility of fully adapting to the environment and the ability to realize scenarios where road conditions would be impossible or dangerous to apply [57].

The best example of the effectiveness of simulators is the life story of Formula One driver Cem Bölükbaşı [58]. He started this profession with virtual simulation games. He trained on the I-Racing video game platform [59] and entered the World Championship on that platform and was in the top 20. He later joined when Formula 1 organized its own esports championship in 2017 and placed the 5th in the world. He states that he has done about two thousand races before he switched to real tracks and these experiences carried him to real tracks. It is seen that simulators are used in many fields and are effective.

It is obvious that games played with immersive technologies motivate players to try more [54]. The result of comparative research determining how immersive serious play affects the motivation of players compared to a non-immersive serious game shows that immersive gaming experience has great motivational potential [5]. According to the same research, immersive games are not only preferred by users, but also attract the attention of people who have not played them yet. Games with immersive technologies can be designed to increase the performance of students, their motivation and interest in lessons. Despite the difficulties, some students try to understand the course content through games [60]. Games with immersive technology are also used for individuals to develop themselves and gain independence. A study involving individuals with ASD (autism spectrum disorder) aims to prepare them for bus use and

to help them live more independently [61]. Games are also used to develop individuals and gain independence. Another study aims to help players improve their driving skill and basic driving knowledge and to give the player confidence before driving a real car in the real world [62].

The decision was made to use VR in serious game design, as many studies have shown that immersive technologies are more engaging, motivating, and help build self-confidence. VR games are effective at immersing the user in the game more effectively and tricking the brain. Thanks to immersive gaming technologies, the player feels more fluid, fascinating and motivating than normal games [5]. The reason for choosing serious games with VR is that the first goal is not entertainment, but education. The primary purpose of serious games is effective learning [5]. They often involve a simulation of real-world events or processes designed to solve a problem. The simulation aims at problem-based learning by putting the player in the role of a problem solver, responding to realistic scenarios.

4.2 Game Design

While the game was being designed, the player was assigned as an Uber driver in order to assign a duty and responsibility to the player, which is the basis of serious games. According to the story, the customer gets into the vehicle from the city and goes to the seaside town, which is near the city, with the directions entered in the navigation. Throughout the game, the player has to traverse city roads with straight roads, a straight forest road, mountainous country roads and a winding coastline. The biggest reason for choosing an Uber driver is that passengers can give a score afterwards. Although the scores are not shown to the players during this test period, they are kept in a local file.

In case the player did not play with the steering wheel pedal set before, a racetrack scene that is not subjected to test score was added as the first phase. In addition, thanks to this scene, it is aimed that the player gets used to the VR glasses even if they do not have VR experience. The familiarization phase felt when getting into a new car for the first time was aimed to be eliminated with this scene.

The city scene was put in some specific errors. As can be seen in the Figure 4.1, directions that do not comply with the traffic signs on the road in navigation were used

to draw attention to and measure traffic accidents and carelessness caused by navigation errors, which we are likely to encounter in real life. Apart from that, one of the most specific mistakes is having to make a u-turn in flowing traffic in order to turn from the wrong direction. It is expected that the player will not have much difficulty in this scene because of flat roads.

Figure 4.1 : Navigator fail samples.

After leaving the city, the player goes to the mountainous region with a flat and deserted tree-lined road. However, the purpose of this way is to measure the time with the reaction test. Reaction tests are widely performed in developed countries. It can be considered as a prerequisite before going into traffic. However, this measurement is not made for people who have a license in our country. Players are expected to score within accepted reaction times to traffic around the world. Since the players in the testing phase are all licensed people, they are active drivers in traffic. At this stage, the braking times were measured as a result of the jumping of the animals placed at random intervals 5 times on the road.

On the other hand, it is expected that the player will have more difficulty in the scene where there are mountains and coastline. They must carefully cross the uncontrolled railway, which is the first obstacle they will encounter. The first rule of the uncontrolled railway is that when the railway arrives, the train must stop and rest. These sounds are set in the game. If the player does not pay attention to the traffic signs and does not stop when the player comes to the railway, there is a high probability of crashing with the train. It is checked whether the players will pay attention to this

and whether they can read the signs on the road. In case of a crash with the train in this scene, the game will go back to the mountain scene.

The mountainous region consists of curved and gravelly mountainous roads. It is thought that players who have not driven in such areas before will have difficulties in this phase of the game. In gravel road driving, feedback is given by the steering wheel and the player has to hold the steering wheel more tightly to prevent the vehicle from slipping.

4.3 SteamVR Setup

Since HTC Vive VR headset was used for the research, it was decided to use the SteamVR Unity Plugin when choosing. Headset controllers are disabled. Instead, the buttons of the steering wheel were integrated to move through the menu. Since SteamVR allows freedom to move within the play area, and in order to restrict this freedom in the game and move with the vehicle, the tracking space origin in the SteamVR settings in the Figure 4.2 should be set to 'Tracking Universe Seated'.

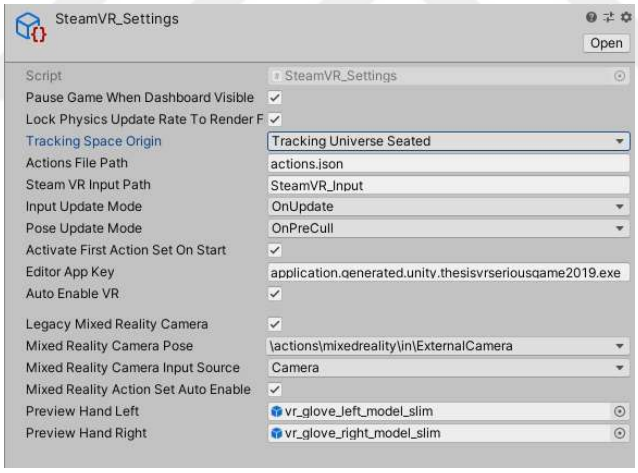

Figure 4.2 : SteamVR settings.

4.4 Logitech Steering Wheel SDK

Firstly, Logitech Gaming SDK [63] is downloaded from the Unity Asset Store. This asset enables control to Logitech Gaming products. Also, it contains sample scripts to help integrate Unity games with Logitech G-series products. This package is a combination of many Logitech SDKs:

- Logitech|G Arx Control App SDK

- Logitech|G LED Backlighting SDK
- Logitech|G G-Keys SDK
- Logitech|G LCD SDK
- Logitech Steering Wheel SDK

In this thesis VR game, three of these are required. The first of them is the Logitech Steering Wheel SDK, which automatically wraps the wheel's DirectInput controls. Additionally, this SDK permits the use of predefined force feedback effects or the creation of new effects by specifying specific forces. The second of these SDKs is the Logitech|G G-Keys SDK, which enables you to set G-Key functionalities without exiting your game. The last SDK is the Logitech|G GamePanel SDK, which adds a second screen capability to Logitech gaming keyboards equipped with Game Panel. This enables for the display of in-game information, system statistics, and more. This SDK enables you to include Game Panel features into your application's code.

4.5 AI Traffic System

It was considered important to add walking pedestrians and vehicles to increase the realism in the city in the game. Pedestrians and vehicles had to act in accordance with traffic lights. Added AIs that decide their own moves instead of navigating specific route's waypoints. Routes with waypoints and features of each waypoint were drawn for its to decide on its own direction. On these routes, AIs were asked to decide which way to go. STS asset was used for vehicles and traffic lights.

The working logic for traffic lights is to create an empty parent object and use this object as a manager. It contains a struct called TrafficLightCycle. This structure includes waiting times according to the light type as seen in the Figure 4.3. In addition, it maintains a list that determines which waiting times will be applied to the traffic lights with AITrafficLight component on the stage. For the game, a total of 30 seconds of waiting time was determined for the lights on the main road, and a waiting time of 60 seconds for the lights on the side road. Thus, the traffic lights encountered by each player or each time a player plays will differ. This structure changes the lights according to the waiting times. Two structs must be selected and the coroutine is run in the code, one of which is lit red while the other is lit green.

