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Did You See the Waving Police Officer?
The Influence of Stimulus Depth on Inattentional Blindness in Immersive Virtual Reality

Name:	Annefie Wietske Tuinstra
Student ID:	s3234185
Date:	13/07/2026
1st supervisor:	Dr. Maarten H. Lamers
2nd supervisor:	Prof. Dr. Ineke van der Ham
3rd supervisor:	Edwin van der Heide, MA

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Leiden Institute of Advanced Computer Science
Leiden University
Einsteinweg 55
2333 CC Leiden
The Netherlands

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Annefie Tuinstra

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Abstract

Inattentional blindness (IB) refers to the failure to notice an unexpected stimulus when attention is directed toward another task. This study investigated whether the stimulus depth of an unexpected visual stimulus within the foveal field influences the occurrence of inattentional blindness in an immersive virtual reality (VR) environment. Twenty-one participants played a rhythm game in VR while an unexpected waving police officer appeared at one of three distances. Although descriptive differences were observed between the conditions, statistical analyses found no significant association between stimulus depth and the occurrence of inattentional blindness. The highest proportion of missed stimuli occurred in the farthest condition, where 3 of 7 participants (43%) failed to notice the police officer. In the closest condition, only one participant missed the stimulus, but participants in this condition were most often unable to accurately recall or describe its appearance. The stimulus in the middle condition was noticed by all participants. In addition to varying the distance from the participant, the stimulus was also positioned differently relative to the primary task across conditions. Together with these findings, it suggests that depth alone may not be a decisive factor in determining whether an unexpected stimulus is consciously noticed in immersive VR, but also the placement of the stimulus relative to the primary task may play a role. Further research with larger and more diverse participant samples is needed to clarify the influence of depth perception on inattentional blindness.

Keywords: *Inattentional Blindness, Virtual Reality, Depth*

Contents

"The single most important lesson is that there seems to be no conscious perception without attention."

A. Mack & I. Rock

Inattentional Blindness (1998)

I INTRODUCTION

During my work at a virtual reality (VR) arcade, I am continuously exposed to a wide range of user behaviors in immersive environments, which ultimately inspired this research. When using head-mounted displays (HMDs) connected via cable, players are guided by boundary and cable-management systems designed to prevent excessive twisting or stepping outside the designated play area. What stands out, however, is how often people seem to miss important information, even when it is presented directly in front of them. Players can become so absorbed in the virtual experience that they fail to notice on-screen messages or even respond to my voice. Observing this repeatedly raised an intriguing question: how is it possible that such seemingly obvious stimuli go unnoticed? Rather than simply being distracted, it appears as though attention becomes so narrowly focused that other information is effectively filtered out. This led me to question whether people are truly "blind" to these stimuli, or if the immersive nature of VR might even contribute to a form of perceptual blindness.

This phenomenon of missing clearly visible signals in front of you while attention is directed elsewhere is known as inattentional blindness (IB) and has been widely studied over the past decades. IB can be described as the failure to perceive a highly visible and unexpected object when attention is directed toward another task, even when the object appears at fixation (Mack and Rock, 1998). In other words, people can look directly at something without consciously seeing it.

One of the most well-known demonstrations of this effect is the "gorilla experiment" by Simons and Chabris (1999). In this study, participants were asked to count the number of ball passes between players in a video. During the task, a person in a gorilla suit walked through the scene and thumped its chest. Remarkably, many participants failed to notice the gorilla at all.

Although this result may seem surprising, it highlights a key mechanism underlying IB: when attention is strongly focused on a specific task, unexpected stimuli are often filtered out.

Importantly, IB does not just happen in the corner of our vision, but also within our area of attention. Research by Mack and Rock (1998), as well as in Simons and Chabris (1999) showed that the missed stimulus can appear in the *fovea* (the central area of the visual field where acuity is the highest) and still go unnoticed. This demonstrates that directing one's gaze at a location does not guarantee conscious perception of everything presented there.

Moreover, the likelihood of IB is closely related to attentional demands. A high perceptual load increases the probability that unexpected stimuli will be missed (Cartwright-Finch and Lavie, 2007). Similarly, findings from the gorilla experiment indicate that as the primary task becomes more demanding, the occurrence of IB increases (Simons and Chabris, 1999). Together, these findings suggest that IB is strongly influenced by how attentional resources are allocated and how cognitively demanding the primary task is.

Over the years, numerous studies have investigated factors that may influence the occurrence of IB. One such factor is stimulus salience, which refers to the extent to which an object stands out from its surroundings and attracts attention due to its visual or perceptual properties. For example, Mack (2003) systematically examined how stimulus salience affects the likelihood of noticing an unexpected stimulus by manipulating properties such as size, shape, and color of the unexpected object. While such studies have provided valuable insights, they largely overlook another potentially important factor: the perceived depth of the unexpected stimulus. In other words, it remains unclear whether the depth at which an unexpected object is presented affects the likelihood of it being noticed. Although some real-world replications of the gorilla experiment suggest that proximity may play a role, the evidence remains inconclusive. This highlights the need for further investigation, which the present study aims to address. Understanding how the spatial location of unexpected events influences attention has important implications for the design of safety systems. For example, in domains like aviation, simulator cockpit training could benefit from insights on how pilots allocate attention to unexpected events at different depths while using head-up displays. A well-known study by Fischer and Haines (1980) demonstrated that the use of head-up displays could induce IB when pilots mistakingly attended to the display instead of the environment in front of them. Determining whether the perceived depth of visual stimuli affects the likelihood of noticing them could provide information on how to design interfaces to minimize the effects of IB.

