The effects of a researcher's presence during VR experiments

A study on human responses during fire alarms

Sebastian Siljehav Ozimek & Niclas Nilsson
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Sebastian Siljehav Ozimek & Niclas Nilsson

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Effekten av forskarens närvaro på resultaten i en VR-miljö.
The effects of a researcher’s presence during VR experiments.

Författare/Author:
Sebastian Siljehav Ozimek & Niclas Nilsson

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Sebastian Siljehav Ozimek
Niclas Nilsson
Silvia Arias

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Abstract
The aim of this study is to investigate if a researchers presence affects participants performing a virtual reality evacuation, and if by removing the researcher, the results better resemble the results produced in a real world experiment. Initially, a study on previous research in human behaviour in fire, the effect of a researcher's presence and Virtual reality experiments was conducted. 54 participants, divided into two groups, performed experiments in VR. One group had a researcher present in the room, and the other group of participants were left alone during the experiment. While the participants performed the experiment, a virtual fire alarm would sound and their reactions to the alarm were documented. At the end of the experiment, all participants answered three questions verbally while still being in VR. The results from the different groups were then compared. The results from this experiment showed that by removing the researcher from the room, the number of participants reacting to the fire alarm when in a virtual environment increased. Thus producing results that closer resemble the results from the real world experiment done by Arias et al. (2025). This suggests that the physical presence of a researcher may influence participant behavior in VR experiments.

Brandteknik
Lunds tekniska högskola
Lunds universitet
Box 118
221 00 Lund

www.brand.lth.se
Telefon: 046 - 222 73 60

Division of Fire Safety Engineering
Faculty of Engineering
Lund University
P.O. Box 118
SE-221 00 Lund
Sweden

www.brand.lth.se
Telephone: +46 46 222 73 60

Preamble

The following report is a thesis project within the Fire Engineering Program, course VBRM01 at Lunds Tekniska Högskola. The course is worth 22.5 credits.

It has been a fun experience performing experiments with people, since none of us have had any experience with it before, and to do a thesis regarding human behaviour. It feels special to also study a topic that has not been well researched before. We feel that this could be an important contribution to the continuous research in improving experiments in VR.

We want to thank our supervisors Silvia Arias, associate senior lecturer at the Division of Fire Safety Engineering, for her support during this thesis. Silvia has always helped us when needed and given us helpful tips along the way. And of course, letting us use their VR environment to perform our experiments.

We would also like to thank Jonathan Wahlqvist, associate senior lecturer at the Division of Fire Safety Engineering, for all his help with troubleshooting when the technology malfunctioned and giving us tips on how to use the VR technology.

Lastly, we would like to thank all the teachers at Lund university, who allowed us to invite the students to join as participants during their lectures. And a big thank you to all the participants that made this thesis possible.

Sammanfattning

Syftet med denna studie är att undersöka hur en forskares närvaro påverkar deltagare som utför experiment i Virtual Reality (VR). Denna studie är baserad på ett tidigare arbete utfört av Arias et al. (2025). De studerade skillnaden mellan ett verkligt experiment och ett liknande experiment utfört i VR. Deras studie visade att färre deltagare reagerade på ett brandlarm när de var i VR jämfört med när de var i det verkliga experimentet. Det är därför har vi valt att studera hur människor blir påverkade av en forskares närvaro under experiment i VR.

VR är ett verktyg som konstant utvecklas och som används inom många olika områden. Det används bland annat inom underhållning, undersökning av mänskligt beteende och som ett hjälpmedel i undervisningssyfte. Fördelen med VR experiment jämfört med experiment utförda i verkligheten är att man ej behöver utsätta människor från direkt fara och att det är kostnadseffektivt när det kommer till att reproducera experiment. Det finns mycket forskning och experiment om användning av VR.

Hur en forskares närvaro kan påverka deltagare som utför VR experiment är ett relativt ostuderat område idag och därför valdes detta som huvudtes för denna studie.

Först utfördes en litteraturstudie som innefattade både studier på människors beteende vid brand, tidigare experiment om forskares påverkan på deltagare under experiment och tidigare VR-forskning inom brandteknik. Bland annat studerades Role-rule modelen, Hawthorne effekten och Observer expectancy teorin. De dessa tre teorierna har gemensamt är att de alla diskuterar hur människor kan påverka andra människor, både medvetet och omedvetet. Dessa teorier togs sedan i beaktning under utformning av experimentet.

Problemställningarna som behandlas under detta arbete är följande:

1. Påverkar en forskares närvaro deltagarnas reaktioner när ett brandlarm ljuder i VR?
2. Hur påverkar en forskares närvaro deltagarna som utför ett VR experiment? Är det bättre om forskaren är i samma rum som deltagaren eller i ett annat rum?
3. Kan man använda resultatet från detta VR experiment för att göra framtida VR experiment mer realistiska?

Experimenten utfördes i V-huset i Lund och bestod av totalt 54 deltagare. Deltagarna delades upp i två grupper (grupp 1 och grupp 2) där grupp 1 hade en forskare närvarande under experimentet och grupp 2 var själva i rummet under experimentet. VR miljön som användes och ljudet från brandlarmet kommer från tidigare experiment av Arias et al. (2025). Alla deltagare live-streamades till en dator som var placerad utanför rummet. Vad de såg och gjorde i VR skärmdelades till en annan dator som också var placerad utanför rummet. Experimentet gick ut på att deltagarna svarade på frågor i VR, ovetande om att ett brandlarm någon gång under experimentet kommer att ljuda. Deras reaktioner när brandlarmet ljöd antecknades och jämfördes sedan mellan grupperna. Reaktionerna delades upp i visuella reaktioner, icke visuella reaktioner och inga reaktioner. När brandlarmet slutat ljuda svarade deltagarna muntligt, medan de fortfarande befann sig i VR, på tre frågor:

1. Vad det var för ljud?
2. Var kom ljudet ifrån?
3. Om ni inte reagerade, varför?

I grupp 2 var det fler deltagare som reagerade visuellt på brandlarmet jämfört med grupp 1. Både grupp 1 och grupp 2 hade liknande svar gällande var ljudet kom ifrån.

När experimentet var avslutat fick alla deltagare svara på en enkät angående deras upplevelse i VR. Majoriteten av deltagarna svarade att de uppfattade VR rummet som realistiskt.

Resultaten från detta experiment visade att genom att ta bort forskaren från rummet ökade antalet deltagare som reagerade på brandlarmet i den virtuella miljön. Detta gav ett resultat som ligger närmare resultaten från det verkliga experimentet som genomfördes av Arias et al. (2025).

Summary

The purpose of this study is to investigate how the presence of a researcher affects participants performing experiments in Virtual Reality (VR). This study is based on previous work done by Arias et al. (2025). They examined the difference between a real world experiment and a similar experiment conducted in VR. Their study showed that fewer participants reacted to a fire alarm when they were in VR compared to when they were in the real world experiment.

VR is a tool that is constantly evolving and is used in many different fields. It is used in entertainment, human behaviour studies and as an educational aid. The advantage of VR experiments compared to real life experiments is that the participants do not need to be exposed to any danger and it is cost effective when it comes to reproducing experiments. There is extensive research on the use of VR. VR has great potential to be used as a tool for future research purposes, and it is therefore important to improve VR in order to obtain results that are reliable.

How the presence of a researcher may affect participants performing VR experiments is a relatively unstudied topic, and this was therefore chosen as the main focus of this study.

First, a literature review was conducted, including studies on human behaviour in fire, previous experiments on the influence of researchers on participants during experiments, and prior VR research within fire safety engineering. Theories such as the Role-rule model, the Hawthorne effect, and the Observer expectancy theory were studied. What these three theories have in common is that they all discuss how people can influence other people, both consciously and subconsciously. These theories were then taken into consideration during the design phase of the experiment.

This thesis aims to investigate the following questions:

1. Does the researcher's presence affect the participants' reaction to a fire alarm in virtual reality?
2. How does the researchers' presence affect the participants when performing a VR experiment? Did it leed to a benificial result? Or is it better if the researcher is present.
3. Will the results from this VR experiment be able to be used to make VR experiments more realistic?

The experiments were conducted in the V-building in Lund and involved a total of 54 participants. The participants were divided into two groups (Group 1 and Group 2), where participants from Group 1 had a researcher present during the experiment and participants from Group 2 were left alone in the room during the experiment. The VR environment used and the virtual fire alarm sound were taken from the previous experiment done by Arias et al. (2025). All participants were live streamed to a computer located outside the room. What they saw and did in the VR environment was screenshared to another computer, also located outside the room. The experiment involved participants answering questions in VR, unaware that a fire alarm would sound at some point during the experiment. Their reactions when the fire alarm activated was documented and compared between the groups. The reactions were categorized as visual reactions, non-visual reactions, and no reactions. When the fire alarm stopped, participants verbally answered the following three questions while still being in VR:

4. What is that sound?
5. Where is the sound coming from?
6. If you did not react, why?

Group 2 hade more participants visually reacting to the fire alarm compared to group 1. Both groups gave similar answers regarding where the sound came from.

When the experiment was completed, all participants answered a questionnaire about their experience in VR. The majority of participants reported that they perceived the VR environment as realistic.

