COMPARING THE DIFFERENT PERCEPTIONS OF SITE ENGINEERS, WORKERS, AND GRADUATE STUDENTS TO SAFETY TRAINING BY USING EYE-TRACKING TECHNOLOGY

by

ZAKI MARWA

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ABSTRACT

COMPARING THE DIFFERENT PERCEPTIONS OF SITE ENGINEERS, WORKERS, AND GRADUATE STUDENTS TO SAFETY TRAINING BY USING EYE-TRACKING TECHNOLOGY

The construction industry is known to be risky and full of trammels; therefore, an appropriate safety training method is needed to mitigate the hazardous effects of construction activities. Researchers and practitioners have been trying to improve the construction site's conditions for decades. However, construction accidents still take place in many countries around the world. On the other side, scientific and industrial advancements considered to be essential in mitigating site incidents; therefore, scientists have been trying to employee information technologies in this regard. Virtual environments have favorable effects on safety management. This study aims at exploring the potential of a virtual environment application and a traditional safety training application in safety management. More specifically, a virtual environment based safety training tool entitled V-SAFE.v2, and a least engaging safety training application embedded by a Powerpoint presentation were used to examine participants' reactions and concentration levels during safety training. In this regard, eye-tracking technology was utilized to explore the participants' eye movement during the safety training sessions. Five engineers, five workers, and five graduate engineering students participated in the study. In the experiment, participants experienced V-SAFE.v2 software which simulates scaffolding assembling activities in a virtual environment, after that, they were asked to attend the Powerpoint presentation that contains detailed information about the scaffolding activities along with an eye-tracking device in front of them. After finalizing the tests, participants filled a survey that is related to their backgrounds and experiences. The main findings from this study show that engineers concentrate faster than workers and students during all sessions of safety training, and

all participants spent more time exploring different areas of interest during the highly engaging safety training. Therefore, it was concluded that using virtual environment applications in safety training leads to better concentration levels. Furthermore, it is foreseen that advanced technology applications and training scenarios will be used more widely in order to make construction sites safer workplaces in the future.

ÖZET

TEZ BAŞLIĞI

İnşaat endüstrisi riskli ve zorluklarla doludur; bu nedenle, inşaat faaliyetlerinin tehlikeli etkilerini azaltmak için uygun bir iş güvenliği eğitimi yöntemi gerekmektedir. Araştırmacılar ve uygulayıcılar, inşaat sahasının koşullarını yıllardır iyileştirmeye çalışmalarına rağmen, inşaat kazaları hala gelişmiş ülkeler de dahil olmak üzere birçok ülkede devam eden yaygın bir sorundur. Diğer yandan, bilimsel ve endüstriyel gelişmelerin saha kazalarının azaltılmasında etkin rol oynayacağı düşünülmektedir. Bu sebeple, birçok araştırmacı iş güvenliği alanında yeni gelişen teknolojileri kullanmaktadır. Bu kapsamda, sanal ve artırılmış gerçeklik uygulamalarının iş güvenliği yönetimi üzerinde olumlu etkileri olduğu gözlenmektedir. Bu çalışma, iş güvenliği eğitiminde sanal ortam uygulamasının potansiyelini ve geleneksel iş güvenliği eğitimi ile karşılaştırmayı amaçlamaktadır. Çalışma kapsamında, sanal ortam tabanlı V-SAFE.v2 isimli bir sanal iş güvenliği eğitim aracı ve iş güvenliği eğitimi içeren sunum tekniği kullanıldı. Verilen eğitimler sırasında, katılımcıların tepkilerini ve konsantrasyon seviyelerini incelemek için katılımcıların göz hareketleri göz izleme teknolojisi ile takip edilmiştir. Araştırmaya beş mühendis, beş işçi ve beş lisansüstü mühendislik öğrencisi katılmıştır. Deneyde, katılımcılar öncelikle sanal bir ortamda iskele montaj faaliyetlerini simüle eden V-SAFE.v2 ortamında eğitim aldılar. Daha sonra, katılımcılardan iskele çalışmaları hakkında detaylı bilgi içeren bir sunuma katılmaları istendi. Testleri tamamladıktan sonra katılımcılar özgeçmişleri ve deneyimleriyle ilgili bir anket doldurdular. Bu çalışma, mühendislerin her iki eğitim oturumunda da işçilerden ve öğrencilerden daha hızlı konsantre olduklarını göstermektedir. Ayrıca, tüm katılımcıların V-SAFE.v2'de aldıkları eğitim boyunca farklı ilgi alanlarını keşfetmek için daha fazla zaman harcadıkları belirlenmiştir. Bu nedenle, sanal or-

tam uygulamalarının iş güvenliği eğitiminde kullanılmasının daha iyi konsantrasyon seviyelerine yol açtığı sonucuna varılmıştır. Ayrıca, gelecekte şantiyelerin daha güvenli işyerleri olmalarını sağlayacak ileri teknoloji uygulamalarının ve eğitim senaryolarının daha yaygın kullanılacağı öngörülmektedir.

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LIST OF SYMBOLS/ABBREVIATIONS

AR	Augmented Reality
AOIs	Areas of Interest
CAS	Computer-aided Simulation
CAT	Computer-aided Technology
CT	Conventional Training
MR	Mixed Reality
RV	Reality Virtuality
SG	Serious Games
VE	Virtual Environment
VR	Virtual Reality
VSAFP	V-SAFE.v2 practice session

1. INTRODUCTION

1.1. Problem Determination

A vast proportion of on-site activities and practices impose site workers and engineers to risks. Working-from-height activities are one of the most hazardous operations in the construction industry [1]. For this reason, ensuring safety during the scaffolding activities is essential to keep site personnel away from hazards. Implementing safety training to site personnel decreases the possibility of site accidents. Researchers (e.g., Başağa et al. [1]) studied the significant obstacles in finding a comprehensive health and safety training programs tailored to the needs in the construction sector. They found that participants have different preferences for safety training methods according to their ages and academical backgrounds. As a result of these efforts, occupational health and safety training techniques have been improved substantially during the last decade. However, safety training is usually conducted in the same way for construction workers, engineers, and students. Yet, trainees might be more engaged if different safety training application was utilized. For instance, engineers might prefer the conventional way of safety training (such as booklets), while workers might prefer highly engaging safety training (such as computer game applications). Therefore, this study examines and compares the participants' behavior during various safety training techniques to distinguish participants' concentration levels in safety training.

1.2. Background of the Research

The construction industry is one of the most hazardous industries, and construction workers are exposed to danger more than any other sector [2, 3], however, this claim cannot be held against the critical role of the construction industry in a country's economic development and innovation. More clearly, many countries depend heavily on the construction industry to improve their economies, and to attract foreign investments. On the other side, the construction industry also has some adverse aspects to society, one of these aspects is the continuous exposure to risks. The construction industry includes human-machine interaction. Consequently, there are many risks associated with this interaction. For instance, Lin et al. [4] emphasized that the construction industry comprises many dangers due to the ongoing variations on-site and the ways of handling these variations. However, the approach to mitigate these risks is to design an appropriate safety training method that avail construction site staff. On the other side, researchers and practitioners have been trying to investigate the most hazardous activity on-site and mitigate its effects.

The definition of safety, hazard, and accident according to the national safety council (NSC) is as follows: safety: "is the control of recognized hazards to attain an acceptable level of risk" ,hazard: "is an unsafe condition or activity that, if left uncontrolled, can contribute to an accident", and Accident: "is an occurrence in a sequence of events that produces unintended injury, death, or property damage. accident refers to the event, not the result of the event." According to the official website of social security institution [5], the Turkish construction industry is considered to be one of the most hazardous industries; 788 deaths in Turkey are caused during construction activities annually. Moreover, Lipscomb et al. [6] stated that one of the most dangerous on-site activities is working from height activities. Therefore, an appropriate safety training technique should be followed by researchers and practitioners to decrease its effects.

1.2.1. Safety Training in the Construction Industry

Safety training in the construction industry is essential in achieving the required level of safety. Many researchers studied the effect of safety training on workers or engineers using different techniques [1, 7, 8]. The studies asserted the importance of safety training in reducing site accidents and fatalities. Moreover, Burke et al. [9] distinguished three levels of safety training methods. The levels are, (i) the Least Engaging, (ii) the Moderate Engaging (iii), and the Highly Engaging safety training methods. On one side, the least engaging safety training methods are the methods that use conventional training materials, such as presentations, booklets, and lectures. These methods are easy to prepare by practitioners and easy to attend by participants.

However, some studies asserted the adverse effects of such practices. For instance, Nielsen [10] discussed that the least engaging safety training methods might be tiresome and extended. On the other side, the highly engaging safety training methods are the methods that converge on hands-on-practice, hands-on-demonstrations, and behavioral modeling [9]. The highly engaging safety training methods were proved to increase participants' recognition and to support self-regulated learning [11]. Furthermore, highly engaging safety training includes various techniques; one instance is the application of virtual simulation technology in safety management.

Virtual environments first appeared in 1970-1975 when humans interacted with computers under the name of "Man-Machine Graphical Communication System" [12]. Virtual environment applications are recently utilized in the construction industry as a safety training tool; for instance, Sacks et al. [13] used a virtual technology application to strengthen workers' recognition of site hazards. Also, Guo et al. [14] tested a multi-user safety training tool in a tower crane. Although many research studies emphasized the advantages of utilizing a virtual environment in safety training, a limited number of studies discussed its role in working-from-high activities. Therefore, further research is required in this regard.

1.2.2. Human Behavior and Eye-tracking Technology

Working-from-height activity is an instance of a stressful situation that affects human behavior on-site. Reactions during stressful situations are affected by human behavior, background, and experiences. An average human being engaged in a stressful situation will have a fear feeling. The fear feeling is a normal state of reaction, and it depends on the surrounding situation and the subject him or herself [15].

Moreover, situational awareness also has a prominent role in peoples' behavior in stressful situations; for instance, people try to escape from the fire differently during a fire evacuation [15]. Besides, emotions also have an essential effect on human behavior during risks. For example, Bonnet et al [16] discussed that various emotions and decisions could be generated by engaging in risky activities that change people's behaviors.

Therefore, numerous techniques have been examined to follow up the human practices during risks. One of these techniques is Eye-tracking technology.

Eye-tracking technology includes the tools that measure the human eye movements during any learning processes [17]. Many researchers utilized Eye-tracking technology to investigate the potential cognitive differences of learners. Wang et al. [18] employed eye-tracking technology to investigate the cognitive differences of 40 undergraduate students during several learning patterns. The study concluded that using visual and physical models improves students learning abilities and strengthen their cognitive capacities. Moreover, Albert et al. [19] used eye-tracking technology to investigate the visual patterns adopted by construction workers during construction activities. The research indicated that superior hazard realization was observed by workers who have had a higher fixation time on demonstrated visuals. Therefore, eye-tracking technology was used in the study to investigate the cognitive abilities of various participant categories.

1.3. Aims and Objectives of the Research

This study aims to compare the different perceptions of site engineers, workers and graduate engineering students during two safety training techniques by using eye-tracking technology.

On the other side, the research objectives are:

1- To research the previous studies that investigated various training techniques.

2- To collect data using eye-tracking technology from different participants with different backgrounds.

3- To compare the behaviors of site engineers, workers, and master engineering students during safety training by using statistical analysis.

1.4. Research Method

The experimental design of this research has two main phases, in the first part, a virtual environment based training tool as a highly engaging safety training is utilized. In the second part, a Powerpoint presentation as a conventional and least engaging safety training is used. Moreover, the participants are also asked to fill out a survey in order to collect their demographic information.

Firstly, Many safety engineers still prefer to use conventional ways of safety training to construction workers [20]. The simple way to prepare this safety training materials and the limited project budget might be the reasons behind using conventional safety training. Moreover, traditional methods of safety training are easy to be performed and understood by the construction workers. The lack of interaction among trainees or between trainees and the training tool, the lack of behavioral modeling, the lack of hands-on practice, and the lack of providing feedback made the PowerPoint presentations a least engaging tool. The researchers designed a brief and informative presentation to be used in the experiments. The presentation consists of 11 pages, each page contains images and texts that represent the scaffolding activities.

On the other side, V-SAFE.v2 software was used as a highly engaging safety training in this study. V-SAFE.v2 is a virtual environment based safety training tool that simulates working at a height activity using scaffolding. V-SAFE.v2 software is an interactive tool that allows participants freely to decide, choose, and interact accordingly in a virtual environment. This interaction can be practiced either between trainees or between trainees and autonomous agents. These autonomous agents are choosen to follow the right sequence of steps during the training session, so that the software would be able to evaluate the real participants' performances accordingly.

Moreover, V-SAFE.v2 includes two separate training sessions. The first one assists the trainee by highlighting the correct options and providing inference texts. This session introduces users to key steps to be followed in the following training session of V-SAFE.v2. The second session of V-SAFE.v2 is simply a repetition of the first session, but without any assistance, trainees are required to memorize and follow the same sequence of actions during this session in order to finalize the test successfully. At the end of the V-SAFE.v2 training session, a detailed report pops up on the user screen to reveal the errors that were made by each participant.

At the end of the training sessions, participants are required to fill a survey that is related to their background. The survey questions examine the participants' background in gaming technology and the academical level. The survey helped researchers to compare the effects of age, occupation, or even gaming experience to participants' concentration levels during safety training.