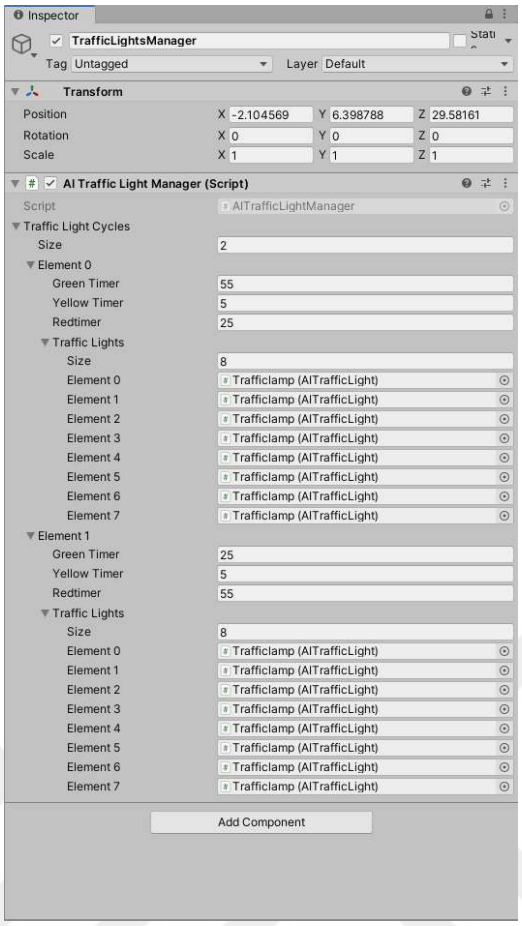

Figure 4.3 : AI traffic light manager component.

In addition, certain vehicles were not placed on the stage to ensure the difference in each playthrough. Instead, the tools are selected in a pool scriptable object as shown in the Figure 4.4. For vehicle traffic, cars selected in the scriptable object were randomly spawned at the specified spawn points. Apart from the player's car, 12 car prefabs were prepared in the game.

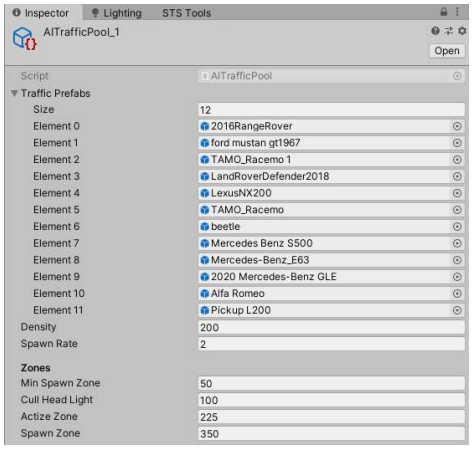

Figure 4.4 : AI traffic pool scriptable object.

There is AITrafficCar component as seen in the Figure 4.5, which includes the features of AI vehicles and provides mobility. Each of the cars has a sensor containing 3 colliders, as seen in the Figure 4.6, front, right and left. These sensors enable the vehicle to hit the obstacle in front of it or to decide whether to change lanes to the right or left. Each vehicle has a random speed component and a random material component. Thus, vehicles with different materials and vehicles with different speeds can be spawned from a single prefab. In order for the vehicle to move, Wheel Colliders provided by Unity and therefore Rigidbody component are used.

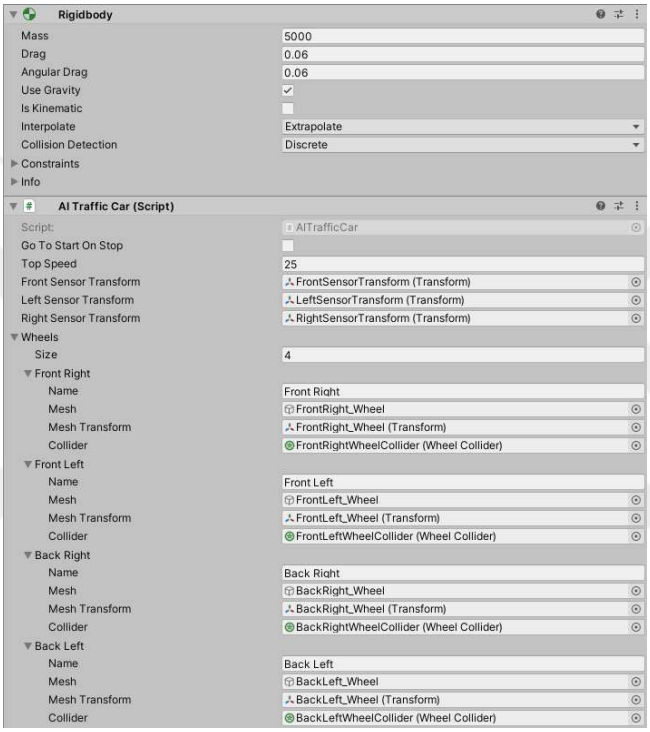

Figure 4.5 : AI traffic car component.

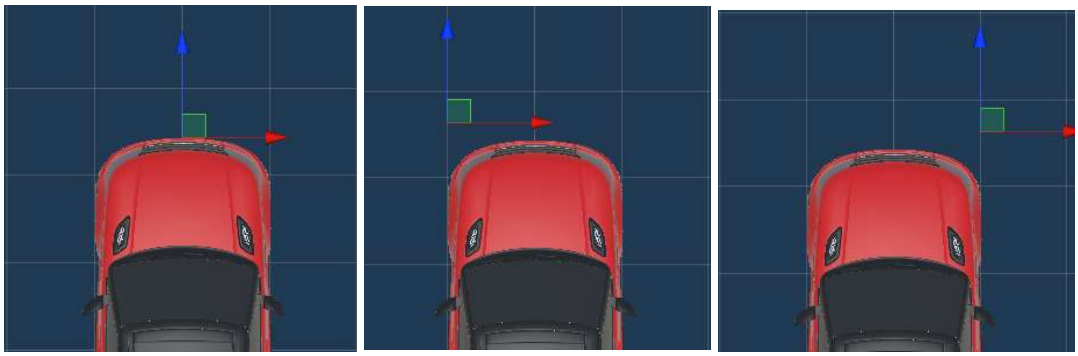

Figure 4.6 : AI traffic car sensors.

Waypoints and information on these waypoints are kept in order to determine the routes that AI cars can go. A seen in the Figure 4.7, the information on whether there is a possibility to change lanes on the AI Traffic Waypoint component is kept as a Lane Change Point list. Route information, which is the parent of the waypoints, is kept on the traffic lights. Thus, the traffic light sends information that vehicles on the route should stop or pass. In addition, in cases where there is more than one new route during the route change, AI cars decide the route to go by randomly choosing from the NewRoutePoints list. In addition, a specific maximum speed can be determined for waypoints. Apart from this, if there is an event that is desired to be triggered when the waypoint is reached, it is defined in the OnReachWaypointEvent section.

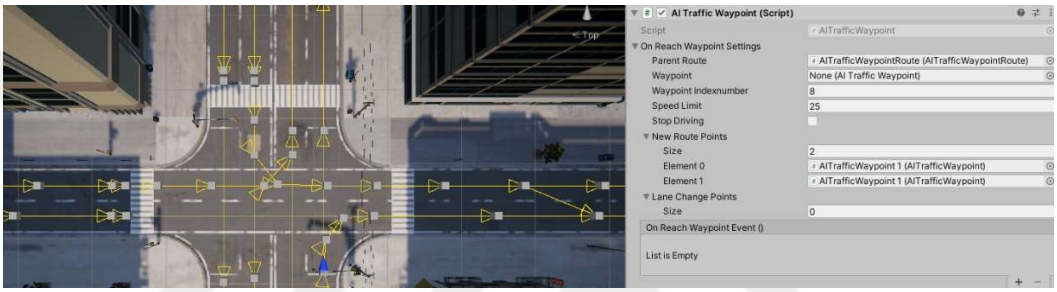

Figure 4.7 : AI traffic waypoints in game scene.

4.6 Practice Level

Even if those who will be in the test group have experience with VR, they need to get used to it as they will experience the racing steering wheel for the first time. Thus, it was decided that the tests performed would be more accurate. The steering wheel and pedal set used for research is the Logitech G29 Driving Force set. In this set, steering wheel and pedals can give feedback.