The results from this experiment showed that by removing the researcher from the room, the number of participants reacting to the fire alarm when in a virtual environment increased. Thus producing results that closer resemble the results from the real world experiment done by Arias et al. (2025)

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1 Introduction

Virtual Reality (VR) has proven to be a versatile tool to study human behaviour in different fields. It has been used to study pain and anxiety (Andreatta et al., 2023), fear (Gromer et al., 2019), and phobias (Miloff et al., 2020). It has also been applied to understand learning (Shen et al., 2019), brain processes (Hertweck et al., 2019) and memory (Schöne et al., 2017). The technology has especially useful advantages in the field of Human Behaviour in Fire, as it allows studying fire evacuation scenarios without exposing participants to the intrinsic risks of real fire and smoke. Within this field, VR allows studying decision-making (Arias et al., 2021), way-finding (Dachner and Kinateder, 2016) and pre-evacuation (Arias et al., 2018).

It is important for researchers to take into account the tendencies that the participants might have. One of those tendencies is that participants tend to rely on the researcher in case of an emergency. The role-rule model (Tong and Canter, 1985) describes the behaviour that can be expected when an emergency occurs. Participants heavily rely on the researcher for guidance and help when an uncomfortable or dangerous situation occurs. By removing the researcher from the room, and therefore their sense of security, will they act independently and try to resolve the situation? By performing an experiment in VR without the researcher being present in the room, the participants' "safety net" is removed. This will ideally make the results from VR experiments more accurate, i.e. that the behaviour of the participants in the VR experiment better match the behaviour of people in real-life evacuations. (Arias et al., 2025)

One of the theories in human behaviour in fire is called "Social influence" which refers to the "power" people have on other people. People want to be seen as "normal" and do not want to be seen as different from everybody else. Social influences affect how people might behave differently in different social settings. People generally behave differently with a group of friends or a crowd of strangers than they would have if they were alone, for fear of standing out and risking an embarrassing situation. This has been shown in several previous experiments, for example the experiment done by Latané and Darly (1970) called "Where there's smoke, there's (sometimes) fire". In their experiment they would put their test subjects in a room to answer a questionnaire and then after a couple of minutes they would start to fill the room with smoke through a small vent in the wall. One sample of participants would be alone in the room (alone condition) and another sample had two other people in the room (group condition), which were told not to react to the smoke. In the first experiment the researchers came to the conclusion that the participants reacted for the most part very reasonably and reported the smoke to the researchers after a couple of minutes. The second group of participants saw the smoke and then looked at the other two participants in the room for answers but were not given one. Only 1 out of 10 participants reported the smoke in the second group. Compared to the first group where 75 percent reported the smoke within 6 minutes of the start of the test. The difference between the alone condition and with the two other people in the room is highly significant. Since the difference was so significant in their experiment, it raises the question on whether this difference also applies in a virtual environment. Therefore, this thesis will test these two conditions (with and without the researcher in the room).

Previous studies have shown that the presence of the researcher in the room can play a role in the behaviour of the participants. Aaron (1964) discusses how a researcher's behaviour can influence the social behaviour he wants to study, and therefore affecting the participants and the results from the study. This further amplifies the importance of performing this study to help future VR experiments get results that closer resembles results from real world experiments. (Arias et al., 2025).

1.1 Field of use for VR technology

VR is a tool widely used in many different fields. It is used for entertainment, research and learning purposes. The main obstacle for VR is the technology available. As technology develops so does the realism in VR, creating a broader field of use.

Flight simulators are today a big part of flight academies and widely used during their training. The first flight simulator dates back to the beginning of 1900s and looked completely different compared to the ones used today. Back then they consisted of a small modified aircrafts. In the 1910s they progressed into devices connected to the ground but still capable of responding to aerodynamic forces. (VRgineers, 2021). Today they consist of a full-scale replica of a cockpit mounted on a multi-axis motion system. Inside of the cockpit there is a complete control panel and a 360° that simulates what the pilot would see during a real-life flight. Today the use of VR is discussed as a suitable alternative to the flight simulators. (Somerville et al., 2026)

Research regarding the use of VR to reduce the sensation of pain and anxiety has been conducted. Nerini et al. (2024) was observing how pediatric patients, that underwent cancer treatment, experienced excessive pain and anxiety. There had been previous studies done regarding the use of VR in distressing procedures and it showed great results. A study was therefore conducted to analyse if VR could be used as a method of lowering the experienced pain and anxiety during cancer treatments and therefore lowering the suffering. (Nerini et al., 2024)

The use of VR to treat phobias may be a viable option. Lindner et al. (2020) conducted an experiment where they used virtual environment exposure therapy on a subject suffering from arachnophobia. The subject self-performed an automated single-session treatment simulated with real-world conditions. A follow up study was conducted six months after the self-performed treatment. The result showed that Virtual Reality Exposure Therapy (VRET) is a promising alternative for the treatment of phobias. (Lindner et al., 2020)

1.2 Background

Arias et al. (2025) conducted an experiment to assess how distances were perceived in reality and in VR. Each participant performed an experiment in both VR and reality and the results was then compared to each other. The VR environment used were a corridor and a lecture hall modelled according to a real-life lecture hall and corridor found in V-Huset (Lund University). To recruit participants, an online survey was created.

The second phase of the research focused on identifying which aspects of the VR environment make it realistic. Perceived distances and sound directions were two of the aspects. As mentioned before, they created a lecture hall and corridor environment in VR. The participants then performed an experiment in VR and an identical experiment in real life. The ones performing the first part of the experiment in the lecture hall would perform the second part in the corridor. Different settings were used in VR to assess what key aspects impact the results. During both parts of the experiment, in VR and real life, participants answered questions regarding distances to different objects. The objects in VR and real life were placed at the same distance from the participants. During the VR experiment, a fire alarm sounded without the knowledge to the participants. The reactions of the participants were noted.

During all their experiments, a researcher was present.

After the VR experiment was concluded the participants answered questions regarding were the sound came from, what type of sound it was and if it was in reality or VR. The participants not reacting to the alarm were asked why. (Arias et al., 2025).

1.2.1 Their results

The experiment done by (Arias et al., 2025) concluded that more participants reacted to the fire alarm in the real-world experiment than in VR. But the ones that ignored the alarm in the real-world experiment said that they did that because the researcher in the room did not react and did not tell them to stop the experiment. Therefore, the effect of the researcher in the room lead the participants to not react to the fire alarm.

The participants that did not react to the alarm in the VR experiment were asked why and they answered that they already knew it was a fire alarm, that they thought it was a part of the experiment, or that they were busy with the task given during the VR experiment (Arias et al., 2025). Figure 1 present their results regarding how many participants from the different experiments reacted to the alarm.

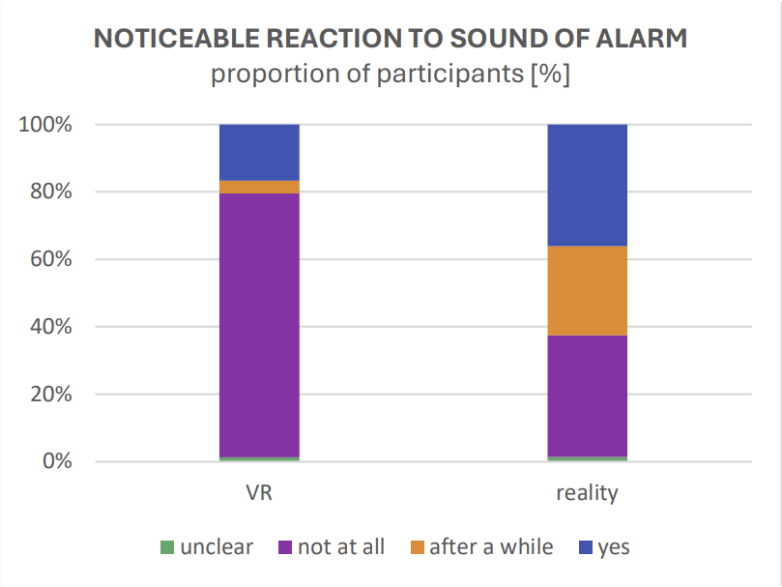

Figure 1. Noticeable reactions to sound of alarm from Arias et al. (2025). Reproduced with permission.

This means that ignoring the alarm is more likely in VR but not unlikely in reality. (Arias et al., 2025).

The real-world experiments showed that not only did more participants react to the fire alarm, but they were also better at specifying the direction from which the sound originated. In their real-world experiments, 74 percent of the participants in the lecture hall, and 80 percent of the participants in the corridor, gave the same correct answer “back right” to where the sound came from. However, the answers from the participants in the VR experiments showed more variation, with participants answering “behind”, “right”, “everywhere”,” above”. Since the answers from the participants in the VR experiments showed more variation, Arias et al. (2025) decided to combine the answers “behind”, “right” and “back right” into one category and calling them “correct”. They then combined the answers “left”, “everywhere”, “front”, “above” and “outside the room” into a different category called “incorrect”. When comparing the “correct” and “incorrect” answers, the participants in the real-world experiments were still more accurate.

Since the experiment done by Arias et al. (2025) concluded that participants in the real-world experiments reacted more often to the fire alarm than they did in the VR experiments, this thesis will explore whether the results from VR experiments can be improved by removing the researcher from the room.

- Does the researcher's presence affect the participants' reaction to an fire alarm in virtual reality?
- How does the researchers' presence affect the participants when performing a VR experiment? Did it leed to a benificial result? Or is it better if the researcher is present.
- Are there more visible reactions from the participants to the evacuation alarm when no researchers are present in the room?

1.3 Purpose

The purpose of this project is to study the effect of a researcher's presence on participants performing a VR experiment.

1.4 Goal

The goal is to gain information that can be used to improve the implementation of future VR experiments and contribute to increase the validation efforts of VR in fire evacuation experiments.