On the other side, the eye-tracking technology was utilized during V-SAFE.v2 and the PowerPoint presentation sessions. The eye-tracking technology is a new trend in the construction industry, and it was used to examine the participants' gaze points during safety training. Tobii Pro X2-30Hz device was utilized in this study to perform this examination. It is a screen-based device, in which it can be set for any display screen (such as Laptop Screens, or TV screens).

Moreover, Tobii Studio 3.2 software was used to collect and classify data from the eye-tracking device, the data outputs are classified into tables according to the selected metric. In this research project two metrics were used, the first one is time to first fixation metric. This metric is defined as the number of milliseconds that are required by a participant to observe a specific area of interest. The second metric is the total fixation duration, which is defined as the number of seconds that are spent by a participant focusing on a particular area of interest. After that, the data was exported to the IBM SPSS statistics software for the final analysis., SPSS software consists of many analysis methods that were used in many studies. In this study, the Mixed-Design or Split-plot Anova test (SPANOVA) was utilized. The primary purpose of a mixed-model design ANOVA is to understand if there is an interaction between occupations, and training methods on the participants' time to first fixation and total fixation duration during safety training.

1.5. Research Limitations

Study limitations can exist due to constraints on research design or methodology, and these factors may impact the findings of the study. This study comprises three main limitations. The first limitation is the lack of prior research that compares the perception of engineers, workers, and students to various safety training methods. Although many studies examined participants' behavior during different safety training techniques, a limited number of studies compared the response of engineers, workers, and graduate engineering students. However, this comparison was conducted in this research project. The second limitation is the self-reported data that were collected using the induction survey. Participants might have answered the survey question improperly in order to finish the training session as soon as they could.

1.6. Organization of Thesis

This thesis examines the participants' behavior during two safety training methods. The organization of this thesis is as follows. Chapter 2 introduces readers to the previous related studies, occupational health and safety, human behavior in crises, and safety training along with virtual environment application studies are presented in this chapter. Chapter 3 describes the methods that were used in the research. The least engaging safety training that is dedicated by a PowerPoint presentation and the highly engaging safety training that is dedicated by V-SAFE.v2 software was described in this chapter. V-SAFE.v2 software was described in this part as a virtual reality game that simulates scaffolding assembling activities. Then the eye-tracking technology was introduced as a new technique that record participants' eye pupil's movements during the safety training. Chapter 4 introduces the reader to the methods used in data collection. Tobii Studio 3.2 software was utilized to collect and compromise data from the eye-tracking device.

At the end of chapter 4, the data collected from the survey are discussed. In Chapter 5, IBM SPSS statistics 25 was ıntroduced, mixed-design, or split-plot ANOVA test (SPA NOVA) was utilized in this research to examine two hypotheses. In chapter

6, the study results were extracted using Microsoft excel and IBM SPSS statistics. In chapter 7, the study results were discussed; the major findings were summarized in two sections. The perception of areas of interest part, that proves that previous site experience increases participants' perception to safety training. Then, the concentration level section, which discusses that participants with academical background focus more during safety training sessions. In chapter 8, the study's conclusions were summarized.

2. LITERATURE REVIEW

2.1. Construction Safety Management

Construction projects consist of various unique factors, such as high ratio of unskilled workers, repeated work, and weather conditions. Construction sites may be under many variations in topology, topography, and work conditions during the project execution. These characteristics and variations make construction safety managing more intractable than managing safety in other industrial factories. The difficulty in changing site conditions created the outer limits of safety management. For instance, working at high heights is not avoidable if the structural project is a bridge, it is impossible to bring in high rise cranes into tunnel projects, or a construction project being carried out in the center of a crowded city has different restrictions than a project being executed at the outskirts of a city [21].

In construction projects, improper safety management during project execution may cause accidents. Occupational accidents take considerable attention from practitioners. Extensive efforts have been made to mitigate the high number of occupational accidents in construction, specifically via technical frameworks, principles, and solutions [21]. The International Labor Organization (ILO) anticipated that more than 60,000 accidents take place annually in the construction industry around the world, for the rate of one accident every 10 min [22]. So, people who work in the construction industry should be firmly familiar with safety management, climate, and culture.

Neal and Griffin [23] defined perceived safety climate as "individual perceptions of policies, procedures and practices relating to safety in the workplace" while Pidgeon [24] defined safety culture as "the set of beliefs, norms, attitudes, roles, and social and technical practices which are concerned with minimizing the exposure of employees, managers, customers, and members of the public to conditions considered dangerous or injurious." therefore, construction site characteristics should be defined in advance to specify the safety climate and the associated safety culture accurately.

2.2. Occupational Health and Safety

The construction industry is characterized by complexity and the high number of operations during project execution, that in return create many occupational risks [25]. Rozenfeld et al. [26] discussed the undergoing changes in Job Safety Analysis (JSA). Which is defined as "Practical method for identifying, evaluating and controlling risks in industrial procedures". In another study done by Hinze et al. [27], researchers analyzed the occupational health and safety and its relationship to construction designing phase, in which researchers concluded that earlier planning for safety training would prevent around 45% of site accidents. On the other hand, many researchers studied the risk prohibition during construction stage, for instance: (i) the effect of human behavior was investigated by Hizne and Jimmie [28]; (ii) the effectiveness of health and safety strategy by Erten et al. [29]; (iii) and the power of responsible parties on occupational health and safety training by Toole and Gambatese [30]. Therefore, to prevent or reduce onsite accidents, a thorough research about accident pattern should be done.

2.2.1. Occupational Site Accidents

Human-based accidents are the most severe accidents in the construction industry. Many researchers have addressed many accidental classifications. Specifically, fatal or non-fatal categories have been addressed by Gürcanlı et al. [31] in Turkey, the researchers found that fall from height accidents are at the top of the accidental list with 426 (54.1%) out of 788 deaths in 2012, including 191 (52.9%) of non-fatal injuries. Moreover, practitioners mentioned that working from height caused 15,500 (44.4%) accidents of the total number of accidents (34,952) in 2017 according to the official website of social security institution [5]. Academia has an enormous potential in developing accident causation research models [32]. Many accidents can be avoided by identifying and revoking accident causation factors, therefore identifying accident contributing factors is essential for incident prevention.

In a study done by Sousa et al. [33] various accidental pattern is assumed; however, two categories are adopted: (i) accident evaluation studies and (ii) accident causation patterns. The accident evaluation studies explore the research that can be utilized to provide information about hazard identification, hazard analysis, and hazard assessment. The accident causation patterns are a generic institutional arrangement that represents accidents causes, categories, and outcomes. Sousa et al. [33] concluded that with the current group of categorizations, the focus of the research is bounded to the execution phase of construction projects. Therefore, further research should be implemented to explore the cautions of site accidents.

Haslam et al. [34] discussed the contributing factors in site accidents, investigating the causations and consequences of 100 individual construction accidents in Great Britain. Results showed that 70% of site accidents are raised from workers or working teams, while problems accuse 27% of them with suitability and conditions of materials. Based on the information above, models of adverse effects have been suggested, which acknowledge the adaptive conditions of site workers. To sum up, construction site conditions, and hazardous tasks are the leading causes of construction site injuries and fatalities. Academic researchers have been working along with site employees to improve working conditions in construction, falling from height accidents take considerable care by practitioners and researchers, therefore, highlighting this issue is essential in terms of occupational site accidents.

Falling from height incidents is the top reason behind site fatalities in the construction industry. Many researchers investigated the reasons and the associated results of fall from height accidents [3, 35–38]. Limscomb et al. [35] investigated the reasons behind the falling of 95 carpenters who fell during 3-years period in the U.S. The study concluded that many accidents could have been avoided by using the conventional fall protection tools. On the other side, many fall-from-height prevention methods were practiced inappropriately in the construction industry [36]. Kaskutas et al. [36] mentioned that it was reasonable to see workers walking in a slim end of a 2nd story wall in two-thirds of the worksites audited locations in the U.S. The lack of safety knowledge, lack of management and inconsistent safety pieces of training are the major causes of fall-from-height accidents [39].

Rubio-Romero et al. [37] discussed that 40% of site accidents in Spain are caused by falling-from-heights accidents, 30% of these accidents are caused by falls from temporary construction equipment such as scaffolds. There are many studies regarding the safety level of scaffolding equipment since it is considered as the primary cause of fall from height accidents in the industry [37]. Some studies showed the risk involved when handling more loads on "suspended scaffolds" [40]. While another research insisted about the ergonomically unsuitable techniques within disassembling scaffolding [41]. A research conducted in Poland by Hola et al. [3], includes a set of 177 onsite scaffolding accidents. The study shows that 43.5% of accidents resulting in severe body injuries, while 35.6% of these accidents cause light body injuries [3]. As mentioned earlier in this part, a considerable percentage of falls accidents occur because of human response to potential risks, so, human behavior in crises should be scrutinized.

2.3. Human Behavior in Crises

It is known that any human engaged in a stressful situation has a tension feeling regardless of their experience, age, safety training, or gender. This tension is the normal state of reaction to hazards [42]. The reaction of ordinary people to stressful events relies on the surrounding situation, the subject him or herself, and the task requirements [43]. Tucker et al. [44] tested the changes in participant's anxiety along with various hazard levels. The study stated that participants who were given information about environment layout before experimenting have less anxiety and less time to evacuate.

Ahn et al. [15] discussed the analysis of fire evacuation process for a sophisticated shopping mall in Korea. The study argues that the main reason for evacuation delay during a fire is peoples' conflict about exit's location; this conflict might delay the evacuation process significantly. Researchers use a three-stage agent base model in the study to model people's behavior. First-time visitors were used in intention to simulate the worst predictable case, which is all visitors run towards one exit. To mitigate this issue, an appropriate directing should be provided to agents which mainly depends on the situational awareness. Shortland et al. [45] discussed the effect of situational awareness in mitigating people conflicts during crises.

Situational awareness is defined as the incessant and prompted information extraction from the surrounding and the capability to expect results of actions and proceed accordingly [45]. As shown in Figure 2.1, situational awareness process consists three steps. The first one is hazard or risk detection, the second one is hazards' perception, and the last one is the projection of the consequences associated with risks and the consequences decisions [46]. In the construction industry, Level II (hazard perception) is crucial, workers and site engineers may unconsciously behave in a wrong way during risks when they cannot perceive and assess hazards [46]. Researchers discussed that emotions affect risk detection, perception, and decision-making process significantly, yet, there is no study that explores the exact nature of these emotional obtrusions.

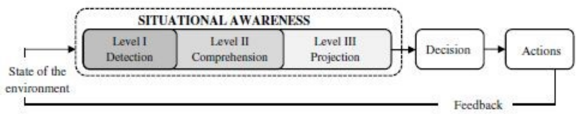


Figure 2.1. model of situation awarness (Endsley 1995)

Emotions are internal, and psychical states that indicate a person's feelings towards the surrounding circumstances [47]. It is found that situational emotions affect people's reaction significantly [47]. Risk-taking and emotions are linked effectively, where, engaging in risky activities can generate vigorous emotions [16]. Emotions affect decision-making noticeably; in a study done by Drevets and Raichle [48], it was found that blood fluxes decreased in the areas devoted to risk-based decision-making when exposure to tense emotions. On the other side, in a study done by Patrick and Christopher [49] , people engage in abnormal risk-taking behaviors when they cannot fully experience negative emotions such as panic and fear.

Many researchers have discussed some assumptions related to emotions and its relation to risk-based decision-making and risk-perception [50,51]. Loewebstein et al. [52] discussed risk-as-feelings hypothesis, which assumes that feelings, such as panic, worry, and fear are the feelings that lead people to respond to critical situations. So, it is evident that emotions affect people's behavior significantly; however, the relationship between emotions and actions is not fully understood. Majority of the studies mentioned above were conducted using synthetic conditions; therefore, there is a need for an experimental setting that is much closer to the real-life situation. In this regard, virtual environment and Eye-tracking applications have dramatically affected research outcomes in examining human behaviors in crises.

2.4. Safety Training

Construction accidents are considered the most severe and intense among industries. Therefore, practitioners should follow a well-designed safety training courses on-site. Başağa et al. [1] studied the effectiveness of occupational health and safety training in Turkey. Researchers examined workers with different ages, experiences, and educational levels. Face to face surveys was carried on; they asked workers about safety training methods and its applicability in Turkey. The researchers concluded that the occupational health and safety Turkish training law had not been fully applied in the domestic construction industry. Another study done by Cunningham et al. [53] discussed hazards when non-native workers exposed to inappropriate safety training sessions. The study took place in the United States, and the results showed that non-native workers who work in small firms are less likely to receive safety pieces of training using their native language or even receive the safety training itself.

Therefore, various safety training techniques have been used to mitigate accidents' effects and severities. For instance, Hinze et al. [27] conducted face-to-face interviews in 57 projects in the U.S to address the effectiveness of various hands-on-practice techniques. The study concluded that intense orientations and safety sessions bear effective performance. Also, Hallowell [54] approved that the U.S construction companies considered the implementation of orientations, toolbox talks, presentations, and informal safety discussions as the most conventional ways used. Legal Reports BLR [55] reported that workers learn more about safety procedure by using various training methods, in which commensurate with worker's situation. For instance, on practice workers learn by practical instructions, while visual workers learn more by sight methods. In the same regard, Perlman et al. [56] debated that experienced participants identified more hazards during safety training sessions, the study proved that experienced engineers in fact identified more hazards during safety training. Burke et al. [9] discussed three levels of safety training methods, the Least Engaging, Moderate Engaging, and Highly Engaging safety training methods. The least engaging safety training methods, highly engaging safety training methods, and the differences between them are considered in the following sub-sections.