The test phase consists of 2 types of roads, which allow it to experience different types of turns, wide and narrow roads, as seen in the Figure 4.8. In addition, there is also a slope in certain parts of the track to get used to the VR feeling. Before proceeding to the test phase, 3 laps on the racetrack are required. When the practice rounds were over, it was decided to switch to the real test phase. During the familiarization phase, participants are expected to become accustomed to the handling physics of the car.

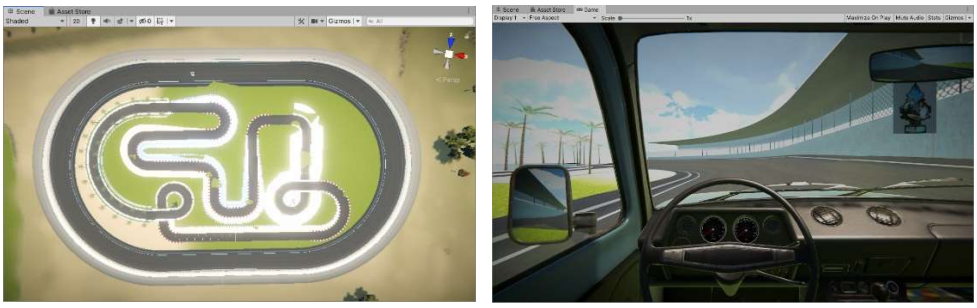

Figure 4.8 : Race track view for practice level.

4.7 Reaction Time Test

When using a vehicle, we perform many different functions simultaneously. Tasks that require complex cognitive processes, such as moving the vehicle, controlling the mirrors, using the gas and brake in a balanced and appropriate manner, monitoring the surrounding vehicle, pedestrian, road and traffic signs and giving the necessary reactions, and adjusting the distance with other vehicles, become simple and automated for drivers. However, during all these processes, cognitive and psycho-motor abilities such as concentration, selective and continuous attention, stress resistance, reasoning ability, perception, speed-distance estimation, hand-foot-eye coordination, recognizing stimuli and reacting accurately and quickly, play very important roles.

Attention is one of the most important functions related to driving. It must be continuous in order to concentrate on all stimuli in the environment at the same time, and must be selective in order to select appropriate stimuli for the response to be made, perform the necessary responses and ignore the inappropriate stimuli. Some studies have shown that 25% - 50% of traffic accidents are caused by driver inattention. Selective attention has been found to be the most important variable in predicting and preventing the accident [64] [65] [66].

The unit of time between giving a stimulus to the person and the beginning of the person's voluntary response to this stimulus is defined as the reaction time [67] [68] [69]. Reaction time measurements are seen as a scale for determining the duration of the response to a stimulus in activities that are a part of daily life such as traffic and sportive activities [68] [70] [71]. In daily life, warnings can be given to the person in different ways. While driving in traffic, warning and response forms may be different, such as pressing the brake, turning the steering wheel or changing the position of the

opponent according to the action of the opponent in sporting events when an object appears on the road unexpectedly.

There are stages of information processing for the central nervous system triggered by the stimulus. These stages are generally recognition of the stimulus, selection and programming of the response, and the emergence of the action [68] [70] [72]. The reaction time of a person depends on various factors. Although these factors are stated as age, gender, physical activity level, preparation for warning, alcohol intake, fatigue, respiratory and circulatory system disorders, there are different opinions. It has been observed that people who do physical activity regularly have higher physical work capacity values and give faster neuromuscular system responses than sedentary people of the same age [67] [68].

All prospective drivers undergo eye tests before obtaining a license. A young healthy individual without any visual impairment can detect a target 90 degrees to the right with his/her right eye and 90 degrees to the left with his/her left eye. This corresponds to that person has a 180-degree field of view in the horizontal plane. However, when we look at the eye health standards required for obtaining a driver's license, it is not clear exactly how much field of view should be obtained due to the differences between countries [73]. In studies examining the relationship between performance from tests evaluating the visual field and traffic accidents, this relationship was mostly not found [74] [75] [76] [77]. A study of 17000 drivers found a very weak correlation between visual field width and accident involvement [74] [75]. Another study conducted on a larger sample (52000 drivers) found that drivers with normal visual field (greater than 160 degrees) did not differ from drivers with limited visual field (140 degrees and below) in terms of the number of backward two-year accidents [78]. There are more recent studies showing that there is no relationship between the width of the visual field and accident [76] [79] [80] [81]. In another study in which they evaluated the driving performance of patients with visual field problems, they showed that there was no significant relationship between moderate and severe visual field impairment and actual driving performance [82].

According to WHO data, the countries with the lowest number of accidents are high-income countries and these countries do not give driving licenses to candidates who fail the reaction time tests. But in contrast to these countries, in our country, we do not need to take any reaction test in order to have a driver's license. Therefore, in the test

phase, it was also tested whether drivers with or without visual impairment could pass the reaction test, which plays a major role in preventing accidents. During the rection tests, a straight and deserted road was designed from the city in the game to more rural areas, and a traffic sign was placed at the beginning of the road, indicating that the animals jumped on the road, as seen in the Figure 4.9. It is expected that the driver should be prepared for any sudden exits on the road as he or she has to look carefully at the road signs.

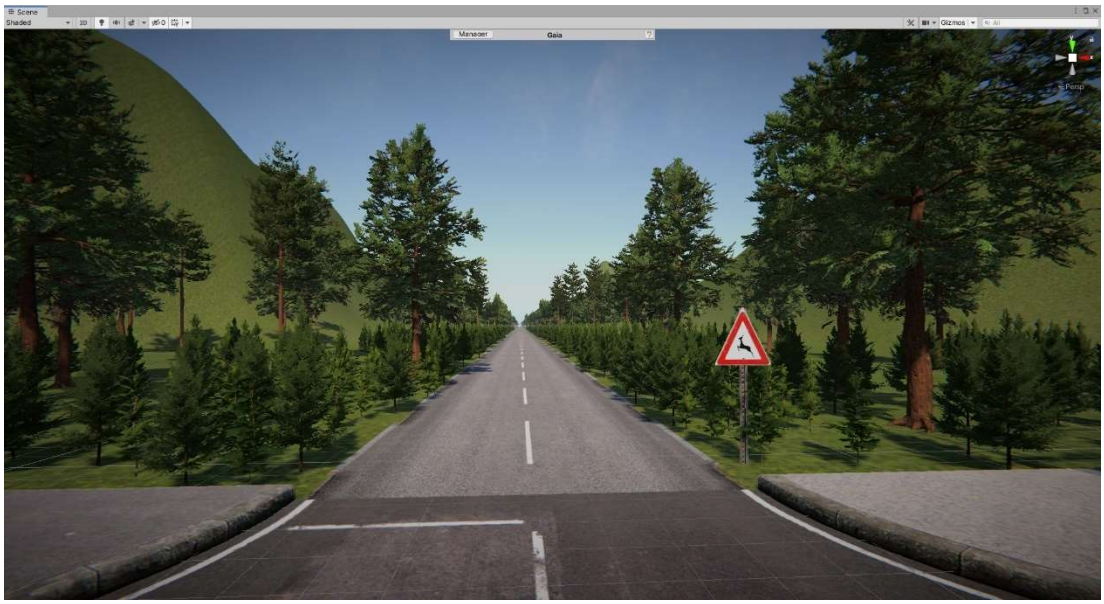

Figure 4.9 : Beginning of forest path used for reaction time measurement.

The majority of active drivers in traffic may be good drivers, but are their reaction times fast enough to avoid a accident? There is a simple game designed to measure reaction time online. It is a game that you can test by entering [83] on the website and tells you your reaction age. Research has been done on 2000 people of different ages with this interactive game. In this study [84], it was found that many external factors affect the reaction time. It was found to be influenced by some other factors, including the participant's amount of sleep and driving experience. People who regularly drink higher levels of alcohol have been shown to respond up to 20% slower than those who drink lower levels of alcohol. It has been observed that the reaction times of drivers who drive more than one vehicle per week are on average 10% faster than non-drivers. More generally, people with a license respond 8% faster than those without a license. The report also suggests that reaction time gets better with the driving experience. Drivers with 1-2 years of driving experience were found to have a 27% faster response time than those with a license for less than a year. There are five obstacles with

different exit ranges in the forest measuring the reaction in the Uber Driver game. In this study, reaction times were measured without considering external factors. It was also decided to look at how the reaction time of the driver was affected at each obstacle. Looking at the results of the report prepared by Justpark [84], more experienced drivers are expected to have faster reaction times.