1.5 Methodology

The thesis can be divided into the following three sections:

- Literature review
- Planning and execution of the experiments
- Summary and analysis of results

The thesis began with researching previous VR experiments and theories in human behaviour in fire. A previous experiment done in VR (Arias et al., 2025) forms the basis of this thesis. That experiment combined with the experiment Latané and Darly's (1970) formed the idea of designing an experiment that would examine whether a researcher present in the same room as the participant would affect or influence the behaviour of the participant.

Therefore, an experiment was designed, aiming to expose participants to a virtual environment including an evacuation alarm, which will be played unknowingly to the participants. Their behaviour will be documented when the alarm sounds. Two samples of participants will be asked bogus questions and exposed to the same virtual environment. One sample will have a researcher present in the same room. The other sample will be supervised through a live camera. The differences in the response of participants will indicate if the presence of a researcher has an impact on their behaviour.

The last part of the thesis are the summary and analysis of the results, and it will result in the knowledge of whether the researcher's presence in the same room as the participants has an impact on the results or not when conducting an VR experiment.

1.6 Delimitations and limitations

The thesis is delimited to only study the effect the researcher has on the participant and will not study other factors that may influence or affect the participants response to the alarm. Environmental factors like sound level or the layout of the room will not be studied since this thesis will only use one room set-up and the same sound level for all the participants.

This thesis will have a small number of participants, which might affect the reliability of the results.

The observable reactions from the participants will be assessed by visual inspection and is therefore limited to the researchers' interpretations.

The responses provided by participants during the post-experiment interviews may be influenced by social desirability bias, also known as the Hawthorne effect (Dickson and Roethlisberger, 1966). Participants might have attempted to answer the questions in a way they believed aligned with the researchers' expectations, which can affect the accuracy and reliability of the results.

2 Theory

Virtual Reality is defined in this thesis as "an artificial world of images and sounds created by a computer that is affected by the actions of a person who is experiencing it" (2026 Encyclopædia Britannica, Inc). The virtual environment that is created by computers can be presented/displayed by different methods, for example by using screens or with Head Mounted Displays. In this thesis head mounted displays will be the way of presenting the virtual environment to the participants.

2.1 Previous VR research in fire engineering

The use of VR in fire evacuation experiments is a well-studied subject that has had a lot of progress made in the last few years. The studies made aim to make VR a suitable option for conducting evacuation experiments.

"Virtual environments provide a maximum of experimental control, are easy to replicate, have relatively high ecological validity, and allow safe study of occupant behaviour in scenarios that otherwise would be too dangerous." (Kinateder et al., 2014).

Previous research by Arias (2021) aimed to analyse the differences between VR experiments and physical-world (non-VR) research methods in order to get realistic behaviour in evacuation experiments. Arias (2021) used five different virtual environments which consisted of a hotel-room, a high-rise hotel building, a two-story house, a nightclub and an underground particle accelerator. This experiment highlighted that in order to make the participants perception of realism in VR experiments better, future experiments have to consider several factors and not only the visual effects. Arias (2021) concluded that in order to get a participant, in a VR experiment, to react as he or she would in the case of a real fire threat, it is not enough to make the virtual environment look realistic. You also have to make the virtual environment feel realistic. This might be possible by increasing the perceived fear for the participants or by lowering their sense of security. Will the removal of the researcher from the room affect the perception of fear or change their sense of security?

Kinateder et al. (2014) researched the strength and weaknesses regarding the use of VR in fire evacuation experiments. In their research, different methods such as hypothetical studies, lab experiments, field studies and VR experiments were compared. By studying the different methods, one gets a better understanding on the limitations of using different research methods and which aspects need to be further studied and improved in VR experiments. VR experiments had many strengths such as replication, ecological validity, safety for participants, low cost, repeated measurement and many more. The weaknesses were need for confirmation/validation, technical limitations, inter-individual differences in ease of interaction with VR and non-intuitive interaction methods. The main problem seems to be that virtual reality is not reality. People participating in VR experiments know that they are in an artificial environment and not in reality. (Kinateder et al., 2014).

A common issue presented from the research made by both Kinateder et al. (2014) and Arias (2021) is that participants in VR know they are in an artificial environment. To improve the results from VR it might be necessary to assess what aspects need to be addressed for VR to show similar results to the results produced in the real world. And therefore make VR a more suitable option to be used when performing evacuation experiments.

2.2 Human behaviour theories

Theories explaining human behaviour while conducting experiments and the human behaviour in fire, relevant to this thesis, are the following:

2.2.1 Role-Rule model

The role-rule model explains that an individual's behaviour in case of a fire or emergency is affected by their perceived role in the present situation. The theory also says that people will not only react instinctively, according to Tong and Canter (1985). Tong and Canter (1985) describes that people's

behaviour continues to be guided by the role-rule influences, which existed before the emergency, when faced with a fire threat. For example, if a fire alarm were to sound in a restaurant, the first immediate reaction from the guests might be to look towards the staff to see how they react and to seek information about if there is a real threat and if they (the guest) are supposed to evacuate or not.

2.2.2 Hawthorne effect

The Hawthorne effect is a psychological effect that can be seen among participants when conducting experiments in several different fields (Dickson and Roethlisberger, 1966). It refers to the change of behaviour in the participant when they know that they are observed. Roethlisberger describes the Hawthorne effect as "The phenomenon in which subjects in behavioral studies change their performance in response to being observed ." (Dickson and Roethlisberger, 1966) . This psychological effect on the participants behaviour is hard to eliminate when conducting experiments since the researcher must observe the participant in order to gain some information regarding the experiment.

2.2.3 Observer expectancy

The Observer expectancy effect refers to the way an observer's perceived expectations can influence the behaviour of those that are being observed (Rosenthal, 1976). They continue to describe the effect with an imaginary medical experiment, which describes that if the observer expects a participant to be more stressed, then the observer will act as if the participant is more stressed. With either body language or by asking leading questions the observer might influence the participant to act more stressed.

The Observer expectancy effect (Dickson and Roethlisberger, 1966) is similar to the Hawthorne effect (Dickson and Roethlisberger, 1966) in the sense that both refers to how a participant and a researcher unknowingly affects one another. There are a few differences between the two psychological effects. While both theories involve mutual influence between researchers and participants, the observer expectancy effect covers more direct influences than the Hawthorne effect.

2.3 Presence of a researcher during VR experiments

Many studies have been made regarding how a researchers presence might influence or affect the participants during an experiment or survey. This has also been mentioned above. But how does a researchers presence affect the participants during VR experiments?

Gallup et al. (2019) studied how different types of presence might affect the participants during an VR experiment. They performed 5 different tests in VR but changed how the participants would be observed. The first two experiments are the ones relevant for this thesis. In the first test a researcher was present in the same room as the participant and in the second test the researcher was absent, leaving the participant alone. In the VR environment a screen was placed, presenting a person yawning. They wanted to compare the participants response to contagious yawning with and without a researcher present. The results showed that there was a significant difference in the number of contagious yawns, "with the presence of a researcher completely inhibited this response" (Gallup et al., 2019). In the second test (researcher absent) participants yawned 18 times while the first test (researcher present) none yawned. This indicates that a researchers' presence may influence the behaviour of participants performing VR experiments. (Gallup et al., 2019)

In an experimental study on the impact an embodied agent can have in a VR experiment, Walas (2023) studied four different groups of participants, who were exposed to four different conditions in VR. The first group were alone in the Virtual Environment (VE), the second group were also alone in the VE but with the knowledge that a researcher was observing a screen that was showing the participants point of view. The third and fourth group had a non-playable character standing in the participants field of view in the VE which was "watching" them in the VR. The experiment tested the participants reaction time and their accuracy when conducting a Stroop test (Stroop, J.R. 1935). Walas (2023) revealed that when the participants were aware that they were being observed, the participants

performed better on the Stroop task. Therefore, Walas (2023) concluded that “the social *presence of the experimenter could enhance task performance in the VR environment”*.

3 Ethical aspects

Ethical considerations are to be made when assessing the use of VR equipment. The use of head mounted displays (HMD) may lead to discomfort, such as dizziness, nausea, eye fatigue, among others. Therefore, the participants will be able to terminate the experiment at any point without having to give a reason.

3.1 Ethical aspects in this thesis

From the Nuremberg Code (1949) and the Declaration of Helsinki (World Medical Association, 2024) five ethical principles are identified as relevant for experiments involving human participants in the field of human behaviour in fire. These five principles are:

- Restriction of harm and suffering
- Outweighing of risks by benefits
- Informed consent
- Right to terminate the experiment
- Protection of integrity

How all the ethical principles are considered in this thesis is presented below.

3.1.1 Restriction of harm and suffering

VR may cause motion-sickness leading to nausea and/or loss of balance. This may come as a consequence of the virtual environments' inability to fully represent the participants motion in real life. The occurrence of motion-sickness depends both on the participant and the virtual environment. Some participants are more susceptible to feeling motion-sickness. In the present study, participants will not move within the virtual environment, although they will be allowed to turn their head around to look at the environment they are in. The lack of displacement in the virtual environment is likely to reduce the risk of motion-sickness. Participants will be informed about this risk and that if feelings of nausea or loss of balance occur, take off the headset and close their eyes. Note that this risk is not limited to this experiment, but is present in all VR experiences. A researcher will always be present closely monitoring the participant and terminating the experiment if needed. The participants in the VR experiments will be covered by insurance from the arrival to the experimental room until their departure. The applicable insurance is the personal injury protection insurance. The VR experiments will be conducted in a controlled environment, and in a setting in which the participants will be aware that they are taking part in an experiment. A first aid kit and water will always be present when the experiments are conducted. If an acute medical situation occurs, i.e. fainting or a panic-attack, professional medical help will be summoned by calling 112. Previous experience has shown that no such events has occurred.