2.4.1. Least Engaging Safety Training Methods

Various methods and techniques are used in safety management, such as conventional training methods (CT) and computer-aided technologies (CAT) [57]. Least engaging safety training or conventional safety training methods in construction was defined in studies done by Demirkesen et al. [58] as "the methods that are used in traditional construction sites, such as booklets, presentations, lectures, and videos."

Furthermore, CT methods have been assumed to be not ideal in practice [14]. The conveyance of Health and Safety knowledge should be done accordingly with employees' preferences [14]. Construction employees tend to lose attention memorizing safety instructions that are delivered by using the conventional methods [59]. According to the same study, workers would prefer more engaging safety training methods than the least engaging ones. The lack of safety knowledge that conventional training methods include is because of the following [13, 14]: (i) the conventional safety training might be long and tedious, so, participants' concentration may decrease accordingly; and (ii) the lack of feedback in CT may decrease improvements. Therefore, academia started to explore more engaging methods. Such as computer-generated simulations (CGS) and virtual environment applications.

2.4.2. Highly Engaging Safety Training Methods

Definite evidence is absent on the effect of the conventional occupational health and safety training in accidents [9], this is a consequence of the assertion that participants can receive, operate, memorize, and then practice training without error [9]. Highly engaging training methods have been discussed thoroughly during the last decades. Burke et al. [9] Defines the highly engaging safety training as the training methods that focus on hands-on-practice, hands-on demonstrations, and behavioral modeling. Burke et al. [60] upholded the anticipate of engaging training methods under the title of ”engagement hypothesis”: engaging methods are always preferable in improving safety training performance. In engaging training, the learning experience is actively superior to other training methods [60]. Bell and Kozlowski [11] emphasized the importance of tightly structure of the learning environment, as limiting trainees' control, and providing step-by-step instructions, completed tasks and its concepts, rules, and strategies. Engaging methods do not only give people control over their desires but use formal training design elements to shape the cognitive, motivational, and emotional learning processes that support self-regulated learning [11].For instance, in a study done by Leder et al. [61], a comparison of participants' perception was performed in safety training of pillar drill during a virtual environment application and a PowerPoint presentation, the results of this study showed that participants' concentrate more during the highly engaging safety training than the least engaging safety training.

Furthermore, Chang et al. [62] examined differences on flow experiences and different kinds of cognitive loads (intrinsic, extraneous, and germane cognitive loads) between game-based learning and non-game-based learning groups. Participants were students of two classes taking a general education course, named Life and Technology, in a university. There were a total of 103 participants in the experiment: 50 students in one class (experimental group) used game-based learning materials; 53 students in the other class (control group) used non-game-based learning materials (web page-based learning material). The results revealed that the game-based learning group significantly created more flow experiences than the non-game based learning group.

To sum up, previous research asserts that adaptiveness, behavioral pursue, and efficient sophisticated knowledge transmission are the conditions of excellent Occupational Health and Safety (OSH) performance, and the highly engaging safety training includes these factors. Additionally, Burke's theorization emphasizes that engaging training is always better than non-engaging or least engaging training due to hands-on-practice and visualization improvements.

2.4.2.1. Engaging Safety training Models. Engaging safety training consists of many models, such as computer games, computer-aided simulations, virtual environment, augmented reality, and mixed reality. Augmented Reality (AR) and Mixed Reality (MR) are sophisticated technology that are utilized for visualization purposes [14]. In contrast to virtual realities, which is displayed separately in the computer-based screen, AR and MR integrate virtual and real-world conditions [63]. AR and MR technologies superpose the real-world physical environment using computer-based visuals (image, and text) to enhance participants' recognition and perception to the real-world using HMD devices or unique cameras [64]. MR is the next level of AR [64], MR is not just superposing virtual content on the real-world substances but anchors virtual content to the real world and gives a participant the ability to react with virtual content in the real world. Further detailed explanations about VR and its applicability in constriction is discussed in the following part.

2.5. Virtual Simulation Technologies in Construction Safety Management

The official concept of virtual environment was brought up in 1989 [12] after the first human-computer based interaction was carried out under the title of "Man-Machine Graphical Communication System" [12]. Virtual simulation technology has been defined differently in many studies, Lanier et al. [12] defined the official term of virtual environment as "the computer-generated simulation of three-dimensional images of an environment or sequence of events that someone using special electronic equipment may view, as on a video screen, and interact within a seemingly physical way " virtual simulation technology applications consist 3D environment models, This environment does not necessarily depend on a real one, this technology tries to subrogate participant's perception to surroundings with a computer-generated 3D model. It is also aims to create a real sensation for users by using immersive technologies, such as 3D or 2D environments, however, virtual simulation technology gives a limited sensation of reality because of the limited capabilities in transferring real sensations [65].

The limited level of 'realism' is due to the shortage of feedback to determine the level and standard of participant's perception [18]. The feature of virtual simulation applications is the events simulations that are impossible to simulate in the real world, for instance Shendarkar et al. [66] simulated the safe evacuation of a residential building using VR application. Moreover, VR applications have been widely used in architecture, engineering, and construction (AEC) industry. Notably, in architectural design checking and administration [67], construction education [68], construction planning [69], operation and maintenance [70], and safety training [13].

Virtual simulation applications have been used in the safety training field recently. Comparing to conventional training methods, these training methods are more useful and engaging to increase participants recognition of hazards [13]. Zhao et al. [71] used virtual simulation applications in electrical hazards' recognition. Participants have recognized on-site electrical hazards thoroughly after virtual environment safety training session. Furthermore, Teizer et al. [72] suggested a model that combines ironworkers' real-time location tracking and a 3D virtual environment. The model was proved to increase ironworkers' hazard recognition and consequently, their productivity and performance [72].

Albert et al. [73] focused on virtual environments to improve hazard recognition skills of construction workers. The researchers developed a high fidelity virtual environment and tested its feasibility with 6 workers. After defining the initial knowledge level of all participants by conducting a paper-based test, they walked in a virtual environment to identify workplace hazards. Then, the same written test was applied to the participants again. The empirical test results indicated that the participants increased their performance by 27% after experiencing a virtual environment. Another study done by Sacks et al. [13] contributed in developing a tool that identify workplace risks in a virtual construction environment. They conducted a study with 66 participants to test the efficiency of the simulation tool. The subjects were divided into two groups; one of them received traditional safety training by using 2D materials, and the others were trained by the 3D immersive virtual environment to recognize construction site hazards. According to results, the second group which trained in the 3D environment performed better in terms of identifying workplace hazards.

Guo et al. [14] conducted another study on safety training using game technologies. In this study, the authors introduced and tested a multi-user safety training tool for dismantling a tower crane. In this study, project managers and crane operators used a game-based training tool and answered a survey related to conventional safety training that is dedicated by a booklet, and virtual simulation application that simulates crane operations. The findings of the survey showed that crane operations would be safer and more efficient with the support of game-based training tools comparing to traditional tools.

Even though many studies emphasize the advantage of using virtual environments in safety training [14, 18, 73], a limited number of studies clarify the role of virtual environments in scaffolding activities. Nadhim et al. [38] discussed that scaffolding activities are one of the leading causes of falling-from-heights accidents in construction. The study points out that 23% of falling-from-height accidents take place during assembling, disassembling, or post-assembling activities of scaffolding parts. The same study indicates that the second most serious cause of falling-from-height incidents is because of learners' lack of education, experience, or knowledge level.

To sum up, construction workers lack proper safety training, virtual simulation techniques have an enormous impact in AEC industry. An improvement in hazard recognition abilities, safety training techniques, and performance, were noticed in many studies [13, 66, 71]. Therefore, the development of these applications in construction would definitely reduce fatalities and long-term injuries for on-site workers. Furthermore, a limited number of studies clarify the workers' reactions during safety training sessions. So, the following chapter answers the research question of this study: *how do engineers, workers, and graduate engineering students behave during the least and highly engaging safety training.*

3. RESEARCH METHODOLOGY

3.1. Introduction

One of the essential chapters in any research or practical study is the research methodology. This section extends readers' knowledge about procedures needed to achieve the required aims and objectives. This part provides justifications of selecting the following method to the current research.

Scientists and researchers conducted comprehensive research in the past regarding safety management issues [9, 53, 57]. Researchers summarized the significant obstacles of finding extensive health and safety training programs that fit the industrial needs, especially in developing countries like Turkey. However, health and safety training methods in the construction industry have been improved substantially during the last decade. Therefore, This study aims to draw attention to the differences in indoctrination between civil engineers, workers, and graduate engineering students during various safety training methods.

Moreover, participants' backgrounds and experiences would possibly affect their perception of risks; therefore, researchers should have enough information about participants' history beforehand. So, a well-designed survey was prepared and approved to achieve this purpose in this study. The survey contains essential questions about participants' ages, occupations, 2D, and 3D game experiences and the preferred safety training approach. Furthermore, the safety management field includes a considerable number of safety training methods. The most well-known methods are classified as the least engaging methods or highly engaging methods.

The least engaging or conventional ways of safety training are considered to be an old technique in the construction industry [38]. However, a vast number of construction companies still prefer using these methods in safety training sessions. This might be on account of insufficient project financial budget or the lack of professional executives in the field. On the other side, many companies believe that construction industry personnel still prefer conventional training methods. It is thought that site workers yet do not have a comprehensive understanding of newly developed equipment and techniques. In this regard, practitioners tested many hypotheses regarding conventional and computer-based virtual environment safety training methods.

Conventional safety training sessions could be tedious. Site workers and engineers may lose concentration levels at a specific stage. The lack of focus could be due to a long training session or because of the training course itself. So, 3D games applications are utilized to supply a distinctive advantage in safety management. Safety engineers in the construction industry slightly use game engines; this add-on feature would increase workers' and engineers' interest in training. Therefore, V-SAFE.v2 software is utilized in this research project to simulate the scaffolding activities in construction sites.

3.2. Hypothesis Development

Many studies explored the effectiveness of various safety training methods on participants' perceptions [58, 74]. For instance, Brahm et al [74] studied the performance of trainees during a highly engaging safety training and its relation to site accidents using a representative sample of 2,787 Chilean firms, the researchers concluded that there is a relationship between the level of engagement of safety training and on-site risk perception. Furthermore, Burke et al. [60] insisted on the contribution of highly engaging safety training to participants' perception, the study discussed that highly engaging safety training focuses on hands-on-practice, behavioral modeling, and hands-on-demonstration, which is essential to increase participants' cognition abilities. However, there is a lack in the number of studies that explore participants' behavior during safety training sessions. Consequently, researchers started to examine the application of eye-tracking technology in safety management in order to examine trainees behavior [17–19].

Eye-tracking technology is a new trend in the construction industry. Wang et al. [18] studied different perception abilities of 40 undergraduate students using highly engaging and least engaging safety training with the assistance of eye-tracking technology, the study concluded that highly engaging training embodied by the augmented reality application improves the cognitive abilities of participants. Moreover, Dzeng et al. [75] discussed the effectiveness of on-site experience to hazard recognition abilities of Twenty-five paid volunteers using eye-tracking technology, the researchers found that all participants identified the same number of hazards, however, more experienced participants were faster in finding these hazards using the meantime to first fixation. Therefore, this study contributed to the development of previous studies by combining more sample categories in safety training:

Null Hypothesis (1): There is not any difference in the mean times to the first fixation of highly engaging and least engaging safety training between experienced engineers, workers, and graduate students.

Alternative Hypothesis: There is a difference in the mean times to the first fixation of highly engaging and least engaging safety training between experienced engineers, workers, and graduate students.

Proven evidence is truant about the effectiveness of traditional safety training methods in safety training [9]. Therefore, more sophisticated and effective ways should be used in safety training. Virtual environment applications in safety training were proven to increase trainee's perception of hazards [13]. Researchers used many techniques to measure participants' perception of hazards during safety training using virtual environment applications. For instance, Albert et al. [73] used a virtual environment application along with a survey to investigate risk recognition improvements of six construction workers. Also, Guo et al. [14] utilized a highly and least engaging safety training to examine the recognition abilities of Sixty-six participants. The researchers found that participants focused more during the highly engaging safety training using their observations and survey result. Wherefore, there is little interest in using eye-tracking technology to measure the degree of concentration of participants. Nevertheless, the study that was done by Dzeng et al. [75] utilized the fixation duration metric of the eye tracker to examine the hazards recognition abilities of experienced and novice workers, they found that experienced workers can identify more hazards than novice workers. Based on this conclusion, the current study hypothesized the following:

Null Hypothesis (2) : There is not any difference in mean time fixation duration of highly engaging and least engaging safety training between engineers, workers, and graduate students.

Alternative Hypothesis: There is a difference in mean time fixation duration of highly engaging and least engaging safety training between engineers, workers, and graduate students.