As a result of the research conducted by DriveSafety [85], which produces advanced driver simulators for clinical and academic research, a professional driver who is physically fit and trained in high-speed driving may have a reaction time of 0.2 seconds for a certain situation, while the reaction time of an average driver may be 0.5 seconds, 0.8 seconds or even 1 second slower [86]. Systems of the company use simulation games to shorten the reaction time of drivers or candidates with slow reaction times. Simulator scenarios can also be used to provide practice and training tools to improve reaction times. Clinical simulators have been shown to be able to steadily increase the difficulty of simulations to increase the awareness of a driver and increase reaction speed over time [86]. The maximum reaction time in the game is set to 1 second. Since the tests will be conducted in the middle age category, the expected value is a value below 600 ms. If it goes above this value, it will be seen that they have slower reaction times for their age.

4.8 Experiments

4.8.1 Participants and Questionnaire

Participants consist of two groups. The first group consists of 7 drivers with limited gaming experience and no experience with devices such as VR and steering wheel. The second group consists of 9 drivers who are familiar with the game world and have played at least one with VR and steering wheel. Candidates with less than 15 years of experience in traffic were selected, as the goal of the game is to prepare drivers for all kinds of traffic scenarios, as seen in Figure 4.10.

A pre-test was conducted in order to have information about the test players. In the pre-test, information was collected under five main titles: demographic information, information about the game experience, information about driving license and driving, information about driver behaviors and driver abilities. According to the information gathered from the gaming experience section, it is expected that testers who play

simulation games or have experience with VR and steering wheel will adapt to the game faster.

Figure 4.10 : Photos of some test drivers.

In addition, considering vehicle usage information, it was thought that drivers with experience on gravel roads and mountainous areas would make little or no mistakes during the test. It is expected that test drivers with more urban experience will not make mistakes that are set as urban traps. It is thought that it will be easier for drivers, who have not had previous experience in finding a way through navigation alone, to be less attentive to the road and therefore to make mistakes.

It is expected that they will have difficulties during the game in the subjects that they consider themselves weak in driver skills questions. It is expected that drivers who see themselves weak in slippery ground and mountainous areas during the game will have difficulties. Considering that the speed limits will be observed in the area where the reaction test is carried out and their reactions to objects suddenly appearing on the road will be measured, it is expected that drivers who see themselves weaker in this regard will have difficulty. It can be thought that players who consider themselves strong in

these areas and make mistakes during the game are not objective in evaluating themselves.

The biggest difference between the two groups is that the second group is gamer. Therefore, it is thought that the second group will adapt to the game quickly. It is also thought that this group will find the game more interesting. However, due to the serious nature of the game, they may find the entertainment element in the game insufficient.

4.8.2 Scores

According to the mistakes made in the game, a point system was applied to the Uber driver. It was expected that the drivers who have more driver experience and comply with the rules in terms of driver behavior will get more points. When the game starts, the player has 100 points. It was decided that the player should not see this in the game or at the end of the game. The point system works to reduce score of the player with certain errors. Errors have certain scores according to the hazard ratio. Errors in the points system and the corresponding loss of points are listed in Table 4.1.

Table 4.1 : List of lost point values due to driver mistakes.

Mistake	Lose Points
Car crash	50
Train crash	50
Pedestrian crash	20
Drive in wrong direction	20
Animal crash	15
Red light violation	10
Yellow light violation	5
Lane violation (per 1 min)	3
Safe following distance violation (per 1 min)	2

In the pre-test questions, participants were asked how long they had a driver's license and how long they had been active drivers. In addition, participants were asked how many kilometers they drove weekly and annually on urban and out of town roads. The purpose of these questions is to assume that experienced drivers will be the ones who will get the highest score from the endgame evaluation. When the data obtained after the test were compared, the results were obtained as seen in Table 4.2. As seen in Table 4.2, it has been seen that it does not matter how long they have had a driver's license. Drivers participating in the test are considered experienced if they have more than 1000 km of city driving. In addition, when a comparison is made between experienced

and high-scoring drivers, it has been seen that drivers with more urban driving experience have higher scores. The longer the drivers actively drive, the more their driving skills improve. Therefore, driver candidates can be experienced with VR serious games in which traffic is simulated before they drive actively on the road.

The most striking thing in the results was that Driver E and Driver G scored very little despite having a driver's license. Driver E and Driver G stated that they had difficulty in driving a car because they do not think that they were ready for car traffic. Driver E has made one of the biggest mistakes in the game, even though she has a driving license by passing the driver’s license exams. As she approached the railway, she did not slow down because she did not notice the traffic signs. Thus, she crashed with the train. The inadequacy of the traditional driving exams was once again evident.

Table 4.2 : Comparison by test drivers' driving experience and score.

Drivers	How long have you been licensed?	How long have you been actively driving?	Average km driven per week in city	Average km driven per year in city	Average km driven per week outside the city	Average km driven per year outside the city	Score at the end of the Uber Driver game
Driver A	3 - 7 years	3 - 7 years	< 50	< 500	-	< 100	76
Driver B	7 - 15 years	7 - 15 years	< 100	2000+	< 50	< 2000	84
Driver C	3 - 7 years	3 - 7 years	< 100	< 2000	< 15	< 500	79
Driver D	7 - 15 years	7 - 15 years	100+	2000+	< 15	< 1000	94
Driver E	3 - 7 years	0	0	0	0	0	26
Driver F	7 - 15 years	7 - 15 years	100+	2000+	0	< 2000	88
Driver G	1 - 3 years	1 - 3 years	< 50	< 100	0	0	43
Driver H	3 - 7 years	3 - 7 years	< 100	< 1000	< 15 km	< 500 km	73
Driver I	7 - 15 years	7 - 15 years	< 100	< 2000	-	-	79
Driver J	7 - 15 years	7 - 15 years	< 50	< 500	< 15 km	< 500 km	86
Driver K	7 - 15 years	7 - 15 years	< 100	< 2000	< 15 km	< 500 km	85
Driver L	7 - 15 years	7 - 15 years	< 50	< 2000	< 50 km	< 2000 km	91
Driver M	7 - 15 years	7 - 15 years	100+	2000+	-	< 100 km	93
Driver N	7 - 15 years	7 - 15 years	< 100	2000+	< 15 km	< 500 km	96
Driver O	7 - 15 years	7 - 15 years	< 50	< 2000	< 50 km	< 2000 km	82
Driver P	7 - 15 years	7 - 15 years	< 100	< 2000	< 15 km	< 500 km	94

4.9 Results

The most obvious difference between the drivers selected for the test is that one group is gamer. In the preliminary survey questions, participants were asked about the frequency of playing games, the types of games they played, and the platforms they played. They were also asked whether they had experience with the technologies used for the game. All members of the gamer group have experienced at least one with VR or steering wheel before. Participants, who chose the option '5 - 6 times a week' in the survey and who have mastered different game types, were included in the gamer group. The desired situation in the GEQ questions in Appendix A is to score between 1 and 5. They were grouped as 1 and 2 to mean disagree, 3 to be neutral, and 4 and 5 to agree. The results stated in Table 4.3, Table 4.4, and Figure 4.11 are the results after this grouping.

Table 4.3 identifies VR-related in-game experiences. All participants found the gaming experience with VR interesting and fun. Participants with previous VR experience had less dizziness. The majority of participants who played games with VR for the first time experienced dizziness. According to the results of the pictorial experience questionnaire asked in Appendix B, participants experienced the most dizziness in the mountainous scene. In the game, such a problem was not encountered in the scenes where the road is flatter and there is no jolt in the car. The biggest advantage of playing games with VR is that you are disconnected from your environment and all your focus is on the game. We can see this from the survey responses stating that players were not interested in what was happening around them. Table 4.2 and Table 4.3 should be considered together when asking participants whether they would prefer to prepare with a VR game or with traditional methods if they are preparing for the driver's license exam again. Almost all of the gamer group stated that they wanted to prepare with the VR serious game. The situation was slightly different in the non-gamer group. The participant with the highest game score and the most driving experience preferred traditional methods. In the non-gamer group, two participants who wanted to prepare with VR serious game were determined. These drivers are drivers who have difficulty in getting on the road despite having a license. Other members of this group preferred to remain neutral.