3.1.2 Outweighing of risks by benefits

The low risks associated to this experiment are matched by the benefits participants get from joining the study. The risk for physical or psychological harm is assessed as very low for the participants, which is an assessment based on previous experience from the participating researchers who have conducted similar experiments. The direct benefit for the participants is limited. However, it still adds up to a net gain, as no harm is likely to occur. The knowledge generated from this study is expected to legitimate the data collected by removing the expectation the participants might have on receiving information from the researcher during the experiment.

3.1.3 Informed consent

A call for participants will provide information about the experiment and some of the eligibility criteria. Upon their own request, volunteers will be given information about the experiment as well as the informed consent form for them to be acquainted with before they sign up as participants. The information provided, which is presented in Appendix 4, will explain the experiment, the equipment,

the inclusion/exclusion criteria, the risks and the benefits for the participants. Upon arrival in the experimental room, participants will be given the opportunity to re-read the information provided and give their informed consent in writing by signing the form. Participants will be given the opportunity to ask any questions they may have. Some aspects of the experiment will not be detailed to prevent a biased response, which is a common approach in behavioural experiments. In the case of this study, the information concealed is the fact that an alarm will go off at some point while they are busy assessing the virtual room, and that their reaction to it is a key point of the experiment. The risks associated with this experiment will not be concealed but highlighted.

All participants will receive information about the study, the informed consent form, and a link to an online platform for participants to select a timeslot of their preference. The information they receive and the informed consent form will include the procedure, inclusion/exclusion criteria, information about the risks associated with participating as well as information about the presence of a webcam. It is expected that participants, being adults, will only sign up if they meet the requirements. The experiment will be described along the lines of perception of realism in VR, but no information will be given about an evacuation alarm to avoid having them prepared for the sound and therefore biasing their reaction. Nevertheless, the description of the risks associated to the experiment will be thorough. Upon arrival at the place and time for the study, the researcher will present a printed version of the informed consent form for the participant to sign. The participant will be able to ask questions to the researcher. The participant will be given instructions on the use of the equipment and the general procedure during the experiment. They will be reminded of their right to terminate the experiment at any point and still get their compensation. Only participants giving their informed consent in written form will be allowed to join.

3.1.4 Right to terminate the experiment

The participants will be given information on their right to terminate the experiment at any time in the informed consent form. Before the experiment is launched, the researcher in the room will reiterate the right to terminate the experiment at any time, and the instructions on how to do it (e.g., removing the equipment, saying it aloud, etc.)

3.1.5 Protection of integrity

Recorded experience in VR and questionnaire data will be pseudonymized using a participant number, which will not be connected to their name or email address. The screen recordings will not show the participants' face but only what they can see in VR. Pseudomized data will be stored on password-protected storage accessible only to the participating researchers and thesis students. There will not be a key connecting a given participant to any of the data produced. The informed consent forms, which contain the participants' names, will be safely stored according to the routines at the Division of Fire Safety Engineering at Lund University. These documents will be kept for up to 10 years after the experiment has been conducted, in a safe, and will be destroyed then. Contact information (like email address, phone number) will be stored for up to 6 months after their participation.

3.1.6 Data collection

The data is not connected to the participant in any way. The dataset corresponding to a participant was given an identification number, which will not be traced back to the participant's name or email address. Any contact information (email, phone) used during the recruitment of participants in the onsite VR study will be saved for up to six months, and thereafter deleted.

The data will be handled and stored according to the existing routine at the Division of Fire Safety Engineering at Lund University (Dnr 2015-012).

4 Method

In table 1, presented below, potential different reactions from the participants when the fire alarm sounds are presented and how the different observed reactions are interpreted.

Table 1. reactions and interpretations

Observed actions	**Reaction to the alarm**
Stop performing the given tasks	Yes
Removing the equipment	Yes
If seated, they standup.	Yes
Looking around	Yes
Twitching	Yes
Waving their hands	Yes
Moving around	Yes
Verbally asking to terminate the experiment	Yes
Fainting	Yes
Jumping around/up and down	Yes
If their body language change, e.g. tapping your feet	Yes
Shouting	Yes
No reaction. Participants are disregarding the fire alarm and continuing with the tasks given.	No

4.1 Reproduced experiment

This experiment will be a reproduction of the experiment done by Arias et.al (2025) and will use one of the virtual environments from it. The virtual environment that will be used is the corridor which is based on a corridor in V-Huset in Lund, reproduced on a 1:1 scale, without any modifications. The only aspect under study will be the difference in reactions between the participant with a researcher present and the reaction without a researcher present.

4.1.1 Equipment

The equipment used during the experiments are the following:

- VR head-mounted display (HTC Vive Pro 2) with hand controllers
- Four computers with one computer being equipped with a camera

One computer was connected to the head mounted display (HMD), displaying the virtual environment and the participants actions in VR in real time. That computer was then screen sharing the live feed from the VR environment through Discord to another computer located in the observer room. The second computer inside the VR lab live streamed the real world actions of the participants via a Teams video call to another computer in the observer room.

4.1.2 Virtual environment

The virtual environment was created by Arias et al. (2025) and used in their experiments. The virtual environment was based on a corridor in the basement of V-Huset in Lund which is shown in the figures below. It is a default configuration in a 1:1 scale. Figure 2 displays how the corridor looks in real life and figure 3 displays how the corridor looks in VR.

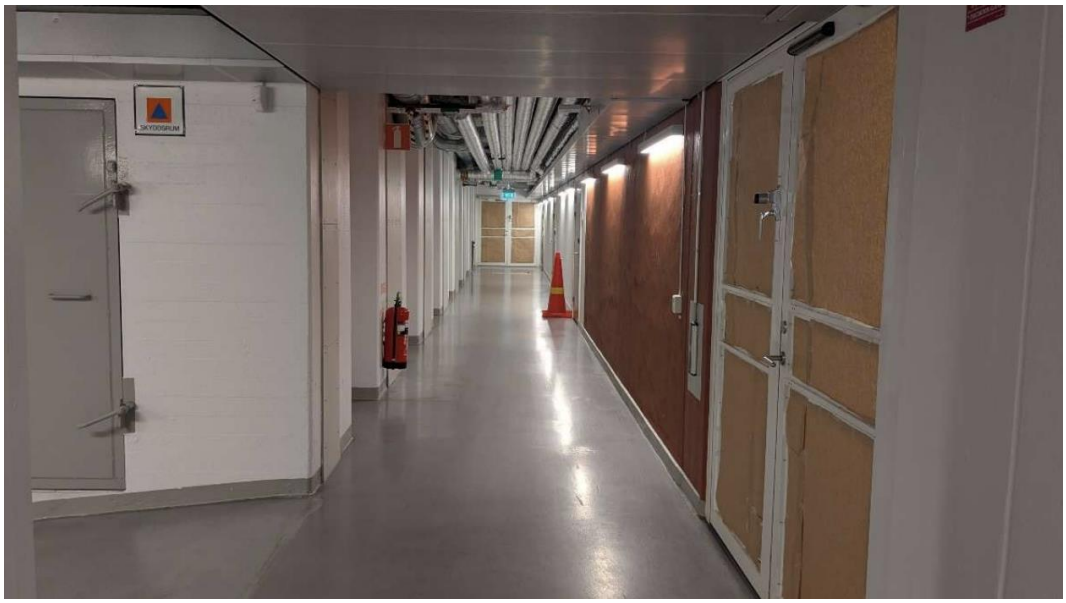

Figure 2. Picture of the corridor in real life. Reproduced with permission.

Figure 3. Picture of the corridor in VR. Reproduced with permission.

4.1.3 Procedure

When the participants arrived at V-huset in Lund they where guided down to the basement were the VR lab is located. Once there they read and signed the informed consent form. After the informed consent form was signed, the participants had the experiment explained, and any questions they had was answered. They where informed that they, at any time, could terminate the experiment and how to do so. The participant would then put on the equipment. Half of the participants would have a researcher present during the experiment, and the other half would have no researcher present during the experiment.

During the experiment with no researcher present, both researchers was located in the adjacent room, observer room, and monitoring the participants, via screen monitoring through an online meeting platform, and what the participants see in VR, via Discord. Audio from the VR lab would also be picked up through Discord. The observer room had two computers, and the VR lab also had two computers, with one also equipped with a camera.

During the experiment with a researcher present, one researcher stayed in the VR lab and visually observeved the participant while the other researcher waslocated in the observer room, also observing the participant.

During the experiment, the participants answered a series of questions, referred to as “Task 1”, “Task 2” and “Task 3”. They answered the questions by using their hand controllers and pressing a button on the answer displayed in the VR environment.

When the experiment starts the participants first answered an SED assessment (Task 1), consisting of 36 questions, presented in appendix 3. An SED-assessment (Semantic Environmental Description) is a standardized psychological assessment tool developed by Professor Rikard Küller to systematically measure how people perceive an architectural space (Küller, 1972). The second part of questions was on distance perceptions in VR (Task 2), presented in appendix 3. The third series of questions consisted of different bogus questions (Task 3), presented in appendix 3. The questions from task 1, 2 and 3 are only meant as a distraction for the participants so they have time to get immersed into the VE and also have something to focus on before and during the fire alarm. When the third series of questions started, the timer of when the virtual fire alarm will sound started as well. When 5 seconds had passed, the fire alarm sounded for 20 seconds. During the fire alarm, the participants’ reactions and behaviour was monitored and documented. After 20 seconds the fire alarm stoped and the participants had new sets of questions, “What is that sound?”, “Where is the sound coming from?” and “If you did not react, why?”. These three questions was answereded verbally and documented by the researchers. When all questions had been answered, one of the researchers assisted the participant with removing the equipment.