3.3. Safety Training Methods

In order to test the aforementioned hypotheses, two different safety training methods are utilized. The first one is related to conventional or least engaging safety training, while the second one is related to highly engaging safety training. On one hand, an informative PowerPoint presentation is used as a least engaging safety training tool, on the other hand, the V-SAFE.v2 software is used as a highly engaging safety training tool. In this study, the PowerPoint presentation and V-SAFE.v2 software include information that is related to scaffolding activities. As mentioned previously, the least engaging safety training does not consist of a high rate of interaction between the participant and the training tool, or among the participants themselves, while the highly engaging safety training requires a high rate of interaction between the participant and the training tool. These techniques will be explained thoroughly in the following section.

3.3.1. Conventional Methods: Safety Training Presentations

Safety training methods that use visuals such as PowerPoint presentations are conventional and least engaging. These training methods do not include any interaction among trainees or trainees and the training tool. However, many construction

companies still prefer this type of safety training. This frequent use is because PowerPoint presentations improve the visualization abilities of participants using pictures, and the associated texts are useful in recognition improvements.
This research implemented a PowerPoint presentation as one of the least engaging and accredited ways of training, many safety engineers and site coordinators prefer PowerPoint presentations in their safety training sessions [13]. PowerPoint presentations are easy to prepare compared to 3D games or any virtual environment application. The presentation that was used in this study includes 11 briefed and informative slides. The contents of this presentation include information that is identical to the on-site scaffolding activities.

To sum up, the least engaging safety training methods include non-interactive techniques such as a PowerPoint presentation. Many on-site safety engineers and workers prefer the least engaging ways because it is easy to be performed. Moreover, the presentation that is used in this study was prepared to be short and informative to meet the research purpose. Additionally, the highly engaging safety training is introduced in the following section.

3.3.2. Highly Engaging Safety Training

Games in general, as well as serious games, are one of the highly engaging tools in training. The games that are being developed for education are broadly defined as goal-directed contests under a specific set of rules and constraints [76]. Contests can be either between individuals or between an individual and a particular system. These games may involve elements of chance or fantasy [76]. The primary goal of games is to keep the user engaged and focused during the training session. Therefore, it should include the following key elements:

- Rules and Goals: the rules define actions and moves that players can make to win the game. The rules depend on the game type, and the game instructions may not include all rules. The goal defines rules and establishes the criteria for winning.

- Interaction and feedback: ımmediate responses and reactions make players firmly involved in the learning environment. Decisions can affect the course of the game [77]. Depending on the final goal of the game, players take an active role in testing different responses to a specific task, and they also start looking at the situation from various perspectives [78].

- Challenge/Strategies: success in a game depends on the strategies that players follow. Players need to consider factors and variables as well as the likely consequences and manage their thinking and actions accordingly [79]. During that process, players' knowledge of phenomena is challenged, and mistakes become more educational [80].

- Motivation/Fun: fun is essential to make participants exciting and engaging. Increased interest leads to increased engagements and thus, time spent in the game. From a pedagogical perspective, the more players are engaged in a game, the more they are willing to invest in the learning process and more likely to remember the experience [78]. This research project utilizes a unique gaming software as a highly engaging tool, this game is called V-SAFE.v2, and it is identical to the on-site scaffolding activities.

3.3.3. V-SAFE.v2

The V-SAFE software package is a highly engaging tool in safety training. The software consists of two versions (i.e., V-SAFE.v1 and V-SAFE.v2) [81], the first version of V-SAFE simulates crane activities in a 3D virtual environment. While the second version of V-SAFE simulates the on-site scaffolding activities (i.e., pre-assembling, assembling, and post-assembling activities).

This study consists of V-SAFE.v2 as a highly engaging tool in safety training, in which one to three participants can interact simultaneously in a virtual environment that simulates scaffolding activities. This interaction would increase the concentration and perception levels of participants. On the other side, in the case of one participant, autonomous agents can be added to the game. The agents can be chosen to perform either the right or wrong sequence of activities. Moreover, V-SAFE.v2 is backed by a cloud-based learning management system (Cloud LMS). The cloud assists V-SAFE in storing and analyzing data.

On the other side, the Unity game engine was used to design the software. The Unity game engine was the first to create video games and simulate real-life activities on PC. This engine is not only used for video game designing, but also for engineering purposes (i.e., Architecture, engineering, and construction AEC). The Unity game engine can be used to produce either complex or straightforward game scenarios.

Hallowell (2012) [54] found that construction workers complain about video games complexity; however, V-SAFE.v2 is user-friendly. Indicative phrases, along with simple but informative design, provide V-SAFE with comprehensibility and smooth usability. The training session is divided into two modules. The first module is the training module, in which a participant is assisted with indicative phrases and pictures, as seen in Figure 3.1, while the second module is used to test participants' ability to memorize the scaffolding activities without any assistance.

Figure 3.1. V-SAFE.v2 Training Session

In the first training section, participants are assisted by highlighting icons or providing supported phrases. For instance, as shown in Figure 3.1, the equipment box is highlighted on the left-hand side to guide participants to click on it and get the personal protective equipment. The assistance is also provided by using informative phrases that indicate the correct sequence of scaffolding activities. In this session, participants are required to memorize steps, sequences, and actions performed to pass successfully to the second module.

After that, the test module is launched. Participants are required to repeat the first module tasks but without any assistance. The participants should have memorized the steps followed in scaffolding activities in order to be able to finalize this module correctly. As mentioned above, one to three participants can contribute to the test, however, in the case of one or two participants, autonomous agents are added to the game. The autonomous agents can be chosen to perform the right or the wrong sequence of activities during the test. However, in the end, a detailed table appears to allocate the correct and mistaken actions that had been performed by the participant, as shown in Figure 3.2. This figure shows that the participant did not make any mistake during the second module of V-SAFE.v2. To sum up, V-SAFE has two versions. The

Figure 3.2. The Performance Report

second version includes scaffolding activities in a virtual environment. The software is user-friendly, simple, and straightforward. After completing the training session, a test session is required. At the end of the test, participants are evaluated depending on their performances.

3.4. Eye-tracking

Eye-tracking technology is a new trend in the construction industry, this technology is utilized by researchers to track the human eye-pupil during the safety training sessions. Eye-tracking technology is utilized in the research to distinguish the focus points of participants during the least and highly engaging safety training. Tobii Pro X2 eye-tracking device is used in the study. The device shows exactly where a participant is looking with a sampling rate of 30 Hz per second, it is also a screen-based device, in which it can be set for any display screen (such as Laptop Screens, or TV screens). It is designed for out-of-lab research work, in which it can be used on-site or off-site. Tobii Pro X2 has many features; some of them are listed as follows:

1- Reliability for various research scenarios: the device is fully portable and flexible for a wide variety of human behaviors. Tobii Pro X2 is placed above laptop keyboard providing high portability, and compact solutions, the software enables researchers to perform studies in any closed area (such as malls, coffee shops, and residential houses).

2- Multilateral for a wide range of studies: the device is utilized for a set of screens (PC, TVs, or tablets), the device is provided with many accessories (such as adhesive tape, and USB cable), along with a large gaze angles, which enables researchers to follow the majority of focus areas.

3- Easy to use: Tobii Pro X2 can be used in windows 7, 8, and 10. It is easy to install and accommodate, and the calibration process is simple, short, and assisted.

4- Precision and robust tracking: the high accuracy and robustness for real-life conditions ensure the high-quality of outcomes. Figure 3.3 below shows the Tobii Pro X2 device.

Figure 3.3. Eye-Tracker Tobii Pro X2 30Hz

3.4.1. Eye-tracking Device Setup

Firstly, the researcher should plug the associated flash disk into the computer device. The flash disk consists of installing documents. The installation procedures are simple and assisted. Figure 3.4 shows that Eye-Tracker software can be connected to a variety of devices.

Secondly, a calibration process is required. For researchers to ensure the accuracy of the eye tracker output, they calibrated the device, and participant face positions as follows. The device is placed in the middle of the screen to align the shown vertical lines, as shown in Figure 3.5. After that, Participants are requested to follow a red circle carefully without moving their faces. The red circle moves systematically between the screen's corners, as shown in Figure 3.5. After finalizing the calibration procedures, the eye-tracker is ready to record the participants' eye-pupil during safety training sessions. So, participants were asked not to move during all sessions in order to achieve accurate results.

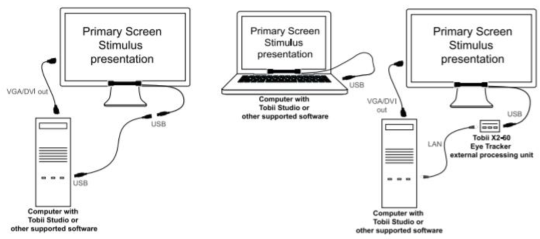


Figure 3.4. Eye-Tracking Setup Procedures

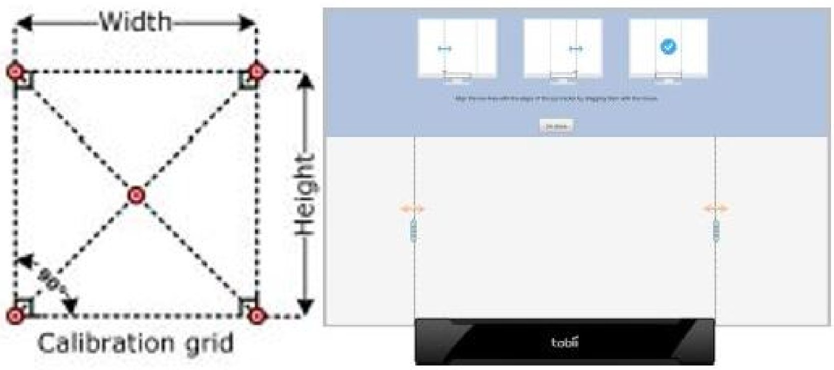


Figure 3.5. Calibration Procedure

3.5. Research Phases

The research started at the department of civil engineering / Boğaziçi University. The study was expected to continue for nine months. It began in February 2019 and continued until November 2019. For simplicity, the study is divided into two phases. The planning phase took two months, while the experiment conducting and data analyzing step took about four months.

The first phase was the planning phase, in which selection of an appropriate construction site and the proper time was set. Researchers chose a construction site which has enough number of scaffolders and roof workers. Therefore, a considerable restoration project was found in Istanbul/ Turkey to serve this purpose.

The second phase is the designing phase. In this phase, tools and documents that are needed for the experiment were prepared. Firstly, a PowerPoint presentation and an induction survey were developed by the researchers, the presentation is designed to be informative and brief, so, 11 pages of informative pictures and texts were prepared and approved. On the other hand, an induction survey was prepared in this phase. The survey includes questions that are related to the participants' backgrounds and experiences. After that, V-SAFE.v2 software, along with eye-tracking TobiiPro X2 device were examined, calibrated, and set ahead.

After the designing phase, it was decided to test the experiment and analyze the outcome data before conducting it on the construction site. Therefore, a pre-test was carried out by researchers to evaluate the experimental and analytical procedures. Thus, a test-based prioritization arrangement was started; the progression order was defined as follows: V-SAFE.v2, presentation, and at the end, the survey. Therefore, it was reported that the pre-test had been conducted successfully, and the order is correctly set. After that, it was decided to conduct the experiment on the pre-defined construction site in Istanbul/Turkey.

3.5.1. Experimental Settings

The experimental settings were prepared and controlled carefully to accommodate the requirements of the research. The Experiment is divided into two sessions, the first session was conducted on the construction site which consists of engineers and workers, while the second part of the experiment was conducted at Boğaziçi university that consists of graduate engineering students. The preparations were started in the early morning on the day of experiment. Figure 3.6 shows that the experiment was conducted indoors, the room and the experimental equipment were prepared beforehand; each section has been explained in detail for engineers, workers, and students. Starting with five site engineers, five worker, and ending with five engineering graduate students, and as mentioned previously, the order of the safety training sessions were as follows: 1- V-SAFE.v2-2- PowerPoint presentation- 3- and survey. The experiment was performed smoothly, and the researchers simultaneously monitored the experimental environment. Each participant spent around 20 to 25 minutes to finish the training. Participants had around 2 to 3 minutes break between each section. During the training sessions, an open discussion took place between participants and researchers, collecting verbal observations and evaluations about the experimental settings. Participants concluded the test successfully. At the end of the test, participants and the responsible coordinators were thanked for the great efforts in helping to complete the experiment successfully.

Figure 3.6. Preparing the Indoor Experimental Settings

4. Data Collection

This section is one of the most critical sections. The data collection part discusses details related to research development and data extraction. It approaches into further information about the data collected from the eye-tracking device and explains about inputs that the survey provides. This part includes two sections; the first section is about the data collected from the Eye-tracker, while the second part is about the data collected from the survey.

4.1. Construction Project Synopsis

Researchers choose a restoration project in Istanbul/ Turkey to conduct the research. The project aims to restore a famous and historical palace in the middle of Istanbul city. An experienced team of engineers and workers carry on the restoration procedures. Scaffolding equipment is used extensively in the project, and this is the main reason that stands behind the project selection.

4.2. Data Collected from the Eye-tracking Device

TobiiPro X2 Eye-tracker is used in the experiment. While the data were collected and analyzed using Tobii Studio 3.2 software, this software collects data from the eye-tracking device and then aggregates them into specific metrics.

4.2.1. Tobii Studio 3.2

Tobii Studio 3.2 is a software package that collects and analyses eye movements with TobiiPro X2 eye-tracker. A wide variety of eye-tracking experiments can be created by Tobii studio. The software runs on windows, and it collects data directly from the eye-tracker through a USB cable or an office network.