Table 4.3 : Summary of the significant results about VR of GEQ.

Drivers	Is the tester a gamer?	VR experience	Training with VR is interesting	Playing with VR is fun	Felt dizzy while playing with VR	While playing with VR, I forgot about my surroundings	If I was preparing to get a driving license again, I would prefer the VR game
Driver A	NO	-	AGREE	AGREE	AGREE	AGREE	NEUTRAL
Driver B	NO	-	AGREE	AGREE	DISAGREE	NEUTRAL	NEUTRAL
Driver C	NO	-	AGREE	AGREE	AGREE	NEUTRAL	NEUTRAL
Driver D	NO	-	AGREE	AGREE	DISAGREE	AGREE	DISAGREE
Driver E	NO	-	AGREE	AGREE	AGREE	AGREE	AGREE
Driver F	NO	-	AGREE	AGREE	AGREE	AGREE	NEUTRAL
Driver G	NO	-	AGREE	AGREE	AGREE	AGREE	AGREE
Driver H	YES	1 - 2 times	AGREE	AGREE	DISAGREE	AGREE	AGREE
Driver I	YES	-	AGREE	AGREE	AGREE	AGREE	NEUTRAL
Driver J	YES	1 - 2 times	AGREE	AGREE	AGREE	AGREE	AGREE
Driver K	YES	-	AGREE	AGREE	AGREE	AGREE	AGREE
Driver L	YES	1 - 2 times	AGREE	AGREE	NEUTRAL	AGREE	AGREE
Driver M	YES	1 - 2 times	AGREE	AGREE	NEUTRAL	AGREE	AGREE
Driver N	YES	-	AGREE	AGREE	AGREE	AGREE	AGREE
Driver O	YES	1 - 2 times	AGREE	AGREE	NEUTRAL	AGREE	AGREE
Driver P	YES	-	AGREE	AGREE	AGREE	AGREE	AGREE

Table 4.4 indicates the experiences during the game with the steering wheel. Both groups stated that playing with the steering wheel set was interesting and fun. While playing with the steering wheel, it was asked whether the physics of the car in the game creates a real car impression on players. In the answers given, all participants except two people said that it created the impression of a real car. As seen in Table 4.2, the two neutral drivers were the ones who had difficulty in driving and got the lowest score from the game. In addition, these drivers may have had difficulties as they were not included in the gamer group. Considering their inexperience and their inability to go to the traffic, everyone except them easily got used to the physics of the car in the game. It can be concluded that the game is easy to get used to and has real car mechanics. In addition, there is no 3D model for hands in the game. Instead, the movement of the steering wheel was transferred into the game exactly. Thus, when players see the effects of their own actions in the game, it is expected that their brain would fall into this illusion. Compared to Table 4.3, participants in the gamer group who had previous VR experience realized that they had no hands as seen in Table 4.4. However, they stated that this situation did not seem strange due to the movement of the steering wheel.

Considering the pictorial survey results in Appendix B, the scenes where the steering wheel forces the participants were the scenes with mountainous and gravelly roads. This is due to the car shaking and the steering wheel moving if not held tight. However, this enhancement is the way real car response is reflected in the steering wheel. Therefore, it is a scene that is expected to be difficult. It was expected that players with high scores in terms of game score think that they are not improving themselves. According to this test, these drivers are Driver N, Driver P, Driver D, Driver M and Driver L. However, contrary to expectations, except for two people of these, the other three people think that they have improved themselves with the game , as seen in detail in Appendix C. It was determined that this was because they had never driven on gravel or mountainous roads before. Figure 4.11 shows graphically result of the significant information of Table A.1 in Appendix C. It was also determined that the participants who say that there is no scene where they have difficulty are the same as those who think that they do not improve themselves in the game. Experienced drivers think that they have not improved because they have previous driving experience. Throughout the game, most drivers improved their driving skills. So, this game can help driver

candidates to ready and practise for real traffic. In addition, as seen in Figure 4.11, every participant stated that if the game is expanded and many more scenarios are added, it will help the driver candidates in preparing for the traffic and will gain self-confidence.

The most important reason for measuring reaction times is that although it is not possible to obtain a license without a reaction test in many developed countries, this test is not performed in our country. We explained the importance and factors of this test in section 4.7 [84]. External factors were not taken into account while performing these tests. Looking at the age and reaction time graph [83], participants were each less than 50 years old. Therefore, 600 ms was determined as the upper limit as a result of the tests. Among the test drivers who did not take the reaction test, it is considered that there are drivers with high reaction times. In Appendix D, there are graphs of the reaction times of the test drivers measured in the game. It has been found that there are drivers with high reaction times that higher than required and expected reaction times. The most important detail is that Driver E, who has very slow reaction times, got the worst score. Studies [86] show that the reaction rate can be increased after a certain period of time with simulations. When we look at the participants' results, it is seen that there is a slight decrease in the first and last reaction times in all of them.

Table 4.4 : Summary of the significant results about steering wheel of GEQ.

Drivers	Is the tester a gamer?	Steering wheel experience	Training with steering wheel is interesting	Playing with steering wheel is fun	Felt like driving a real car	Easily got used to the physics of the car	Not notice that your hands were not visible in the game
Driver A	NO	-	AGREE	AGREE	AGREE	AGREE	AGREE
Driver B	NO	-	AGREE	AGREE	AGREE	AGREE	AGREE
Driver C	NO	-	AGREE	AGREE	AGREE	AGREE	AGREE
Driver D	NO	-	AGREE	AGREE	AGREE	AGREE	AGREE
Driver E	NO	-	AGREE	AGREE	NEUTRAL	NEUTRAL	AGREE
Driver F	NO	-	AGREE	AGREE	AGREE	AGREE	AGREE
Driver G	NO	-	AGREE	AGREE	NEUTRAL	NEUTRAL	AGREE
Driver H	YES	3 - 10 times	AGREE	AGREE	AGREE	AGREE	DISAGREE
Driver I	YES	1 - 2 times	AGREE	AGREE	AGREE	AGREE	DISAGREE
Driver J	YES	1 - 2 times	AGREE	AGREE	AGREE	AGREE	NEUTRAL
Driver K	YES	3 - 10 times	AGREE	AGREE	AGREE	AGREE	NEUTRAL
Driver L	YES	1 - 2 times	AGREE	AGREE	AGREE	AGREE	NEUTRAL
Driver M	YES	1 - 2 times	AGREE	AGREE	AGREE	AGREE	DISAGREE
Driver N	YES	3 - 10 times	AGREE	AGREE	AGREE	AGREE	DISAGREE
Driver O	YES	1 - 2 times	AGREE	AGREE	AGREE	AGREE	AGREE
Driver P	YES	3 - 10 times	AGREE	AGREE	AGREE	AGREE	DISAGREE