After the experiment the researchers explained the objective of the experiment and answerd any questions the participants has. The participants then answered a questionnaire regarding their experience in VR, their age, gender and occupation.

After the experiment was completed and the participants had left, the data collected was put in to an excel file.

Since the participants performed the experiment in VR and therefore had no idea what happened around them during the experiment, the researchers wanted the participants with no researcher present to fully understand that they were left alone. This was done by exaggerating their exit from the room by walking louder and stating that they were now leaving the room. The door was also closed more aggressively so the participants heard it. All this was done to hopefully make the participants understand that from now on, to the end of the experiment, they would be all by themselves, since that was the main focus of the experiment.

4.1.4 Participants

Two independent samples of participants was recruited for this experiment. Each sample consisted of 27 people. To determine the validity of the sample size a power analysis was performed. The recommended minimum sample size, when using a power value of 90%, was 25 participants in each group. The recommended number of participants was achieved. Participants was recruited on campus, and snowball sampling. All participants was adults. Participants was included in the study upon meeting the following inclusion and exclusion criteria:

Inclusion criteria:

- Being legal adults (18+ years old)
- Being able to give an informed consent
- Being able to communicate in Swedish or English

Exclusion criteria:

- Having cognitive impairments which require constant help from another person
- Being blind in one or both eyes
- Suffering from epilepsy
- Having stress and/or anxiety disorders.

The recruitment aimed towards getting an even gender distribution. All participants was covered by health insurance provided by Kammarkollegiet from their arrival to the VR lab until they leave.

The experiment was performed with 54 participants divided into two groups, with 27 participants in each. Group 1, which is the group of participants that did the experiment with one of us researchers in the room, had 15 male and 12 female participants. Group 2, which is the group of participants that did the experiment alone in the room, had 14 male and 13 female participants. The age distribution is presented in figure 4 below, with a majority of participants being between the ages of 21-25 years old.

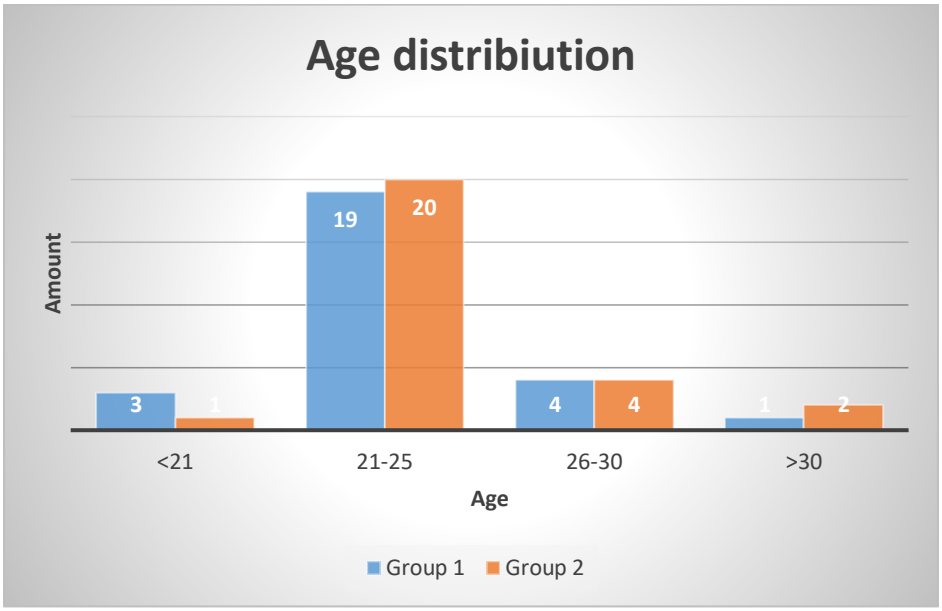

Figure 4. The figure shows the age of all the participants.

5 Results

This section presents the result from the experiment along with observations made during the experiment. When conducting the experiment there were two participants who got confused and did not answer the last three questions. These two participants therefore produced inconclusive results, and were removed from the sample. Therefore, the total number of participants across two graphs in Figure 2 is 52, rather than 54 which was the total amount of participants in the experiment.Figure 5 below presents the results regarding whether the participants reacted or not when the virtual fire alarm was activated. A total of 35 participants reacted, and a total of 17 participants did not react when the virtual fire alarm was activated. Of those 35 participants that reacted, 8 of them did not have a visible reaction but when they answered the last question in the experiment "*If you did not react, why?*" they said that they did in fact react. One of them answered *"I reacted a little bit, but since I was in VR and you didn´t stop the experiment I didn´t think much of it"*. One of them answered *"I reacted, I got scared"* and the other six said that they reacted at first but tried to stay calm and focus on the tasks in VR. Reacting to the alarm means that a participant has shown a visible reaction during the fire alarm, such as looking around the room or any of the other actions mentioned in table 1. A participant not showing any visible reaction but reporting that they did react when answering the question "If you did not react why", are presented in the "yes but not visible" category.

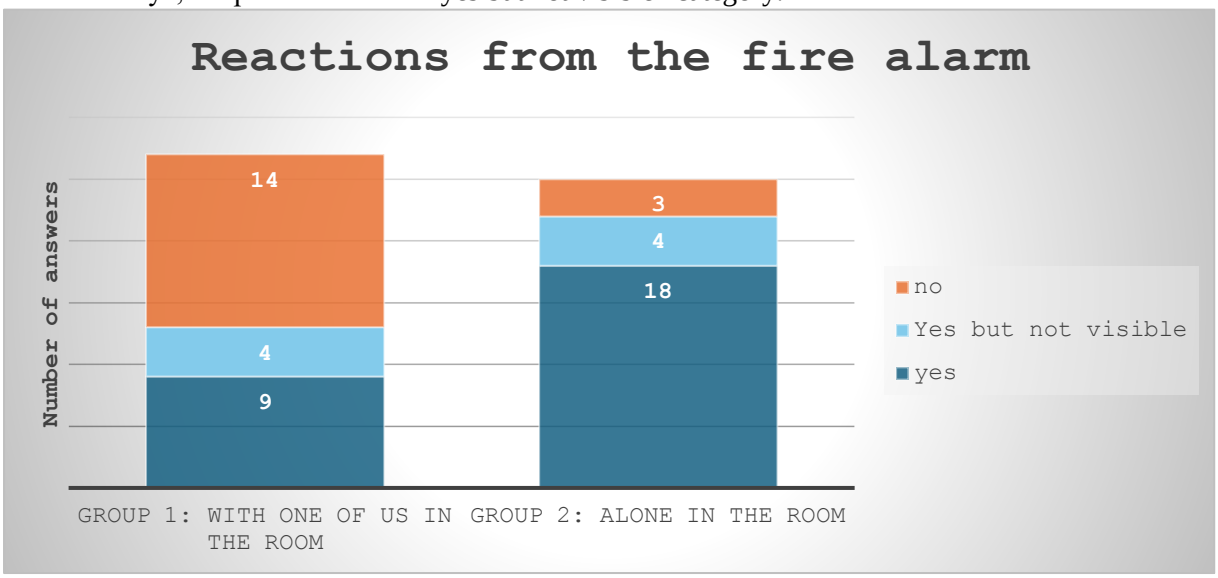

Figure 5. The difference in reactions between both groups of participants.

As shown in Figure 5, more reactions were observed in group 2 compared to group 1.

A Fisher´s exact test was performed using the online website GraphPad. By using a Fisher´s exact test on experiments with smaller sample sizes, the validity of the results from the experiments can be calculated. The Fisher´s exact test that was performed on the website GraphPad, with the results shown in Figure 5, produced a p-value of 0,0030, which means that the result is statistically significant.

The results are based on the observed reactions of the participants and the different actions that were observed is presented in table 2 below. Some participants exhibited several different visible reactions of the ones presented in table 2. Those participants are put in the category in which behaviour they exhibited the most to avoid duplicate entries.

Table 2. Visible reactions observed during the experiment:

Observed reaction	Number of participants	Number of participants

	Group 1 (with a researcher in the room)	Group 2 (Without a researcher in the room)
Hesitated and stopped answering the questions	0	6
Looked around the room	5	10
Grabbed and/or removed the headset	0	2
Asked verbally what that sound was	2	0
Got surprised and scared	2	0

Figure 6 below shows the participants answers regarding the origin of the fire alarm. A total of 16 participants gave answers that did not specify which direction the alarm came from, and all those answers is combined into the category called "Other". That category includes answers such as "from all around me", "from the headphones" and "from the walls".