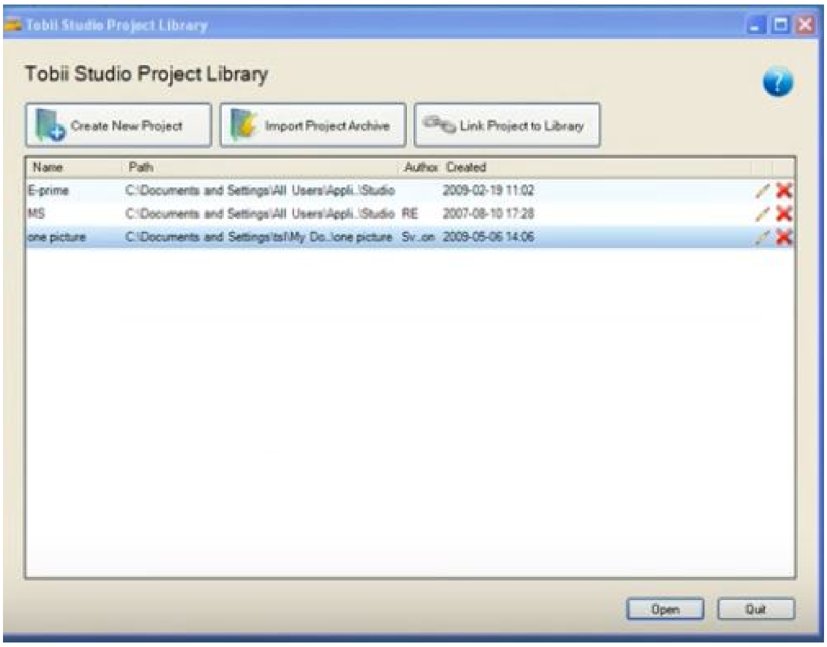


Figure 4.1. Creating a New Project in Tobii Studio

After installing and setting up the software, a new project can be added, or an already existing project can be opened, as shown in Figure 4.1. When a new project is created, the following window pops up, as shown in Figure 4.2. A variety of media can be created using the software package. Text stimuli are used for showing instructions or displaying texts to the respondents. Image stimuli are for presenting still images. While movie stimuli are for presenting AVI video clips, these stimuli are used to record eye movements during video training sessions. Web stimuli are for displaying web pages, such as Google Chrome or Microsoft Edge. The screen recording function records everything the participant looks at in the computer, and this function is utilized to record V-SAFE.v2 training sections.

External video stimuli are used to record the screen from another computer or device. Researchers use scene camera stimuli for recording real objects using a video camera and X30 eye-tracker. In the end, a PDF element displays a browsable PDF document to the respondents, and this option is used to record eye movements during the PowerPoint presentation training session. Moreover, adding an item to a project is done by dragging or dropping elements using the stimuli icon in the middle.

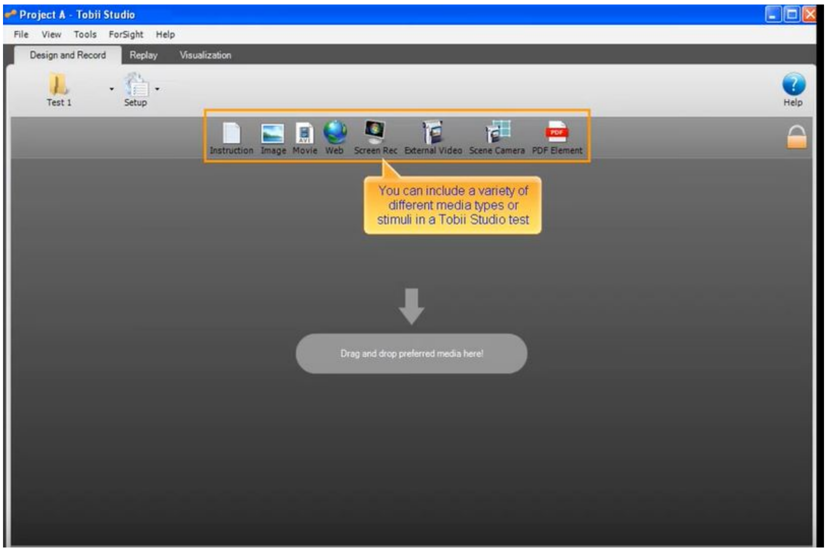


Figure 4.2. Tobii Studio Stimuli

<u>4.2.1.1. Areas of Interests (AoIs).</u> The next phase is determining Areas of Interest (AOIs). Areas of interest are the predefined spots on the display screen in front of the participant. This selection process should be done manually by highlighting areas of interest in either a rectangular, circle or an appropriate shape see Figure 4.3.

Figure 4.3. Highlighting Areas of Interest

As can be seen from Figure 4.3, different colors can highlight areas of interest. This feature helps researchers to distinguish areas of interest effectively. Furthermore, in this project, researchers defined three different areas of interest, namely; 1- Safety

Equipment 2- Text and 3- Scaffolding Assembly Equipment. It is evident in Figure 4.3 that each area of interest has a distinguished title. The areas of interest are defined to be identical in the least and highly engaging safety training, this identification enables researchers to compare the degree of concentration of participants between safety training methods. Furthermore, the period of appearance of each area of interest is fixed for each technique of safety training (i.e., Presentation, and V-SAFE.v2).

Furthermore, at each blink of an eye, the eye-tracker captions a separate recording of the eye pupil. Figure 4.3 contains two blue circles with different numbers, number 1 indicates the location of the first blink, and similarly, number 2 indicates the location of the second blink. More than that, the circle diameter specifies the time spent by participants at this location, the bigger the diameter, the higher the degree of interest of participants in this area. The next stage is to extract the required data for analysis, which is done by calculating the eye-tracking metrics.

4.2.2. Eye-tracking Metrics

A considerable number of eye-tracking output metrics have been used in previous studies to investigate human cognitive abilities [82]. The main measurements that are usually utilized in any research area are fixations. The fixations mainly include "Time to First Fixation," and "Fixation Duration." Time to First Fixation metrics is calculated by counting the number of milliseconds the participant needs to reach an area of interest during the test [83]. While fixation duration is calculated by counting the total number of seconds spends by a participant in specific training. The total fixation duration metric indicates the difficulty of the task. The longer the concentration-time on an area of interest, the more difficult it is to investigate the desired targets [84].

Tobii Studio software calculates time to first fixations and fixation durations automatically for the required recordings. As can be seen in Figure 4.4, the calculation includes many descriptive results such as the number of areas of interest, the meantime, and the sum of the total fixations. In the same figure on the left-hand side, it is possible to choose the participant whose results are to be extracted, and for which area of interest. The results can be exported as an excel file directly by clicking the option "Data Export." This option provides researchers with the possibility of export the data as an excel file.

Furthermore, the total number of data that was used in the statistical analysis is ninety for each metric. More clearly, each training session included three different areas of interest(i.e., safety equipment, text, and assembly equipment). For clarity, V-SAFE.v2 training session included three areas of interest, and the PowerPoint presentation included three areas of interest. So, the sample size can be calculated by multiplying the total number of AoIs by the number of participants in each safety training, which is in this case three multiplies by fifteen equals to forty-five for each training session in each metric.

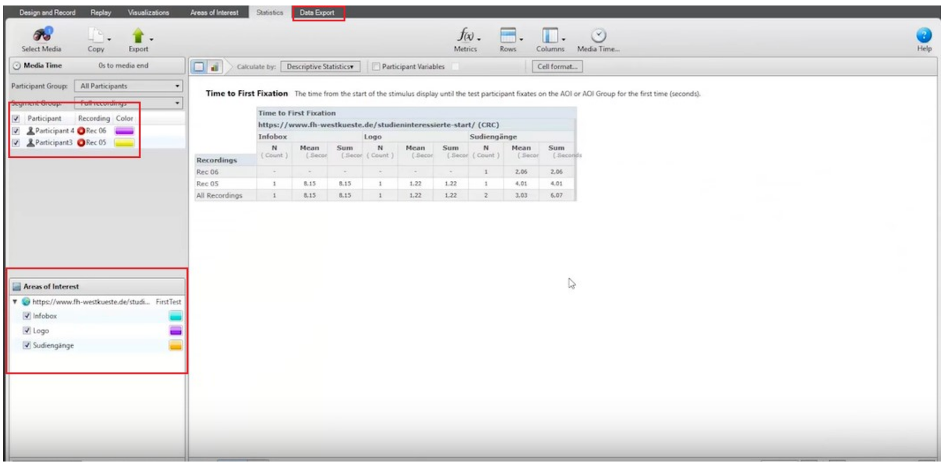


Figure 4.4. Data Exporting in Tobii Studio

4.3. Data Collected Using the Survey

Data collected from the survey is essential for data analysis. Participants' backgrounds, experiences, and ages are substantially related to each other; the relationship between participants background and results are distinguished in this survey. Therefore, researchers collected the data accurately from the survey, and this pours into results accuracy.

In the experiment, participants were able to read and write. However, some construction workers faced some difficulties understanding the intended contexts; therefore, a native speaking engineer attended the experiment and explained the details related to the survey. a filled fifteen questionnaires were collected (5 Engineers, 5 Workers, and 5 Students). The required data are gathered into one excel file, Time to First Fixation, and total Fixation duration metrics are exported from Tobii Studio 3.2. While, the participants' ages, occupations, and work experiences data were exported from the survey.

5. ANALYSIS

5.1. Introduction

A vast proportion of on-site activities and practices impose site workers and engineers to risks. Working-from-height activities are one of the most hazardous operations in the construction industry [38]. Therefore, ensuring the safety on-site is essential to keep workers, engineers, or even engineering students away from hazards. As mentioned previously, the eye-tracker device, along with computer-aided applications, were utilized in this study. The researchers proposed the experimental sequence after an off-site pre-test trail. The experiment started with V-SAFE.v2 followed by the presentation and the questionnaire. Researchers generally use either conventional or non-conventional training methods in their research [58]. Therefore, it is essential to mention that the experimental design of this study is not a common practice in academia.

After conducting the computer-aided experiments, a well-designed survey is proposed. However, a limited number of researchers have suggested an effective safety training programs that are in line with the trainee's background. So, to validate the effectiveness of a specific safety training program to a particular class of people, an induction survey was used in the study. The survey gives a clear and summarized idea about the background of the trainees. In which, questions related to trainees' age, occupation, and both field and 3D game experience were asked.

After that, the quantitative analysis for the raw data was performed with the assistance of IBM SPSS STATISTICS 25. The software package provides a wide range of options to manage data, perform analyses, and share results for a wide variety of research applications. Therefore, the Mixed-Design or Split-plot Anova test (SPANOVA) was utilized by the researchers in this study. The analysis examines the mean differences between two or more independent groups of participants data which are subject to repeated measures.

After all, it is essential to mention that the study is divided into two parts. The first one is about the on-site scaffolding activities that are included in V-SAFE.v2, and the presentation sessions, while and the second one is about the survey that explores participants' background and the relationship between participants' perceptions and experiences. Furthermore, it is also important to mention that IBM SPSS Statistics software was used to analyze the raw data.

5.2. Eye-Tracking Data

The feature of eye-tracking technology helps researchers to assume or predict human behaviors during various situations. As mentioned previously, Tobii Pro X2 30Hz eye tracker was used in the study. The device launches an innocuous infrared red light to follow the eye pupil. Therefore, the tracker internally distributes visions while a participant is experimenting. This light is usually shown in a specific pattern. This pattern lens on users' eye, makes it simple for the infrared camera into the tracker to keep tapes changes and how the light is being reflected. As it was mentioned in the literature review, Eye-tracking has also been used across various disciplines to figure out what people are most interested in [18, 19, 85]. However, eye-tracking technology is not commonly used in the construction industry [85].

Analyzing the numerical data of the eye-tracker by hand calculations is exceptionally complicated. More clearly, It can be seen from Figure 5.1 that the visual plots that the eye-tracker produces are not easy to read. For instance, it can be seen that participants are interested more in reading the text on the left-hand side instead of examining the assembly activities on the right-hand side. However, it is almost out of the question to extract numerical data from such pictures manually. Therefore, the device processes the visual data internally with the assistance of the Tobii Studio software package. Tobii Studio can aggregate quantitative information independently into tables and graphs.

Many numerical outcomes can be exported from Tobii Studio software after allocating areas of interest. As mentioned previously, the sample size is ninety in the conventional training session and ninety in the highly engaging safety training. Therefore, the total number of observations are one hundred and eighty. Additionally, the researchers exported time to first fixation and fixation Duration tabular data for analysis. The extracted data includes many numerical statistics. However, the mean differences for each participant were collected for the final statistical analysis in SPSS software (i.e., mean time to first fixation and meantime fixation duration).

To sum up, the visual data from the eye tracker Tobii Pro X2 device can be extracted with the assistance of the Tobii Studio software package. The software produces a variety of quantitative data. These data can be exported as an excel file to be used in the final statistical analysis. However, to indicate an informative conclusion, the researchers combined the eye-tracking data and the survey data into one excel file.