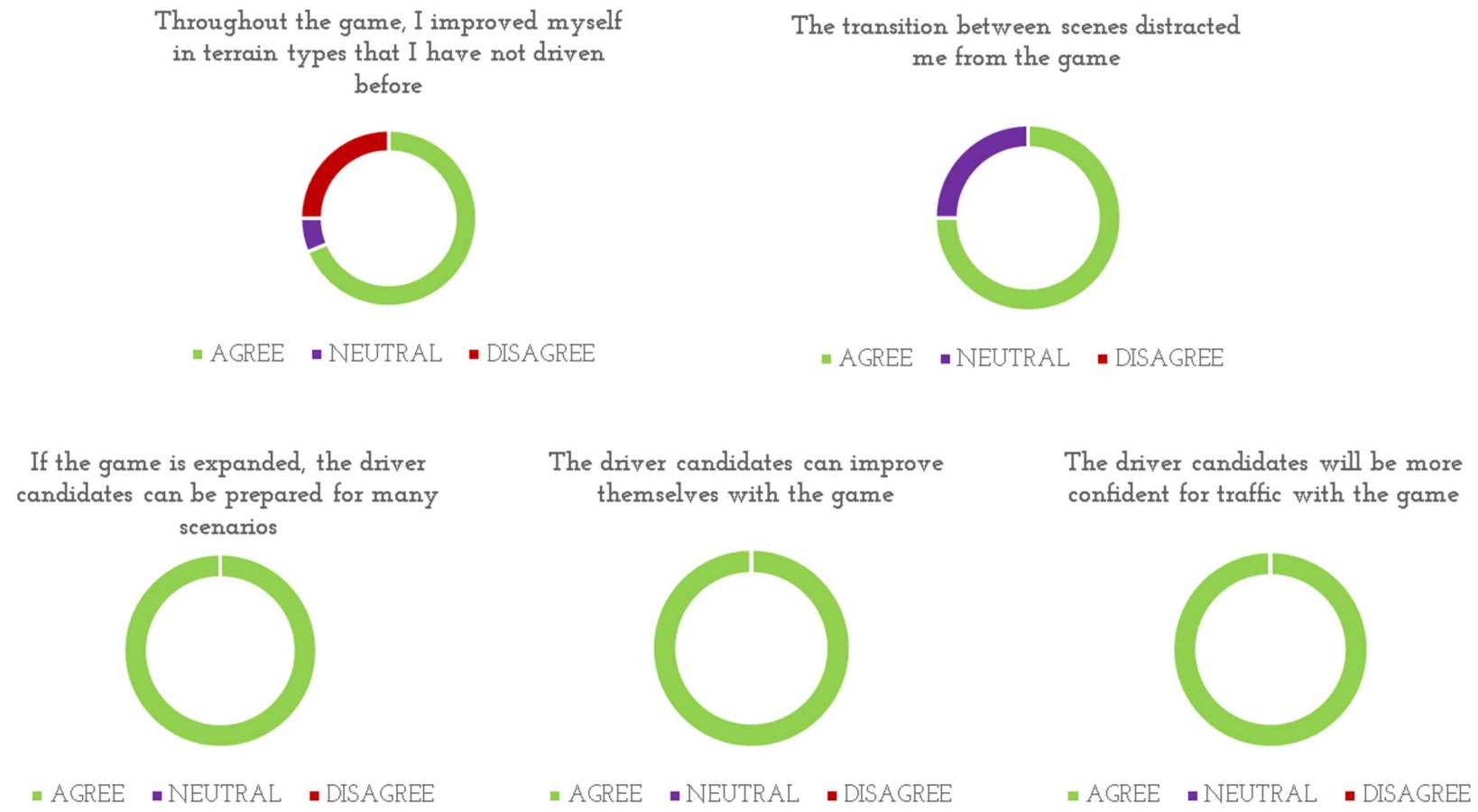

Figure 4.11 : Graphs of the significant results about game and personal opinions.

5. CONCLUSIONS AND RECOMMENDATIONS

It was made in the pre-tests of AR and VR serious games because it was thought that the necessary conditions and exams were not enough to have a license. As a result of research analysis, there are individuals who have a driving license and have received very unsuccessful results. Two of the participants have difficulties in active traffic even though they have driver's licenses. These show that the driving license exams conducted by traditional methods are insufficient for obtaining a driving license. It was determined that there are drivers who do not know the meaning of even traffic signs that are frequently encountered in daily life in AR games. The hypothesis, which is the origin of this research, was strengthened. The reason for choosing immersive technologies is that they are more interesting and motivating than other technologies. AR and VR games were found to be interesting and increase focus and reality as a result of the survey. This result was expected as it is known that immersive technologies are a source of motivation. VR is an interesting and a fascinating technology that enhances the effect of 'being there'. In addition, this effect increases even more when VR is supported by the steering wheel.

During the test process, it was possible to test with drivers who have driving licenses. Due to the pandemic, tests could not be conducted with driver candidates. It is planned to retest with participants who do not have a driving license to measure the effect of the VR game. Some participants thought that they did not improve due to the terrain and situations they had previous experience with. For the upcoming version, it is considered to design an expanded stage that will include many scenarios. It is planned to add weather changes and a night version within this expansion. Every participant stated that in case the game is expanded and many more scenarios are added, it will help the driver candidates in preparing for the traffic and give them self-confidence. It is thought that test results of future driver candidates' test group will reinforce this hypothesis. Also, It is planned to add a training phase for driver candidates to the VR serious game. Thus, driver candidates will learn in detail and practice what to do for

each scenario. In addition, in thesis VR game, tests have been made on automatic transmission cars. In the future, it is planned to add a manual gear option.

Transitions between scenes appear to be distracting in thesis VR game. We conclude that this is a situation that reduced the immersive effect of VR. Due to the lack of equipment and the size of the scenes, three different scenes were designed. In the future, it is aimed that all scenarios will have an uninterrupted flow within a single scene like an open-world game. Compared with Table 4.3, it was determined that participants in the gamer group realized that they did not have hands in-game as seen in Table 4.4. It was not expected to be noticed at the beginning of the test. Therefore, in the next version, it is aimed to transfer the players' hand movements to the game by adding the Hand Tracking feature of the VR headset.

In the reaction tests, people with a very slow reaction rate were detected. Although it is thought that there may be a relationship between the average of the reaction times and the endgame score, no definite relationship has been determined. Since external factors are not taken into account while making these measurements, it is planned to take into account external factors in future reaction time measurements.

It is important for driver candidates to have a driving license by being trained in the virtual world and prepared for all kinds of scenarios before practicing, both for drivers and to prevent accidents. Participants think that they have progressed despite having a license and driving actively. The most important reason for this is that they drive in areas they have not experienced before. Drivers can be prepared for different scenarios that cannot be tested during the exam or taught in courses with such games. It is planned to add a training phase to the VR serious game. Thus, driver candidates will learn in detail and practice what to do for each scenario. Also, it is aimed for the driver candidates to gain experience on real world roads by using Google Maps APIs instead of Terrain Generator asset.

One of this research's aims is setting standard procedures to get a driving license in low-income and middle-income countries and to evaluate reaction time and candidate's behavior with the serious game. However, behavioral evaluation was not taken into account in this thesis, which is the first part of this research. It will be added in future studies.

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APPENDICES

APPENDIX A: GEQ
APPENDIX B: Experiences test with scene pictures
APPENDIX C: Summary of the significant results about game and personal opinions
APPENDIX D: Test drivers' reaction times graphs

APPENDIX A

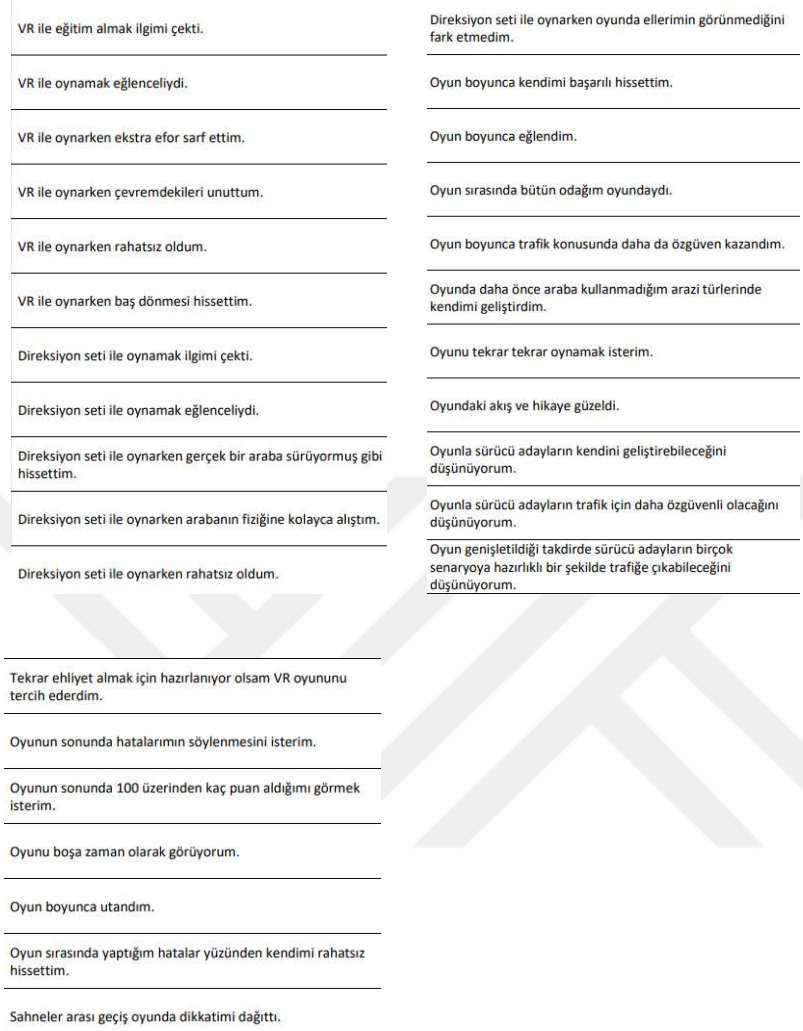
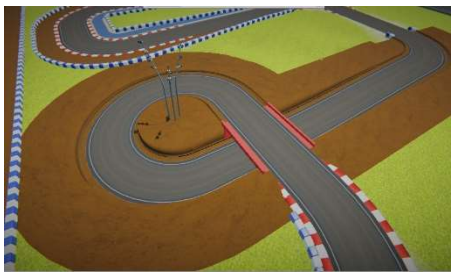