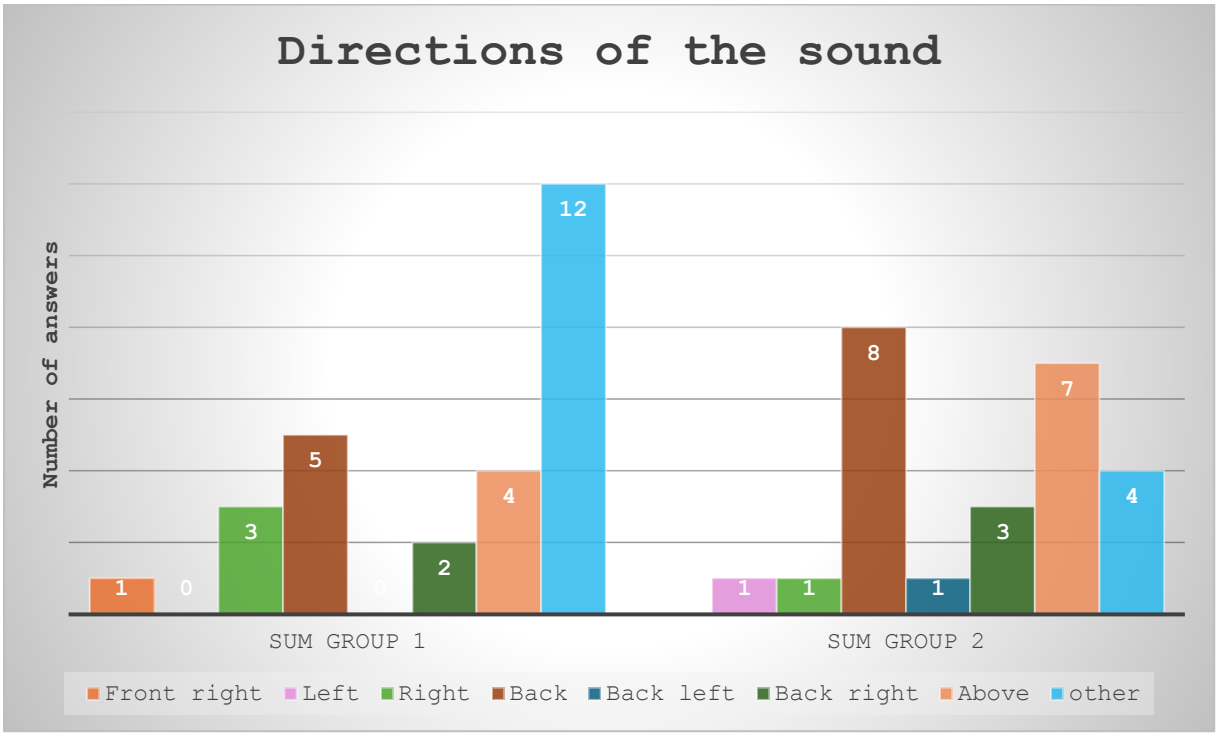

Figure 6. Answers given regarding the origin of the fire alarm.

As shown in Figure 6, the participants answered the question *"Where is the sound coming from"* very differently. The origin of the sound was behind them to the right which means that the correct answer to where the sound is coming from is back right. Only two from group 1 and three from group 2 answered back right.

The previous experiment done by Arias et al (2025) resulted in that 80% of the participants from the real-world experiment answered back right and that 27% of the participants from the VR experiment answered back right. When comparing these results with the results produced from this thesis, there is still a difference in the participants ability to assess sound direction. Participants in the real-world experiment by Arias et al. (2025) performed better compared to participants in VR without a researcher present.

When the participants were done with the experiment they were asked to answer a questionnaire on a laptop regarding their experience in VR. One of the questions on that questionnaire was how realistic they thought the room in VR was and the results are shown in Figure 7.

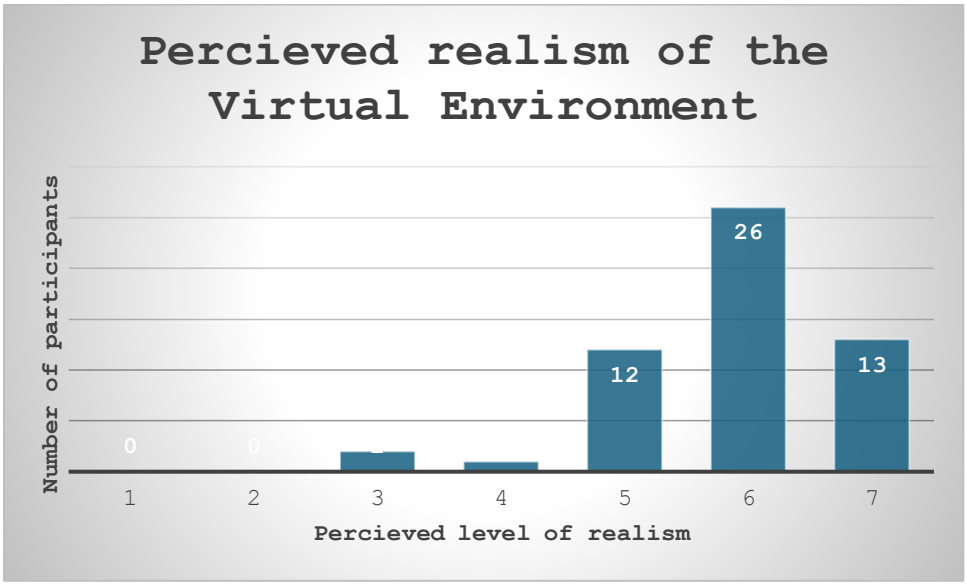

Figure 7. Answers from the post experiment questionnaire. On the vertical axis the number of answers is shown and on horizontal axis the level of realism is shown. Where 1 means not realistic and 7 means very realistic.

6 Discussion

In this section the results from the experiment and sources of error will be discussed.

The number of participants that reacted to the fire alarm in each group differed significantly . In group 1 (researcher in the room), 13 participants reacted to the fire-alarm with 4 of the participants showing no visible reaction. In group 2 (no researcher in the room), 22 participants reacted to the fire-alarm with 4 of them showing no visible reaction. By leaving the participants alone during VR experiments, the reactions to the fire-alarm increased significantly, indicating that a researchers presence during VR experiments might affect the results from the experiment. This implies that there might be a correlation on the effects of a researchers presence and the validity of the data produced using VR. The majority of the participants that had no reaction to the fire alarm said that they did not react to it because they knew that they were in VR or that they knew that they were in a lab environment. Since there were more participants from group 1 that gave this response, 8 compared to 1. A reason why this happened might be that the researcher present in the room made the participants feel more like they were in a controlled lab environment. As mentioned in the section 2.3.1 Role-Rule model, and according to Tong and Canter (1985), people's behaviour and their first reaction in an emergency is based on the perceived role they had prior to the emergency. This might be the reason why the participants in group 1 did not react as much to the fire alarm as the participants in group 2, which did not have a researcher present. The participants in group 1, could have had less of a reaction because they might have thought that if the fire alarm indicated a real threat, the researcher present would have terminated the experiment and told them what to do. When answering the question *"if you didn´t react, why?"*, one of the participants in group 1 that did not have a visible reaction to the fire alarm said that "*I reacted a little bit, but since I was in VR and you didn´t stop the experiment I didn´t think much of it*".

None of the participants knew what the goal of the experiment was and therefore had no idea what to expect. This might lead to the participants reactions being more genuine, compared to if the participants knew the objective of the thesis, or that a fire alarm will sound. The participants not knowing the surprise element of the fire alarm was intended, so that the results from the experiment would not be affected by the participants knowledge and therefore also their reactions to it.

When answering the question *"Where is the sound coming from"* both groups answered with many different directions as shown in Figure 6. Some of the participants gave answers that did not specify a direction but instead answered from what the sound came from, such as "*from the VR*" or *"from the headphones"*. Since the answers regarding the origin of the sound varied as much as they did and there was no statistically significant difference between how many correct answers the different groups gave. No conclusion can be made as to whether the researcher's presence in the room influenced the participants to answer more correctly or less correctly to the question *"Where is the sound coming from"*. One thing that can be seen from Figure 6 is that group 1 hade significantly more answers that were put in the *"Other"* category. The answers that were put in the "*Other"* category were answers such as "from all around me", "from the headphones" and "from the walls". One possible explanation why group 1 gave more indecisive or wrong answers is because they did not interpret the fire alarm as a plausible threat, maybe because of the presence of a researcher (Tong and Canter, 1985), and therefore did not try to figure out exactly where the sound came from. This could be the reason why group 1 hade more answers in the category "other" compared to group 2.

When comparing the results from Arias et al. (2025) regarding direction of the sound, there is still a large difference. When participants performed the experiment without a researcher present, only 12 percent of the participants answered correctly, compared to the real-world experiment by Arias et al. (2025), where 80 percent of the participants answered correctly. When also comparing their results from the VR experiment, 27 percent of the participants answered correctly. Since the results from this thesis showed a lower percentage of correct answers compared to the results from the VR experiments

by Arias et al. (2025), no conclusions, regarding the effects of a researcher's presence on the participants ability to assess sound directions, can be made.

A reason why some of participants answered the question "*Where is the sound coming from?"* with answers such as "*from the headphones*" and "*From the alarm bells"* and "*I don´t know"* instead of giving answers that specified from which direction the sound came from might be because of how the question was phrased, since the question was asked after the fire alarm had stopped. The question was "*where is the sound coming from*" instead of "*where did the sound come from*". Although, this does not explain why there were more of these type of answers in group 1 than in group 2.

Of the 54 participants that did the experiment, most of them thought that the virtual environment they were in looked and felt realistic. As shown in Figure 7 and Figure 8 the majority of the answers were 5,6 and 7, which correspond to a higher level of realism. When answering the questionnaire, some participants also said that they were surprised about how realistic the virtual environment felt. Most of the comments made by the participants that did not react to the fire-alarm were that they knew they were in a VR environment. If the environment feels more realistic, they might be more prone to reacting as well. The realism on the virtual environment used in this experiment has not been studied in this thesis but it has been studied in Arias (2021). But it is important to know that the realism of the environment itself might affect the results.