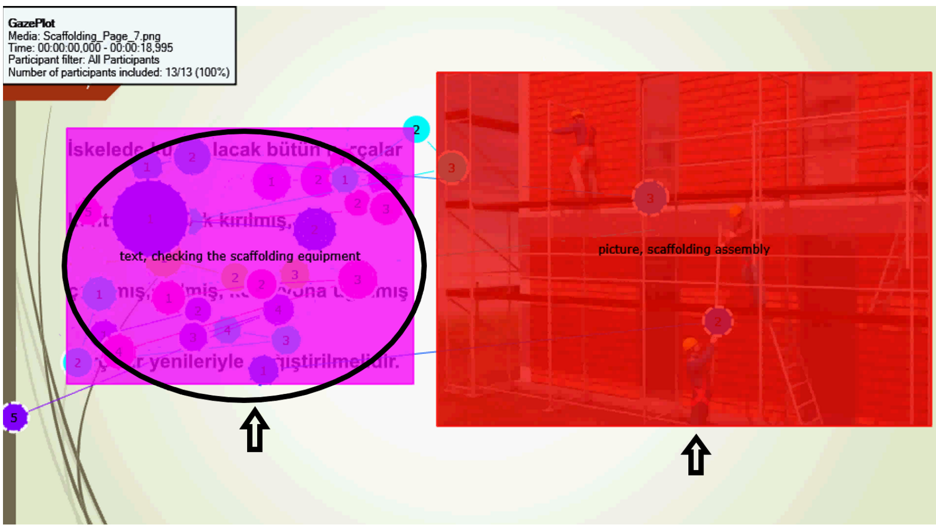


Figure 5.1. Data Exporting in Tobii Studio

5.3. Survey Analysis

5.3.1. Data Sample Characteristic

Five site engineers, workers, and master engineering students participated in this study. Full participation was attained, this rate is a result of organized experimental conditions. In which participants were asked to fill the survey directly after finishing the computer-aided experiment (i.e., V-SAFE.v2 and the Presentation). Therefore, researchers attended the process to keep track of participants' contribution. On the other side, a native speaker engineer was asked to participate in the experiment and aid workers in understanding questions that could be vague to some of them.

5.4. Statistical Analysis

The Mixed-model design ANOVA - or Split-plot ANOVA (SPANOVA)- was used in the study to analyze the data. The test obtained its title because it includes two sorts of variables. (i) One or more within-subject variables, which in this study are the V-safe.v2 and the Presentation, (ii) one or more between-subject variables, which in this study are engineers, workers, and graduate engineering students. Moreover, depending on the design of SPANOVA, two assumptions should also be met: (iii) Normality (the distribution of dependent variable should be normal), and (iv) independency (i.e., participants' records are sampled individually in the data set).

The analysis procedure included three stages. Firstly, the data was divided into two separate data sets, which are Fixation duration and Time to First Fixation. Secondly, the researchers performed the normality test for both data sets to examine the normal distribution of dependent variable. Thirdly, the mixed-design ANOVA test was performed. It was essential to identify the within-subject variables as V-SAFE.v2 and Presentation, and the between-subjects factors as occupations (i.e., Engineer, Worker, and Student). It is also essential to identify a plot that summaries the interaction between the variables and factors mentioned above. The following section introduces the reader to the results of this study.

6. RESULTS

The results of this study are divided into two parts, the first part has been extracted from the survey, while the second part has been derived from IBM SPSS software.

6.1. Survey

The survey results are shown in the following table:

Table 6.1. Survey Results

PARTICIPANT	AGE	Gender	OCCUPATION	FIELD EXPERIENCE	3D GAME EXPERIENCE
1	34	Male	ENGINEER	10	YES
2	22	Female	ENGINEER	1	YES
3	39	Male	ENGINEER	20	YES
4	40	Male	ENGINEER	18	YES
5	33	Male	ENGINEER	7	YES
AVERAGE	**34**			**11.2**	
6	40	Male	WORKER	25	NO
7	48	Male	WORKER	25	NO
8	53	Male	WORKER	10	NO
9	55	Male	WORKER	18	NO
10	45	Male	WORKER	8	NO
AVERAGE	**48**			**17.2**	
11	26	Male	STUDENT	2	YES
12	24	Female	STUDENT	0	YES
13	24	Female	STUDENT	0	YES
14	22	Male	STUDENT	0	YES
15	25	Female	STUDENT	0	YES
AVERAGE	**24**			**0.4**	

By looking at the Table 6.1, firstly, it can be seen that all engineers have site experiences. Two of them had more than fifteen years of site experience with an overall average of about eleven years. Experienced engineers are expected to hold a rich background regarding risks and hazards. More than that, it was observed that engineers were not significantly old. The older engineer is at the age of 40 years old. Therefore, all of them had experienced a 3D game previously.

Secondly, it is seen that two workers had twenty-five years of site experience with an overall average of about seventeen years. However, workers were old, the younger worker is at the age of the older engineer, while the oldest worker was fifty-five years old. Subsequently, workers declared that they did not have any prior knowledge of 3D games. Thirdly, most of the master engineering students did not have any on-site experiences, and they were relatively young, with an average age of twenty-four years old. Therefore, all the students had experienced 3D games before.

6.2. Quantitative Results

6.2.1. Time to First Fixation

6.2.1.1. The First Hypothesis. *Null Hypothesis: There is not any difference in the Mean times to first fixation of highly engaging and least engaging safety training between engineers, workers, and graduate students.*

Alternative Hypothesis: There is a difference in the Mean times to first fixation of highly engaging and least engaging safety training between engineers, workers, and graduate students.

Directional Hypothesis: participants with more site experience obtain less time to first fixation than participants with less site experience.

Table 6.2 shows that the data is not statistically significantly different from a normal distribution according to the Shapiro-Wilk test of normality, which means that the data is normally distributed.

Furthermore, Table 6.3 shows the meantime to first fixation and the standard deviation for the group sample. On one side, graduate students spent more time than

Table 6.2. Test of Normality

Tests of Normality

	OCCUPATION	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
VSAFP	ENGIEER	.124	15	.200*	.975	15	.924
	WORKER	.168	15	.200*	.908	15	.128
	STUDENT	.208	15	.081	.884	15	.054
PRESENTATION	ENGIEER	.178	15	.200*	.916	15	.170
	WORKER	.203	15	.097	.923	15	.212
	STUDENT	.204	15	.093	.913	15	.152

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 6.3. Descriptive Statistics

Descriptive Statistics

	OCCUPATION	Mean	Std. Deviation	N
VSAFP	ENGIEER	.4334	.19200	15
	WORKER	.6321	.31645	15
	STUDENT	1.0046	.66754	15
	Total	.6900	.49266	45
PRESENTATION	ENGIEER	.5278	.23519	15
	WORKER	.7499	.26971	15
	STUDENT	.6241	.18569	15
	Total	.6339	.24530	45

engineers and workers to find areas of interest during V-SAFE.v2 session (M=1.0046 Seconds), on the other side workers spent more time than engineers and students to find areas of interests during the presentation session (M=0.7499 Seconds).

Table 6.4 shows the tests of within-subjects effects. This table is one of the most critical tables in the output. It can be seen from the second box that the null hypothesis is rejected (F=8.576, p=.001) and there is a significant effect of occupations in the meantime needed for the participant to notice areas of interest. Moreover, Table 6.5 indicates that there is a significant effect of between-subjects (i.e. engineers, workers, and students) on mean time to first fixation (F=4.766, p=0.14).

Table 6.4. Tests of Within-Subjects Effect

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
VSAFE_____PRESENTATION	Sphericity Assumed	.071	1	.071	1.024	.317	.024
	Greenhouse-Geisser	.071	1.000	.071	1.024	.317	.024
	Huynh-Feldt	.071	1.000	.071	1.024	.317	.024
	Lower-bound	.071	1.000	.071	1.024	.317	.024
VSAFE_____PRESENTATION * OCCUPATION	Sphericity Assumed	1.186	2	.593	8.576	.001	.290
	Greenhouse-Geisser	1.186	2.000	.593	8.576	.001	.290
	Huynh-Feldt	1.186	2.000	.593	8.576	.001	.290
	Lower-bound	1.186	2.000	.593	8.576	.001	.290
Error (VSAFE_____PRESENTATION)	Sphericity Assumed	2.904	42	.069			
	Greenhouse-Geisser	2.904	42.000	.069			
	Huynh-Feldt	2.904	42.000	.069			
	Lower-bound	2.904	42.000	.069			

Table 6.5. Tests of Between-Subjects Effect

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	39.438	1	39.438	220.036	.000	.840
OCCUPATION	1.709	2	.854	4.766	.014	.185
Error	7.528	42	.179			

Figure 7.1 shows a summarized graph of the outputs, on the left side of the graph, it is seen that graduate students, workers, and engineers had a mean time to first fixation of (1.0046, 0.6324, and 0.4334) Seconds respectively during the V-SAFE.v2 session. On the right end of the same graph, the meantime to first fixation during the presentation session is shown. In which Workers, students, and engineers spent (0.7499, 0.6241, and 0.5278) seconds, respectively.

6.2.2. Fixation Duration

6.2.2.1. The Second Hypothesis. *Null Hypothesis: There is not any difference in the Mean time of fixation duration of highly engaging and least engaging safety training between engineers, workers, and graduate students.*

Alternative Hypothesis: There is a difference in the Mean time of fixation duration of highly engaging and least engaging safety training between engineers, workers, and graduate students.

Directional Hypothesis: The mean time of fixation duration is higher for graduate students than engineers and workers.

Table 6.6. Test of Normality

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	OCCUPATION	Statistic	df	Sig.	Statistic	df	Sig.
VSAFP	ENGIEER	.206	15	.086	.888	15	.064
	WORKER	.253	15	.011	.894	15	.078
	STUDENT	.196	15	.125	.895	15	.080
PRESENTATION	ENGIEER	.122	15	.200*	.977	15	.944
	WORKER	.199	15	.113	.875	15	.039
	STUDENT	.165	15	.200*	.907	15	.122

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 6.6 shows that the data is not statistically significantly different than the normal distribution for the meantime fixation duration of all categories.

Table 6.7. Descriptive Statistics

Descriptive Statistics

	OCCUPATION	Mean	Std. Deviation	N
VSAFP	ENGIEER	57.2305	37.56821	15
	WORKER	38.2400	21.53371	15
	STUDENT	79.6947	25.15125	15
	Total	58.3884	33.03787	45
PRESENTATION	ENGIEER	11.6580	5.86378	15
	WORKER	7.8380	4.54324	15
	STUDENT	19.9427	4.96464	15
	Total	13.1462	7.17345	45

Moreover, it can be seen from Table 6.7 that meantime fixation duration during V-SAFE.v2 session is higher (M=58.3884 Seconds) than meantime fixation duration during the least engaging safety training session for engineers, workers, and students (M=13.1462 Seconds).

Table 6.8. Tests of Within-Subjects Effects

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Vsafe_Presentation_FixationDuration	Sphericity Assumed	46054.230	1	46054.230	131.846	.000	.758
	Greenhouse-Geisser	46054.230	1.000	46054.230	131.846	.000	.758
	Huynh-Feldt	46054.230	1.000	46054.230	131.846	.000	.758
	Lower-bound	46054.230	1.000	46054.230	131.846	.000	.758
Vsafe_Presentation_FixationDuration * OCCUPATION	Sphericity Assumed	3231.562	2	1615.781	4.626	.015	.181
	Greenhouse-Geisser	3231.562	2.000	1615.781	4.626	.015	.181
	Huynh-Feldt	3231.562	2.000	1615.781	4.626	.015	.181
	Lower-bound	3231.562	2.000	1615.781	4.626	.015	.181
Error (Vsafe_Presentation_FixationDuration)	Sphericity Assumed	14670.722	42	349.303			
	Greenhouse-Geisser	14670.722	42.000	349.303			
	Huynh-Feldt	14670.722	42.000	349.303			
	Lower-bound	14670.722	42.000	349.303			

Table 6.9. Tests of Between-Subjects Effect

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	115179.258	1	115179.258	224.539	.000	.842	224.539	1.000
OCCUPATION	10821.017	2	5410.508	10.548	.000	.334	21.095	.984
Error	21544.237	42	512.958					

a. Computed using alpha = .05

Table 6.8 expresses within-subjects effects. The first part and the second part of the test are statistically significant. On one side, the significance of the first four rows in Table 6.8 indicates that there is a significant difference between the total fixation duration of V-SAFE.v2 and the presentation sessions. On the other hand, the significance column in Table 6.8 indicates that the null hypothesis is rejected (F=4.626, p=0.015) and there is a significant effect of occupation on meantime of fixation duration.

Furthermore, Table 6.9 indicates that there is a significant effect of between-subjects (i.e. engineers, workers, and students) on meantime fixation duration (F=10.548, p=0.0003). Furthermore, more time was spent to examine areas of interest during the highly engaging safety training. On the other hand, Figure 7.2 shows that engineers, workers, and students have higher fixation duration during V-SAFE.v2 safety training test.

7. DISCUSSION

Construction projects go under many changes during the project execution. These changes may affect the project performance negatively, specifically safety management procedures are affected significantly during these changes [86]. It is concluded that improper safety management courses do not reduce occupational health and safety accidents [27,86]. Therefore, practitioners have paid more attention to safety management during the last decade [87]. In order to achieve progress in this regard, researchers developed introductory studies to accidental patterns and the associated preventing factors [33,34].

Moreover, academia investigated various types of on-site accidents to distinguish the most hazardous ones. As a result, falling-from-Hight accidents were found to be the most severe [38]. Working from high may cause many accidents to site workers and engineers. These accidents are the results of a wrongly behaved action. Therefore, specific safety training should be implemented to mitigate risks and ensuing accidents according to participants' behaviors.