Figure A.1 : The questions of GEQ

APPENDIX B



(a)

(b)

(c)

(d)

(e)

(f)

(g)

(h)

(i)

Figure A.2 : Scene pictures in picture-test questions after testing

Oyun sırasında...
...rahatsız hissettiğim sahneler
...zorlandığım sahneler
...kolay olduğunu düşündüğüm sahneler
...korku hissettiğim sahneler
...arabayı sürmekte zorlandığım sahneler
...trafik işaretlerine dikkat ettiğim sahneler
...VR gözlükten dolayı zorlandığım sahneler
...direksiyon setinden dolayı zorlandığım sahneler
...bulantı ve baş dönmesi hissettiğim sahneler

Figure A.3 : Questions in picture-test

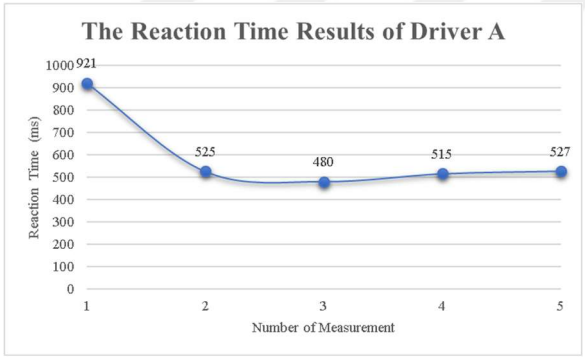
APPENDIX C

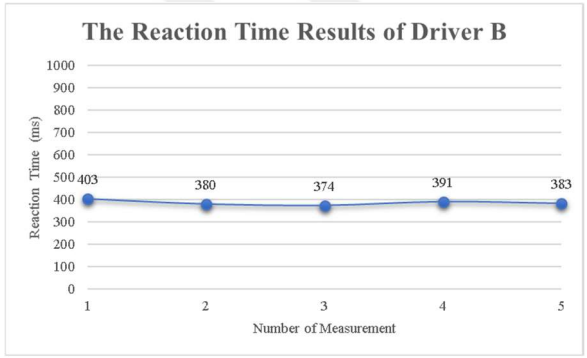
Table A.1 : Summary of the significant results about game.

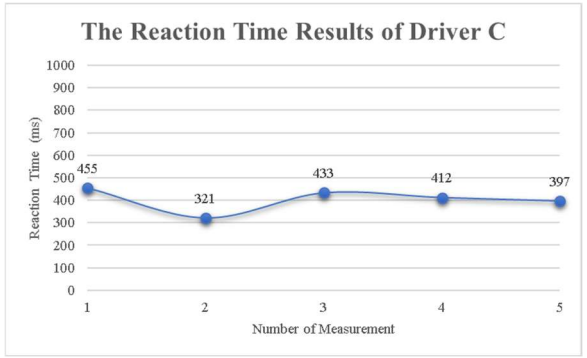
Drivers	Is the tester a gamer?	Throughout the game, I improved myself in terrain types that I have not driven before.	If the game is expanded, the driver candidates can be prepared for many scenarios.	The driver candidates can improve themselves with the game.	The driver candidates will be more confident for traffic with the game.	The transition between scenes distracted me from the game.
Driver A	NO	AGREE	AGREE	AGREE	AGREE	AGREE
Driver B	NO	NEUTRAL	AGREE	AGREE	AGREE	NEUTRAL
Driver C	NO	AGREE	AGREE	AGREE	AGREE	AGREE
Driver D	NO	DISAGREE	AGREE	AGREE	AGREE	AGREE
Driver E	NO	AGREE	AGREE	AGREE	AGREE	NEUTRAL
Driver F	NO	DISAGREE	AGREE	AGREE	AGREE	AGREE
Driver G	NO	AGREE	AGREE	AGREE	AGREE	AGREE
Driver H	YES	AGREE	AGREE	AGREE	AGREE	AGREE
Driver I	YES	AGREE	AGREE	AGREE	AGREE	AGREE
Driver J	YES	AGREE	AGREE	AGREE	AGREE	AGREE
Driver K	YES	AGREE	AGREE	AGREE	AGREE	AGREE
Driver L	YES	DISAGREE	AGREE	AGREE	AGREE	AGREE
Driver M	YES	AGREE	AGREE	AGREE	AGREE	AGREE
Driver N	YES	AGREE	AGREE	AGREE	AGREE	NEUTRAL
Driver O	YES	DISAGREE	AGREE	AGREE	AGREE	AGREE
Driver P	YES	AGREE	AGREE	AGREE	AGREE	NEUTRAL

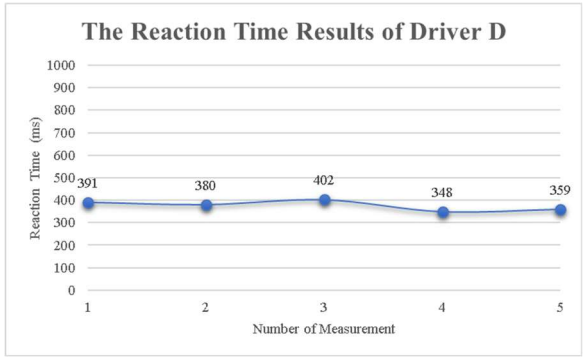
APPENDIX D

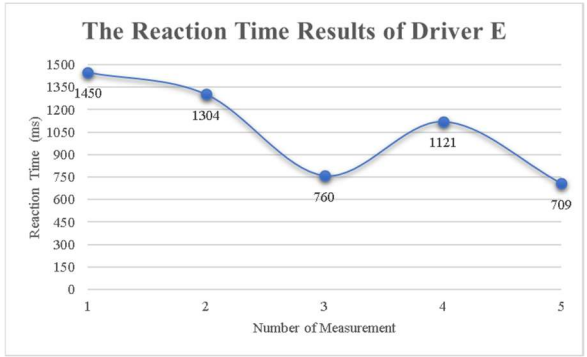
Table A.2 : Test drivers' reaction times graphs.