Regarding the topic of realism, it should be noted that the visual graphics alone might not be enough to make a virtual environment feel realistic. One thing that future research should discuss when conducting an VR experiment is the choice of equipment. The different types of equipment come with different levels of immersion, i.e. the state of being deeply engaged and absorbed in an experience. Equipment with different levels of immersion could influence the extent to which the researcher affects the participants behaviour. During the VR experiments this thesis used a HMD called HTC Vive Pro 2, other types of HMDs might affect the level of immersion. Therefore, also leading to different result. There is a possibility that the level of immersion can affect how much a participant notices the researcher's presence during VR experiment with a researcher in the same room. A higher immersion level might lead to the participant not knowing/remembering that a researcher is still in the same room, causing the results between the two test groups (one with a researcher and one without a researcher in the same room) to not differ as much or not at all, No research has been done regarding how the level of immersion can affect the participants performing a VR experiment and no conclusion can be made. This is merely speculations on the possible effects.

When performing an experiment, researchers might affect the participants beforehand. The observer expectancy effect implies that a researcher's behaviour towards participants can affect the participants and alter the results from the experiment (*Rosenthal, R. 1976*). To avoid such a conflict, this subject was studied and taken into account before the experiments were conducted. This was done by the researchers following a script that included what to say and how to act to the participants. This meant that all participants, from both groups, had the same treatment and information, thus ensuring that there were no difference between the groups regarding the observer expectancy effect.

The virtual fire alarm used in this experiment is the same as the one used in Arias (2025). How realistic it sounds and how familiar the participants are with the sound can influence their reactions to it. When the participants answered the question "What is that sound" a majority of the participants knew what kind of sound it was. Since information about fire alarms is well talked about and what to do in case of a fire, people might be more prone to react and seek information about where the sound is coming from and what to do next. But in this experiment, only a few participants reacted when being with a researcher in the room, indicating that the origin and knowledge of the sound might not matter as much as the researcher's presence does.

During the experiments, two participants failed to answer the three last questions out loud, making their response unusable. Why their results was left as a “no result” is to eliminate the possibility that the researcher can affect their answer. Because when having to ask the questions after the experiment to them, instead of in VR, the tone of the voice, how the question is phrased and the fact that the question is no longer asked in VR, might influence how the participant answer the questions (Aaron, 1964). It also changes the conditions for the participant, compared to the other participants. It is important that all the participants perform the experiment with the same conditions to not affect the outcome. The interesting part is that both of the participants came from group 2. All participants were informed that at the end of the experiments, three questions will have to be answered out loud, that it will say so in the question and what it will say. Even with this knowledge, two participants failed to answer those questions. A common reaction when feeling stressed or anxious is that it becomes harder to remember information received and understand tasks given (Marks and King, 2024). This problem never occurred when the participants had a researcher present. But when left alone it occurred twice. It is therefore not improbable that the reason behind them not answering the question was because of stress or anxiety, derived from the fire alarm. There is of course also a probability that it had nothing to do with a reaction to the fire alarm. In this thesis it will not be interpreted as a reaction because of the uncertainties. During the experiments, a few other participants hesitated and took a few seconds before answering the last questions out loud. Those participants might have also failed to remember to answer out loud but still managed to do so.

The results, regarding if people reacted visibly to the fire alarm, is based on assumptions and interpretations made by the researchers. Some of the reactions registered as a visible reaction might not have been a reaction at all and some of the participants registered as no reaction, might have had a reaction. Experiments based on assumptions and interpretations can lead to inaccurate results. In this thesis two researchers discussed how certain reactions should be interpreted before the experiments started to have an underlying knowledge of what to look for. The results can therefore differ from researcher to researcher, but since the majority of the reactions observed were obvious, and the results from the two groups are highly different, the results from the experiment should be seen as viable and accurate. But to improve the validity, an experiment with more participants can be conducted. Another way to improve the validity would be to use eye-tracking devices. By being able to observe the participants eye-movement, researchers might easier see if the participants are actively searching for the sound source. This can lead to a more conclusive result regarding if the participant reacted or not, when other visible signs are difficult to observe or interpret. Others trying to perform similar experiments should discuss adding eye-tracking or other tools to easer differentiate between a reaction and non-reaction. This was not done when performing this experiment and therefore no advantages regarding the usage of eye-tracking can be made.

During the experiment, three participants had visible reactions, but when answering the last question “If you did not react, why?” they answered that they had no reaction because they knew they were in VR. This conflicted with the observed reaction. But since all three of them had convincing visible reactions, their result was interpreted as a visible reaction. Social desirability bias might have played a part in their responses by them answering the questions as they believe is the most socially desirable answer, having no reaction (Junior, 2022). They can also have answered this way because they believe that they actually did not react to the fire alarm.

In this thesis, a majority of the participants were recruited on LTH:s campus which meant that most participants were students and between the ages of 21-25. Therefore, the experiment was conducted with a rather homogeneous group of students. The result from this experiment might have been different if it were to be conducted with a more heterogeneous group of participants. The advantages of having a homogeneous group of healthy students is that individual differences are reduced, making it less likely that the results can be explained by variations in the participants, such as age or occupation, rather than the experimental conditions. The disadvantages of having a homogeneous

group of people is that the results are not as generalizable as it would have had been if the experiment was done with all kinds of different people. Although, then the sample size would have needed to been bigger.

When analysing the results in the different groups, it was observed that there was a difference between the male and female participants reactions in one of the groups. In group 1, there were a total of 27 participants with 15 male and 12 female participants, but of the 13 participants that reacted to the alarm, 9 of them were female. This means that even if there were 3 more male participants in total, there were more female participants that reacted to the fire alarm. Although, in group 2 when the participants were left alone in the room there were no difference in reactions between the genders. Since this thesis had a relatively small sample size no significant conclusions regarding gender differences in responses to the virtual fire alarm could be drawn from this study.

7 Conclusion

Based on the results from the literature review, the VR experiments, the survey and the discussion, the following conclusions are presented.

Both groups performed similarly on where the sound came from, with group 2 less answers registered as “other”. Therefore, no conclusions can be made regarding how the presence of a researcher affects the participants' ability to assess sound direction.

There is a large difference in how the groups reacted to the fire alarm when having a researcher present, compared to being alone during the experiment. By removing the researcher, an increase in reactions to the fire alarm occurred. Group 2 had a lot more reactions to the fire alarm compared to group 1. Since it was such a big difference, it supports the theory that a researcher's presence affects participants performing VR experiments. To increase the validity of the results, experiments with more participants can be conducted. However, according to the Fishers exact test, it suggests that the results produced are likely to be similar for an experiment with a larger number of participants..

This thesis was based on the previous work by Arias et al. (2025) which concluded that more participants in the real-world experiment reacted to the fire alarm compared to the VR experiment. This thesis was conducted to explore whether the results from the VR experiment could be improved by removing the researcher from the room. The results from this experiment showed that by removing the researcher from the room, the number of participants reacting to the fire alarm increased. Thus producing results that closer resemble the results from the real-world experiment done by Arias et al. (2025)

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Appendix 1. Presentation on the usage of Generative AI

Nedanstående text redovisar hur författaren använt så kallad generativ AI.

Användning av GAI	***YES/NO***
1) *I used in my report a Generative AI tool (e.g. ChatGPT or similar)*	*Yes*
2) *I used a GAI tool as language editor (i.e. to correct grammar mistakes, etc.)*	*Yes*
3) *I used GAI to retrieve information*	*No*
4) *I used GAI to get help in writing code*	*No*
5) *I used GAI for translations*	*Yes*
6) *I used GAI to generate graphs/images*	*No*
7) *I used GAI to help structuring my content*	*No*
Write a short description on how and to what extent GAI-tools were used in your work.	*GAI was only used to translate words when we did not know the english word for it. It was also used for grammar correction in some cases.*

Appendix 2. SED assessment

Below is the SED assessment the participant had to answer during the experiment.

Factor	Description	Adjectives included in the factor	
		Positively correlated	Negatively correlated
1.Pleasantness	The quality of being pleasant, beautiful and secure experienced in the environment	Good, Idyllic, Stimulating, Pleasant, Secure	Brutal, Ugly, Boring
2.Complexity	The degree of variation or specially intensity, contrast as well as abundance of the environment	Motley, Lively, Composite	Subdued
3.Unity	How well the various parts in the environment fit and function together	Functional, Whole, Consistent, Pure style	
4.Enclosedness	A sense of spatial enclosure and demarcation of the environment	Demarcated, Closed	Airy, Open

5.Potency	The degree of power and/or force in the environment and its various parts	Potent, Masculine	Feminine, Fragile
6.Social status	The socio-economic value of the environment including maintenance	Expensive, Lash	Well-kept, Simple
7.Affection	A sense of similarity related to the age of the environment and also, a feeling for the old and genuine	Modern, New	Timeless, Aged
8.Originality	The unusual and surprising in the environment	Curious, Special, Surprising	Ordinary

Original Swedish	**Original English**	**Modified English**
modern	Modern	Modern
Brokig	Motley	Cluttered
Ful	Ugly	Ugly
Egendomlig	Curius	Strange
Dyrbar	Expensive	Expensive
Maskulin	Masculine	Maculine
Stimulerande	Stimulating	Stimulating
Sluten	Closed	Enclosed
Funktionell	Functional	Functional
Välvårdad	Well-kept	Well-maintained
Vanlig	Ordinary	Common
Trygg	Secure	Safe
Stilren	Of pure style	Elegant
Tråkig	Boring	Boring
Ömtålig	Fragile	Fragile
Dämpad	Subdued	Toned-down
Tidlös	Timeless	Timeless
Öppen	Open	Open

Original Swedish	**Original English**	**Modified English**
Idyllisk	Idyllic	Idyllic
Överraskande	Surprising	Surprising
Enkel	Simple	Simple
Ålderdomlig	Aged	Historic
Konsekvent	Consistent	Consistent
Livlig	Lively	Lively
Bra	Good	Good
Avgränsad	Demarcated	Demarcated
Kraftfull	Potent	Strong
Ny	New	New
Påkostad	Lavish	Lavish
Sammansatt	Composite	Cohesive
Trivsam	Pleasant	Pleasant
Feminine	Feminine	Feminine
Helhetsbetonad	Whole	Complete
Brutal	Brutal	Brutal
Speciell	Special	Unusual
Luftig	Airy	Airy

Appendix 3. Questions asked in VR

Task 2. Distance perception

1. Estimate the distance to the end of the corridor?

2. Estimate the distance to the traffic cone?

3. Estimate the distance to the fire extinquisher?

Task 3. Questions

1. What is the color of the floor?
2. What is the color of the traffic cone?
3. What is the color of the fire extinguisher?
4. Can you see your hand controller?
5. What is the color of the hand controller?
6. What is the color of the emergency sign?
7. What is the color of the floor skirting?
8. How tall is the fire extinguisher?
9. How tall is the traffic cone?
10. What is the color of the ceiling?
11. What is the color of the pipes?
12. What is that sound? (Answered verbally)
13. Where is the sound coming from? (Answered verbally)
14. If you did not react, why? (Answered verbally)

Appendix 4. Recruitment material

Presented below is the information each participant received before signing up to perform the experiment.