In order to examine reactions and concentration degrees of engineers, workers, and graduate engineering students during safety training the eye-tracking technology was utilized, "Eye tracking" is a measurement of eye movement, which can reveal aspects of learners' learning processes" [17]. Eye-tracking technology was used by Zimasa et al. [88] to examine the differences in attentional abilities and performance of divers and its effects on hazard recognition. Human behaviors under risks and crises may change due to their previous experience and background. Thus, in this study, the responses of distinct groups of civil engineers, workers, and graduate engineering students during training were examined. In this regard, the eye-tracking technology, along with virtual environment training sessions were applied to follow the behavioral changes under safety training.

As mentioned previously, various methods and techniques are used in safety management, such as conventional training methods (CT) and computer-aided technologies (CAT) [57]. Least engaging safety training or traditional training of safety methods in construction was defined in a study done by Demirkesen et al. [58] as "the methods that are used in conventional construction sites, such as booklets, presentations, lectures, and videos".

In this study, a PowerPoint presentation was used as one of the least engaging ways of training, many safety engineers and coordinators prefer PowerPoint presentations in their safety training sessions [13]. Presentations are easy to prepare compared to 3D games or to any other application. The presentation that was utilized in this study includes 11 briefed and informative slides.

However, definite evidence is absent about the effect of conventional occupational health and safety training in accidents [9]. This is a consequence of the assertion that participants need to receive, operate, memorize, and then train without error [9]. Highly engaging training methods have been discussed thoroughly during the last decades. Burke et al. [9] defines the highly engaging safety training as the training methods that focus on hands-on-practice, hands-on demonstrations, and behavioral modeling. V-SAFE.v2 software was used in this study as a highly engaging tool in safety training, V-SAFE.v2 simulates the on-site scaffolding activities such as pre-assembling and post-assembling activities. In which one to three participants can interact simultaneously in a virtual environment.

Experimental settings were prepared and controlled very carefully to accommodate the requirements of the research, the room and the experimental equipment were prepared before-hand; each section has been explained in detail for engineers, workers, and graduate students. Starting with site engineers, ending with engineering graduate students, and as described previously, the order was as follows: 1-V-SAFE.v2- 2-Presentation- 3- and Survey, each participant took around 20 to 25 minutes to finish the session.

After conducting the highly and least engaging safety training, data was collected using a particular software package called Tobii Studio 3.2. This software converts participants' behaviors to quantitative metrices, this package runs on windows, and it compiles data directly from the eye-tracker through a USB cable or an office network. In this study, The main measurements are the fixations. Fixations mainly include "Time to First Fixation," and "Fixation Duration." Time to First Fixation is calculated by counting the number of milliseconds the participant needs to reach an area of interest during the test [83]. While fixation duration means the number of seconds that are spent by a participant on a specific area of interest, and it indicates the difficulty of a task. The longer the concentration-time on an area of interest, the more difficult it is to investigate the desired targets [84]. In this research, the total number of data that was used in the statistical analysis is a hundred and eighty, more clearly, each participant examined three areas of interest in two different safety training techniques (i.e. V-SAFE.v2 and PowerPoint presentation).

The quantitative analyses for the raw data were performed with the assistance of IBM SPSS STATISTICS 25. The software package provides a wide range of options to manage data, perform analyses, and share results for a wide variety of research applications. The researchers in this study utilized the Mixed-Design or Split-plot Anova test (SPA NOVA). The analysis examines the mean differences between two or more independent groups of participants who are subject to repeated measures.

The analysis procedure included three stages. Firstly, the data was divided into two separate data sets, which are Fixation duration and Time to First Fixation. Secondly, the normality test was performed for both data sets to examine the normal distribution of dependent variable. Thirdly, the mixed-design ANOVA test was performed to test the hypotheses as mentioned earlier. It was essential to identify the within-subject variables as V-SAFE.v2 and PowerPoint presentation, and the between-subjects factor as engineer, worker, and student. It is also crucial to locate a plot that summaries the interaction between the variables and elements mentioned above.

7.1. The Perception of Areas of Interest

Time to first fixation measurement was utilized in this research to measure the pace to identify areas of interest by the participants, Time to First Fixation metric is calculated by counting the number of milliseconds the participant needs to reach an area of interest during the test [83].

Summing up the results, Figure 7.1 shows that experienced engineers spent less time to find areas of interest during the least and highly engaging safety training sessions. Site engineers have both academic background and site experience, therefore, their concentration levels during V-SAFE.v2 safety training are significantly higher than the concentration levels of workers and students. Moreover, Engineers identified areas of interest faster by (17.88%) during V-SAFE.v2 session compared to the least engaging one. Similarly, construction workers behaved in the same way as engineers during the training sessions. Although workers had more years of site experience than the engineers, they spent more time to reach the same areas of interest in safety training. Workers reached areas of interest faster by (15.66%) during the highly engaging training comparing to their performance during the least engaging one. Furthermore, workers spent more time than engineers and students to find areas of interest during the presentation session. Workers reached areas of interests slower than engineers by (29.6%) during the presentation session. Considering Figure 7.1, graduate students reacted contrarily during the sessions. They spent more time to find areas of interest during V-SAFE.v2, and less time during the conventional training model.

Engineers and workers encounter with the scaffolding activities in every working day, therefore, they know each step in scaffolding assembling activities, so, they are able to find the required step faster than the graduate students. on the other side, graduate engineering students do not have enough site experience and therefore they do not have enough background about each step in scaffolding activities, therefore, they spent more time to find areas of interest during the highly engaging safety training.

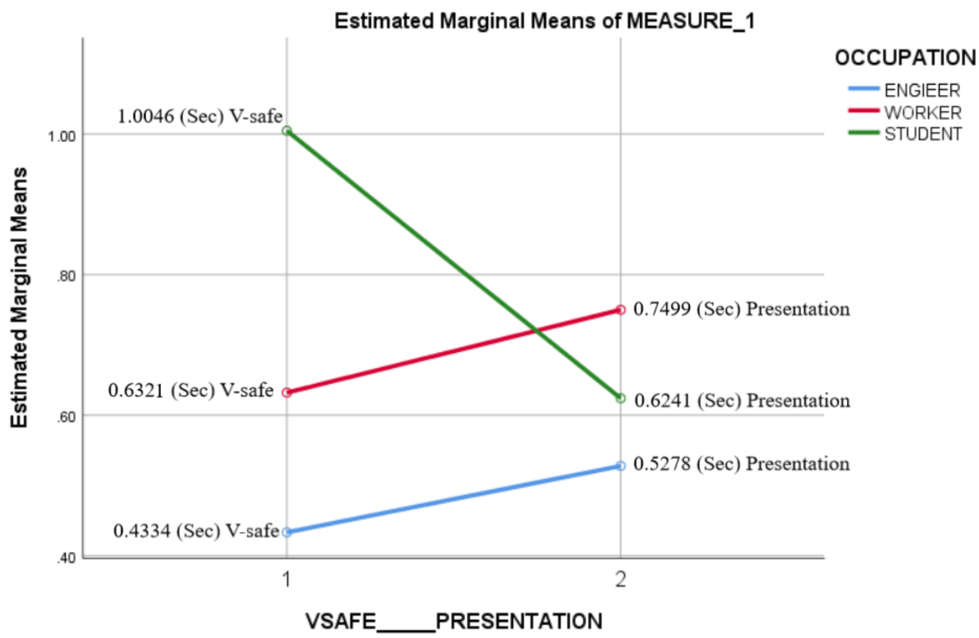


Figure 7.1. Time to First Fixation Profile Plot

On one hand, even though site engineers and graduate engineering students had 3D game experiences, they behaved differently during the V-SAFE.v2 session. Students might not have engaged sufficiently, or they needed more time to explore the display-screen accurately during the session. Contrarily, engineers participated thoroughly during the V-SAFE.v2 session. It was noticed that site engineers were more interested in experiencing the test. On the other hand, although field workers have not experienced any 3D game before, they were responsive and engaged during V-SAFE.v2. Experiencing a virtual environment based training tool for the first time could be the reason behind this interest, or the user-friendly interface of V-SAFE.v2 could have made the process more simple to them. On the right side of the graph, it is observed that workers spend more time than engineers and graduate students to find areas of interest during the PowerPoint presentation session. Furthermore, to investigate the level of concentration for each participant, the meantime of fixation duration was examined

7.2. The Concentration Levels

One of the essential measurements in investigating the focus level of participants during safety training is the meantime of fixation duration. It was mentioned previously that fixation duration is the time spent by a participant on a specific area of interest. The first glance at Table 6.7 shows that participants concentrated more during V-SAFE.v2 session than the conventional training session. As mentioned previously, Albert et al. [73] studied the effectiveness of augmented reality applications on construction workers. It was concluded that workers' performance in risk identification improved by 27% after the augmented reality training, which is in line with the current research findings.

Figure 7.2 shows that graduate engineering students spent a long time focusing on areas of interest during the V-SAFE.v2 session (79.6947 seconds). Whereas workers have had less time focusing on areas of interest during the same session (38.24 seconds). Furthermore, engineers spent on average (57.2305 seconds) to examine areas of interest. Workers and engineers might skip some steps during the safety training since they have enough background knowledge about the sequence of scaffolding assembling activities. On the other side, graduate engineering students examined the display screen more thorough in order to find areas of interest since they do not have enough background about the scaffolding activities. Similarly, participants performed the same behavior during the least engaging test, students spent on average (19.9427 seconds), while engineers and workers spent (11.6580 and 7.8380 seconds) respectively. Therefore, it was concluded that the utilization of highly engaging safety training in the construction safety management increases the concentration level of trainees.

Conventional training methods have been assumed not to be ideal in practice [14]. The conveyance of health and safety knowledge should be done accordingly with employees' preferences [14]. Construction employees tend to lose attention memorizing safety instructions that are delivered by using the conventional methods [59]. According to the same study, workers would prefer more engaging safety training methods than the

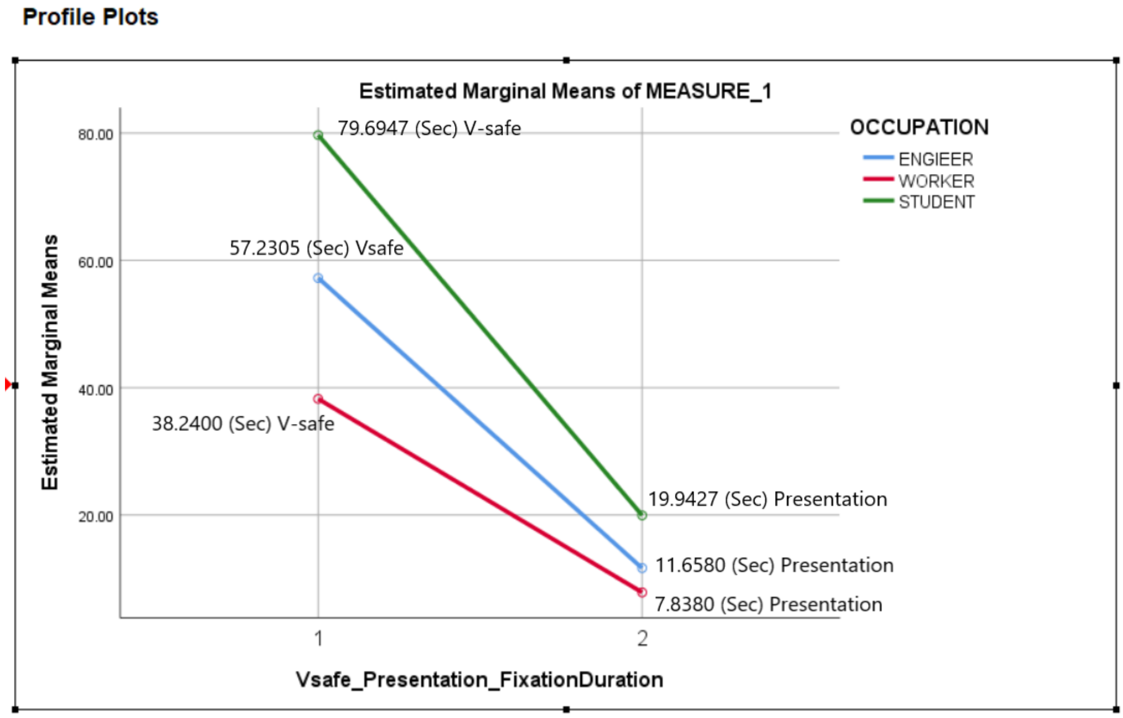


Figure 7.2. Fixation Duration Profile Plot

least engaging ones. Furthermore, according to Perlman et al. [56], it was proved that previous site experience helps participants to increase hazards identification abilities during safety training. The same study also discussed that students that lack site experience showed decreasing capability in hazard recognition, which is in line with this research. Figure 7.2 shows that workers and engineers spent more time concentrating on V-SAFE.v2 safety training than the time spent on the PowerPoint presentation safety training.