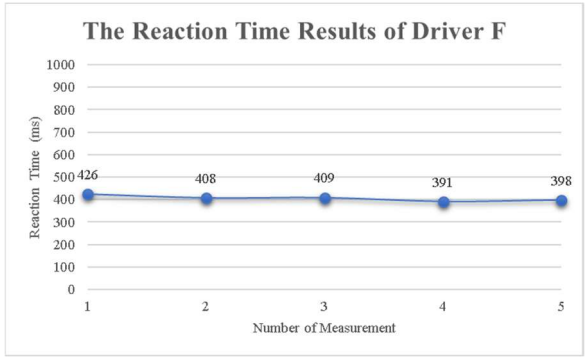


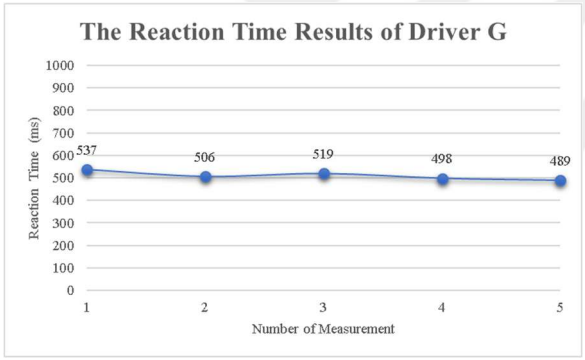


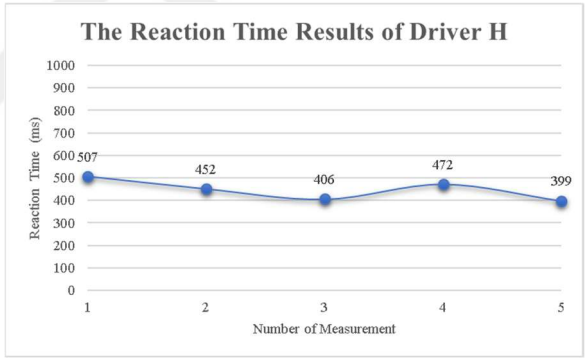


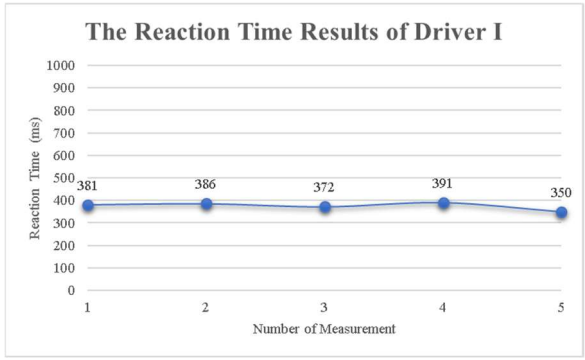


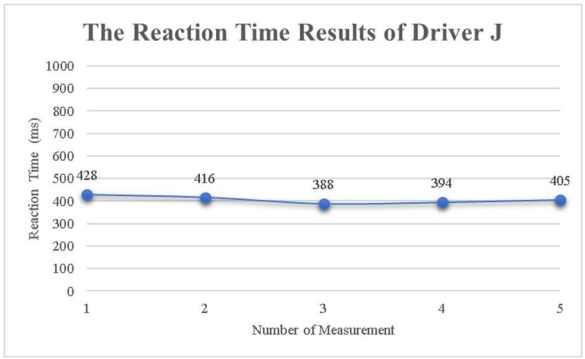


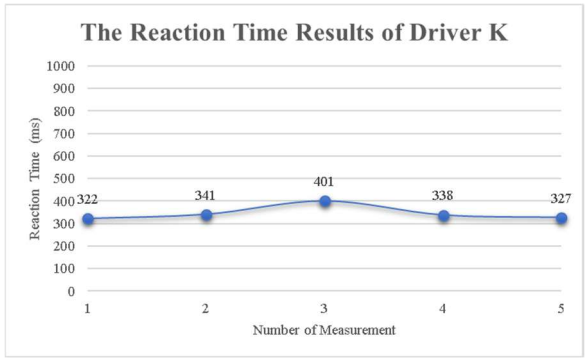


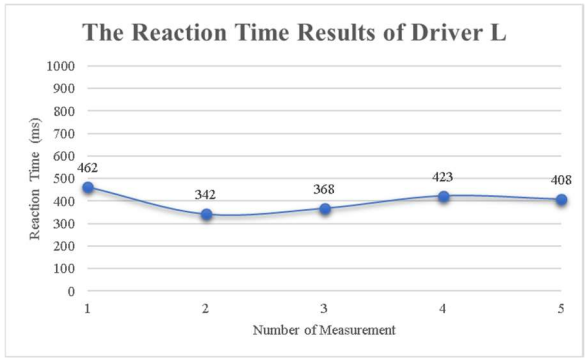

The Reaction Time Results of Driver G
Reaction Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
537
506
519
498
489
1
2
3
4
5
Number of Measurement

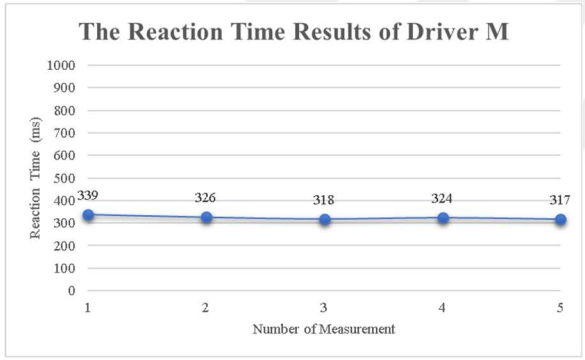

The Reaction Time Results of Driver H
Reaction Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
507
452
406
472
399
1
2
3
4
5
Number of Measurement

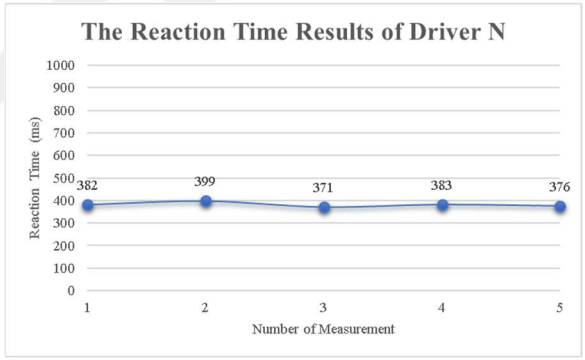

The Reaction Time Results of Driver I
Reaction Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
381
386
372
391
350
1
2
3
4
5
Number of Measurement

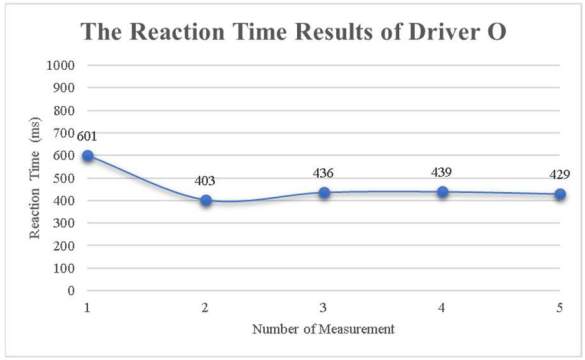

The Reaction Time Results of Driver J
Reaction Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
428
416
388
394
405
1
2
3
4
5
Number of Measurement

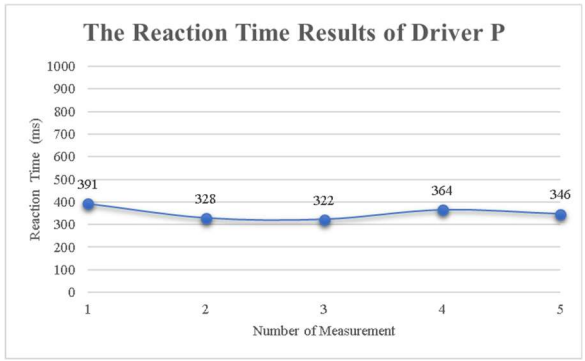

The Reaction Time Results of Driver K
Reaction Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
322
341
401
338
327
1
2
3
4
5
Number of Measurement


The Reaction Time Results of Driver L
Reaction Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
462
342
368
423
408
1
2
3
4
5
Number of Measurement

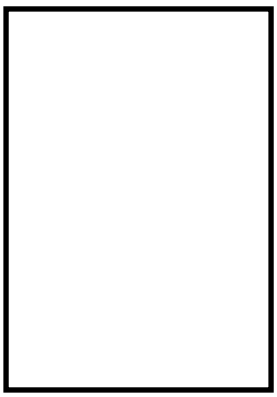

The Reaction Time Results of Driver M
Reaction Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
339
326
318
324
317
1
2
3
4
5
Number of Measurement


The Reaction Time Results of Driver N
Reaction Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
382
399
371
383
376
1
2
3
4
5
Number of Measurement


The Reaction Time Results of Driver O
Reaction Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
601
403
436
439
429
1
2
3
4
5
Number of Measurement


The Reaction Time Results of Driver P
Reaction Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
391
328
322
364
346
1
2
3
4
5
Number of Measurement

CURRICULUM VITAE



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OTHER PUBLICATIONS, PRESENTATIONS AND PATENTS:

- **Avşar, T.**, Sefercioğlu, E.N., Köse, H., 2020. İş Hayatında Oyunlaştırma, *İTÜ Vakfı Dergisi*, pg. 6-11.