Realism in Virtual Reality-experiments

The department of fire engineering at Lund University is conducting a study of various VR technologies to investigate how environments created in VR can be made more realistic. In the long term, the aim is to use VR technology as a research method.

We are now looking for participants who would like to help evaluate different VR environments. In the study, you will be shown a room in Virtual Reality using a VR headset. Your task is to assess the properties of the room by grading a number of statements, on a seven-point scale, which will be shown in the Virtual room.

The study takes approximately 20 minutes. During the experiment there will be water available to you.

Using a VR headset may cause some individuals to experience dizziness or nausea. The effects are temporary, and if you experience such symptoms, you should stop the experiment. Apart from this, the risks to you as a participant are minimal. Throughout the whole study, you are covered by accident insurance through Kammarkollegiet.

To participate in this study, you must be at least 18 years old and be able to speak Swedish or English.

You cannot participate if you have a cognitive impairment that requires assistance from another person. Furthermore, you cannot participate if you have severe visual impairment in one or both eyes, nor rely on hearing aids that prevent you from using headphones.

You must also not have an increased risk of anxiety, depression or epilepsy.

If you want to participate, please register your interest via the following link: https://calendar.app.google/rodq4o3qP85jnugM9 (This link also includes the required inclusion and exclusion criteria which is mandatory to answer)

As a research participant, you may withdraw from the study at any time.

After registering, you will receive additional information about the study, how it will be conducted and how to book a time that suits you. The study will take place in the V-building at LTH.
Address: John Ericssons väg 1 in Lund.

The lead researcher for this study is Silvia Arias at the Division of Fire Safety engineering, LTH. If you have any questions about the study, please contact Silvia via email silvia.arias@brand.lth.se or phone 046-222 73 66.

Appendix 5. Informed consent form

Presented below is the informed consent form each participant hade to sign before performing the experiment.

LUNDS TEKNISKA HÖGSKOLA
Lunds universitet

Avdelning för brandteknik, LTH
Silvia Arias

Information about experiments on perceived realism using Virtual Reality

This document contains information regarding experiments in virtual reality conducted by researchers at the Department of Building and Environmental Technology, Division of Fire Safety Engineering, Faculty of Engineering (LTH), Lund University.

1. Background and purpose

Virtual Reality (VR) has been widely used for entertainment, gaming, as well as education and training. However, as a research method, VR technology has not yet been fully evaluated, meaning it is necessary to investigate whether people behave realistically in virtual environments. This experiment is based on a computer-generated 3D model of a simple room environment. You will be equipped with a VR headset that allows you to see the computer-generated environment. The VR headset used is the HTC Vive Pro 2, a commercial product used worldwide. During the experiment, you will also evaluate various properties of the room by answering a number of questions.

The purpose of the study is to investigate how distance and realism are perceived by participants in VR experiments.

2. Invitation to participate

We are looking for adults (18 years or older) who would like to participate in our experiment. This document provides information that may help you decide whether you want to participate. Your participation is entirely voluntary, meaning you only participate if you wish. You may withdraw at any time from now until the experiment is completed.

3. How is the study conducted?

When the experiment takes place, you will come to V-huset at LTH (John Ericssons väg 1, Lund). Initially, you will be informed about the experiment and asked to fill out a consent form. You will find the consent form at the end of this document, but you will receive a new one on-site. Before the experiment begins, you will be informed about the procedure and have the opportunity to ask questions. After this, you will be equipped with a VR headset consisting of two screens, one for each eye, allowing you to view the virtual environment in 3D. A camera will livestream you and your reactions. What you see in VR will be recorded.
You will not need to move; you will stand in the same position throughout the experiment.

A researcher will be with you at all times. You may stop the experiment immediately at any time by informing the researcher or by removing the equipment yourself. The researcher will assist

you. You do not need to provide a reason if you choose to withdraw. You will receive compensation regardless of whether you complete the experiment or not.

After the experiment, you will be asked to complete a questionnaire containing background information (such as age and gender), as well as questions about the virtual environment and your experience. No personal identifying information will be requested, and your responses will be anonymous, meaning they cannot be linked to you as an individual. Your name and email address will not be connected to the collected data.

After completing the questionnaire, the researcher will review the entire experiment with you, and you will have the opportunity to ask any further questions.

4. What are the risks?

There is a risk of experiencing motion sickness or dizziness while in the virtual environment. If you feel dizzy or unwell, there is a risk of losing balance and falling. Therefore, you must inform the researcher if you feel dizzy or unwell. The researcher will help you remove the equipment if you wish to stop the experiment and can provide water if needed. In some cases, closing your eyes and sitting down may help reduce nausea.

You may experience a warm sensation on your face when using the equipment. This is due to heat generated by the device itself. The sensation is mild and disappears when the equipment is removed.

5. Are there any benefits?

The main benefit is the opportunity to experience being in a virtual environment. More broadly, your participation contributes to increased knowledge about how VR technology can be used and how people perceive virtual environments.

6. Data handling

Data from the experiments will be presented in reports and scientific articles but will not be linked to you or your individual performance. The contact information you provide will be stored for up to 6 months but will not be linked to other collected data. It is stored in case we need to contact you after the experiment to follow up on any discomfort experienced.

During the experiment, a camera will livestream you and your reactions. No recordings will be made in which you are visible.

Your responses and results will be handled in a way that prevents unauthorized access. Lund University is responsible for your personal data. According to the EU General Data Protection Regulation (GDPR), you have the right to access your data free of charge and to request corrections if necessary. You may also request deletion of your data or restriction of its processing. To access your data, contact Silvia Arias (see contact details below). The data protection officer can be reached at dataskyddsombud@lu.se. If you are dissatisfied with how your personal data is handled, you have the right to file a complaint with the Swedish Authority for Privacy Protection.

Collected data will be used to produce scientific articles and reports.

7. How will I receive information about the results?

The results will be published on Lund University's website (http://lup.lub.lu.se/search/). We expect to publish the results in autumn 2026.

8. Insurance and compensation

During the experiment, you are covered by a personal injury insurance policy arranged by Lund University through the Swedish Legal, Financial and Administrative Services Agency. This is an accident insurance covering all aspects of the experiment. You will also receive a gift card that can be used at the café in the V-building, provided after the experiment.

9. Voluntary participation

Participation is entirely voluntary. You may withdraw at any time during the experiment. You may also withdraw your consent immediately after the experiment is completed. In such cases, your data will not be included in the study results. You may not be able to withdraw your consent later than the same day, as your name is not linked to the collected data and it will not be possible to identify your specific data.

10. Who is responsible for the experiment?

The experiment is conducted by researchers at the Department of Building and Environmental Technology, Division of Fire Safety Engineering, Lund University. The responsible researcher is Silvia Arias. You can contact Silvia by phone at +46 46 222 73 66 or by email at silvia.arias@brand.lth.se. You are welcome to contact her if you have any questions about the experiment.

Best regards,

Silvia Arias
Postdoctoral researcher, Department of Building and Environmental Technology, Division of Fire Safety Engineering, Faculty of Engineering (LTH), Lund University
Phone: +46 46 222 73 66

This form is provided for your information. You will complete an identical form during the experiment. You do not need to bring this copy.

Informed Consent – Experiment on Perceived Realism in VR

I have read the above information about the experiment on perceived realism in Virtual Reality and in a real room environment. I have had the opportunity to ask questions and received satisfactory answers. I therefore understand what the experiment involves and hereby consent to participate in the study.

Responsible researcher: Silvia Arias, Fire Safety Engineering, Lund University
Date: 2026-XX-XX

_____ _____

Signatur Plats och datum

_____

Namnförtydligande

Appendix 6. Post experiment questionnaire

Presented below is the questionnaire each participant hade to fill out after the experiment.

VR experience

please assess your experience in VR

realism of the room

	1	2	3	4	5	6	7	
low	○	○	○	○	○	○	○	high

feelings of discomfort

	1	2	3	4	5	6	7	
low	○	○	○	○	○	○	○	high

Background information

How familiar are you with the corridor you saw?

	1	2	3	4	5	6	7	
not at all	○	○	○	○	○	○	○	very

Age *

Välj

Gender *

- ○ female
- ○ male
- ○ non-binary
- ○ prefer not to say
- ○ Övrigt: _____

What's your occupation? *

- ○ work
- ○ study
- ○ Övrigt: _____

Study

What do you study? *

Ditt svar