Virtual simulation technologies have been used in the safety training field recently. Virtual environment training methods are considered more engaging comparing to the traditional ways of training [13]. Albert et al. [73] focused on augmented reality technology to improve hazard recognition skills of construction workers. The empirical test results indicated that the participants increased their performance in hazard identification by 27% after experiencing a virtual environment. Another study was done by Sacks et al. [13] contributed to developing a tool that identifies workplace risks in a virtual construction environment. They conducted a study with 66 participants to test the efficiency of the simulation tool. The subjects were divided into two groups; one of them received traditional safety training by using 2D materials, and the others were trained by the 3D immersive virtual environment to recognize construction site hazards. According to results, the second group that was trained in the 3D environment performed better in terms of identifying workplace hazards.

Moreover, Guo et al. [14] conducted another study on safety training using game technologies; in this study, the authors introduced and tested a multi-user safety training tool for dismantling a tower crane. In this study, project managers and crane operators used a game-based training tool and answered a survey related to both traditional and virtual environment innovative training methods. The findings of the study showed that crane operations would be safer and more efficient with the support of game-based training tools comparing to traditional tools. Zhao et al. [71] used the virtual environment applications in electrical hazards' recognition. Participants have recognized on-site electrical hazards thoroughly after the highly engaging safety training session. Furthermore, Teizer et al. [72] suggested a model that combines ironworkers' real-time location tracking and a 3D virtual environment. The model was proved to increase ironworkers' hazard recognition. Consequently, their productivity and performance [72], these studies are in line with this research, in general, the interest and concentration rate of participants during the highly engaging safety training are higher than the ones during the least engaging safety training.

Even though many studies emphasize the advantage of using virtual environments in safety training [14, 18, 73], a limited number of studies clarify the role of virtual environments in scaffolding activities. Nadhim et al. [38] discussed that 23% of falling-from-height accidents take place during assembling, disassembling, or post-assembling activities of scaffolding parts. The same study indicates that the second most serious cause of falling-from-height incidents is because of learners' lack of education, experience, or knowledge level. Therefore, in this study, a comprehensive comparison was accomplished in order to compare the perceptions of engineers, workers and graduate engineering students during scaffolding safety training. These training sessions consist of information identical with the on-site scaffolding activities

It can be seen that participants with a thorough academical background focused more during the test than the other participants. Figure 7.2 shows that graduate engineering students focused more than engineers and workers during both pieces of training. However, the three categories showed more interest during the highly engaging training than the least engaging training according to Figures 7.1 and 7.2. Consequently, using virtual environment applications in safety training increases the interest rate of participants during the session, and therefore, increases their perception degrees to hazards. The studies mentioned above confirm the findings of this research, but they are not comparing the perception differences between engineers, workers, and graduate engineering students. Therefore, this research closes the gap of comparing engineers, workers, and graduate engineering students' perception of safety training with the assistance of eye-tracking technology.

7.3. Limitations

Each research project is associated with some limitations or shortcomings; identifying these limitations helps future researchers to close research gaps, which is, in return creates greater good in a particular field. This study aims to compare the behavior of site engineers, workers, and graduate engineering students using two safety training techniques. So, the first limitation of this study was the lack of previous research that compares these participants categories during safety training. Moreover, the second limitation is related to the induction questionnaire that was utilized in this research. The self-reported data might have been answered improperly by engineers, workers, and graduate engineering students in order to finalize the survey as soon as possible.

8. CONCLUSIONS

The construction industry is massive, comprehensive, and includes a considerable number of activities. Therefore, the potential of facing hazards and risks during the construction activities is very high. However, to avoid falling into hazardous situations, well-designed safety training courses should be designed and implemented by practitioners. Safety training is essential in the construction industry; it decreases the possibility of facing on-site hazards and increases the ability of identifying risks. One of the most hazardous activities in the construction industry is working-from-height activities. Many training methods were developed in the field of falling-from-height accident prevention or reduction, but the majority have not been applied in the construction site. Many of these accidents could have been avoided if the associated causing factors had been appropriately identified, so, briefing the factors that cause accidents through appropriate safety training would reduce the hazardous consequences.

Safety training is crucial in outdoor industries, especially when the human factor is involved. The construction industry is the most dangerous industry that includes interactions of machines and humans; therefore, appropriate safety training should be implemented to avoid the interaction catastrophes. According to Burke et al. [9] categorization, safety training is divided into three categories, 1- the highly engaging safety training-2- the moderate engaging safety training-3- and the least engaging safety training. On one side, the highly engaging safety training is the training that requires a high rate of interactions between a participant and a particular safety training tool. On the other side, the moderate and least engaging safety training includes less interaction between participants and a safety training tool. However, the least engaging and moderately engaging safety training methods are still preferred by many companies around the world. Budget constraints could be the reason behind the limited application of highly engaging safety training methods.

Virtual simulation technologies are one of the applications of highly engaging safety training, and it is a new trend in the tech field that has rapidly been utilized in various industries. The features that virtual environment applications can provide are quickly implemented in any other sector but proactively being grasped by the construction industry. The construction industry is known for being slow to adapt to new trends in technology. Therefore, the unique pattern of the virtual environment was used in this study to measure its effectiveness on participants. On the other side, a PowerPoint presentation was utilized in this research as a least engaging safety training technique. This presentation consists of information that is identical to the information in the highly engaging safety training session. So, it was possible for the researchers to compare the participants' behaviors during both of the courses.

The training method in this study was smoothly explained to fifteen participants. The experiment was performed in a closed room on one of the construction sites in Istanbul city. Trainees were introduced to each safety training session separately, and then they were asked to start the training session with the highly engaging part that is represented by V-SAFE.v2 software. Then after, it was followed by the least engaging safety training that is dedicated by a PowerPoint presentation. The eye-tracking technology was utilized during the highly and least engaging safety training sessions to record the eye movements of each participant. In the end, trainees filled an induction survey that extended the research analysis and outcomes.

Each participant spent around 20 to 25 minutes to finish the training sessions. Participants had around 2 to 3 minutes break between each session, and an open discussion took place between participants and researchers during the experiment, collecting verbal observations and evaluations about the experimental settings. Data was collected using Tobii Studio 3.2 software package, a wide variety of eye-tracking tests can be created with the assistance of this software, text stimuli are used for showing instructions or displaying texts to the respondents. Image stimuli are used for presenting still images. While movie stimuli are used for presenting AVI video clips, The screen recording function records everything the participant looks at in the computer, and this function was utilized to record V-SAFE.v2 training sessions. It is also essential to define areas of interest for each participant before launching the analysis. In this study the areas of interest were defined manually for each participant with the assistance of Tobii Studio 3.2.

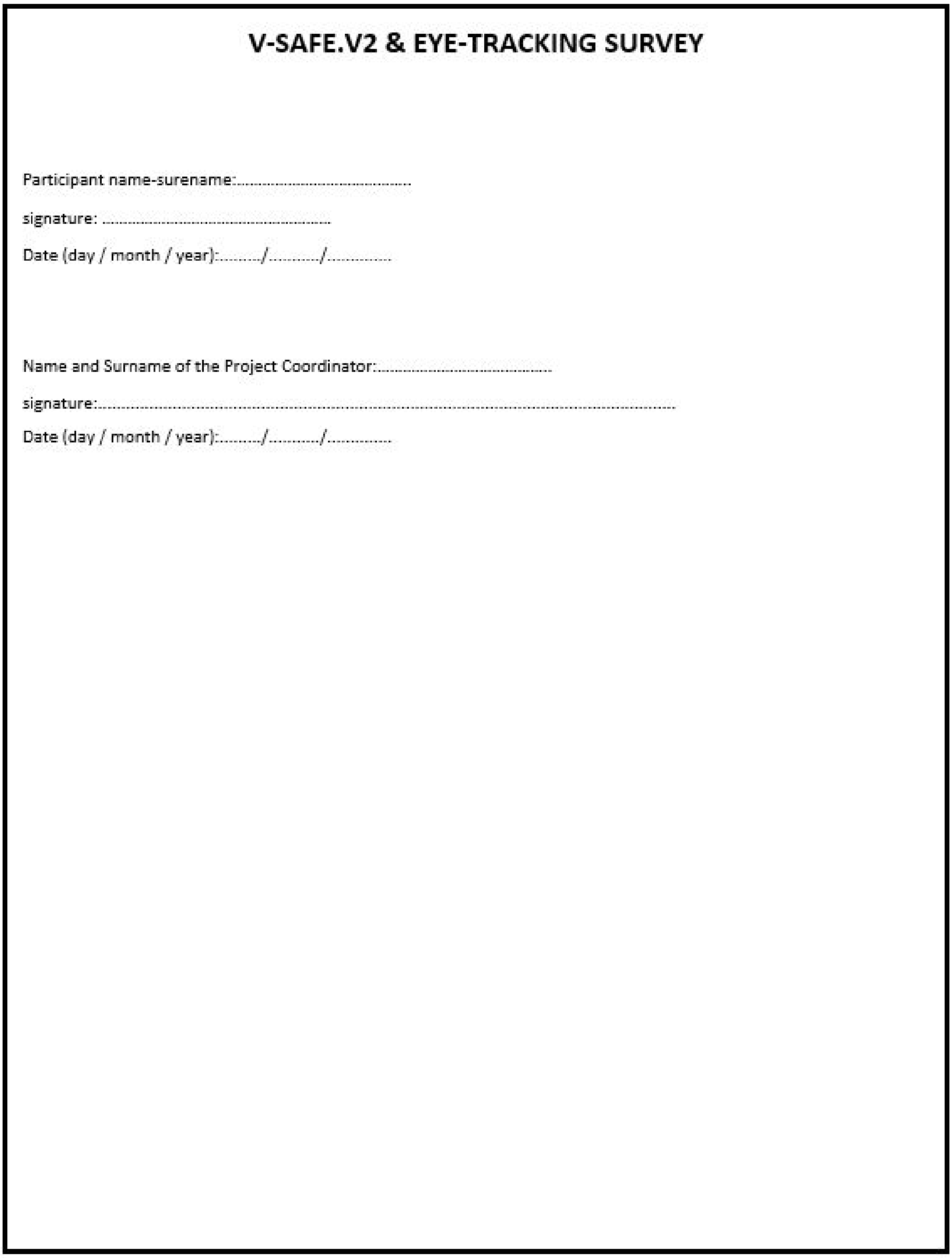
After that, the data were analyzed using IBM SPSS software. The mixed-design ANOVA was performed to analyze the data. Two within-subject variables (i.e., V-SAFE.v2 and Presentation) and three between-subject factors (i.e., Engineers, Workers, and Students) were identified during the analysis. This analysis was divided into two sections; the first section is related to time to the first fixation, and the second section is relevant to the total fixation duration. The time to the first fixation refers to the number of milliseconds that were needed for each participant to observe a specific area of interest, while the fixation duration indicates the number of seconds spent by each participant to examine a particular area of interest. Then, the final results were extracted and discussed. As a result, the objective of comparing the effectiveness of two safety training methods on civil engineers, workers, and graduate engineering students was met with the assistance of eye-tracking technology.

The results of this study prove that site engineers respond faster than workers and graduate students to any visual stimuli during the V-SAFE.v2 session. The experience and the academical level of site engineers might be considered as a piece of evidence to the visible difference in terms of time to first fixations. Moreover, graduate engineering students spent more time than workers to observe areas of interest during safety training sessions. On the other side, site workers have spent slightly more time than engineers and students to find areas of interest during the least engaging safety training session.

Furthermore, this study proves that graduate engineering students concentrate more than site engineers and workers during safety training. In Figure 7.2, The eye-tracking fixation duration graph shows that graduate engineering students spend more time exploring visual stimuli during each safety training session. This leads to the conclusion that utilizing the new technology of the virtual environment in construction safety management leads to satisfying results in terms of concentration levels during safety training sessions.

As a result of this research, it is suggested that governments should regulate a law that obligates the construction companies to design a road-map for safety training sessions in their construction sites. In this road-map, the first step is to ensure the utilization of highly engaging safety training. In order to provide highly engaging training, virtual simulation technologies can be utilized, these technologies should include a detailed information about the potential risks that can appear in a real construction site. After that, the construction and development companies should apply the highly engaging safety training in their construction sites to increase the site personals' perception levels to hazards, which consequently is going to reduce the number of accidents that might cause significant fatalities. It is also recommended that the prospective studies should examine the participants' behavior using various applications of least and highly engaging safety training. For instance, it is recommended that the use of augmented reality applications that are close to the real world would lead to better results than virtual environment applications. It is also suggested that the use of videos and booklets as the least engaging safety training would expand the researching areas and the consequence analysis in safety training management.

APPENDIX A: SURVEY



V-SAFE.V2 & EYE-TRACKING SURVEY

Participant name-surename:..

signature: ....

Date (day / month / year):........../.........../..............

Name and Surname of the Project Coordinator:..

signature:..

Date (day / month / year):........../.........../..............

Figure A.1. Confirmation Form

V-SAFE.V2 & EYE-TRACKING SURVEY

Participant Survey

1. Age:
2. Gender
3. Job Position and Title
4. How many years have you been working in the construction industry?
5. Have you ever played a computer game before? Can you give an example?
6. Did you play a 3D computer game? Can you give an example?

Game Type	1- Never played	2- I have played before	3- I play	4- I Play Frequently	5- I Play Very Often	6- I Play Too much
First Person Shooter (Counter-Strike, Call of Duty, etc.)						
Third Person Shooter (Max Payne, Grand Theft Auto, etc.)						
Construction Simulation (Construction Simulation, Truck Simulator, etc.)						

Figure A.2. Background Questions

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