Investigating depth as a factor in IB presents a methodological challenge. In traditional experimental setups, depth is often difficult to manipulate in a controlled and perceptually meaningful way. VR, however, offers a promising solution. By providing immersive, three-dimensional environments, it allows for precise control over the spatial positioning of stimuli while maintaining a high degree of perceptual realism. This makes it particularly suitable for studying how depth influences attention and awareness.

At the same time, VR is not merely a neutral tool. There is some evidence that immersive environments impose a higher cognitive load compared to non-immersive settings, which may in turn affect attentional processes (Cartwright-Finch and Lavie, 2007). This raises the possibility that IB may manifest differently in VR contexts. However, existing research on IB in VR remains limited and does not yet provide a clear understanding of how attentional mechanisms operate in such environments, nor how spatial factors such as depth influence noticing rates.

Given the increasing use of VR in both research and applied settings, understanding how IB operates in immersive environments is of both theoretical and practical importance. This study investigates whether the perceived proximity of an unexpected stimulus influences the occurrence of IB and the subsequent recall of that stimulus. Through a series of virtual reality experiments that investigate the effects of the distance of an unexpected stimulus using a VR-game, this study aims to further our understanding of IB in immersive environments.

This thesis begins by reviewing the theoretical background of IB, with particular attention to the factors that influence its occurrence. It also examines the theoretical foundations of virtual and augmented reality, identifying areas that remain underexplored and thereby motivating the present research. The methodology and experimental design are then described, followed by the presentation of the results. Finally, the findings are discussed in relation to previous research, their implications are considered, and the thesis concludes with the study's main conclusions and limitations.

II BACKGROUND

II.A Inattentional Blindness

Many people might intuitively assume that opening their eyes allows them to perceive everything in their surroundings. Vision is often experienced as rich and complete, creating the impression that little escapes our awareness. In fact, a survey conducted back in 2011 indicates that people tend to overestimate their perceptual abilities: approximately 75% of respondents believed they would notice unexpected events even when their attention was focused elsewhere. (Simons and Chabris, 2011)

Prior to the the term *inattentional blindness*, research had already emphasized the important role of attention in visual perception. A central contribution was made by Treisman (1985) through their *Feature Integration Theory*, in which they proposed a two-stage model of visual processing. In the initial, preattentive stage, basic visual features such as color, orientation, size, and motion are processed rapidly and in parallel across the visual field. These features are registered automatically but are not yet integrated into unified object representations. In the subsequent stage, focused attention is required to integrate these different features into coherent perceptual objects. According to this theory, attention is not just a selective filter but a necessary mechanism for object perception.

While certain grouping principles like proximity, shape or colour appear to operate preattentively, accumulating evidence suggests that conscious awareness of everything around us depends critically on attentional allocation. Therefore, even if there is evidence that we are able to unconsciously see more than we think, there is still a disparity between the richness of our experience and the actual details of our surroundings.

Early investigation into the evidence of attentional allocation can be traced to Neisser (1979). In a series of experiments, participants viewed a video of two teams passing basketballs and were instructed to attend to one team. During the task, an unexpected individual carrying an umbrella walked through the scene. A substantial number of participants failed to report noticing this event. (Neisser, 1979) described this phenomenon as *selective looking*, demonstrating that attention directed toward a specific task can render other salient stimuli effectively invisible, even when they fall within the observer's field of view.

Building on such findings, Mack and Rock (1998) developed a systematic paradigm to study this phenomenon and introduced the term *inattentional blindness*. Their experimental design ensured that participants were not expecting the critical stimulus and were not actively searching for it, while their attention was captured in another task. Observers fixated on a cross and judged which arm was longer. After several trials, an unexpected stimulus appeared in the same spatial location. Participants were then asked whether they had noticed anything odd. These many experiments aimed to systematically determine the conditions under which IB occurs and to identify which properties of salient stimuli influence whether they are consciously noticed.

These results show that simply looking at a stimulus does not guarantee that it will be consciously perceived. The findings were striking: IB occurred even when the unexpected stimulus appeared at fixation, where visual detail is typically processed most clearly. This highlights that attention, rather than eye position alone, determines what reaches awareness.

Findings of their study are reminiscent with a similar field of research falling in the category *change blindness*, which is the inability to detect changes in a scene, particularly if they are not the center of interest in the scene (Simons and Levin, 1997) (Rensink et al., 1997). Similarly, it shows that attention is necessary to consciously perceive change.

A widely known demonstration of IB is the "gorilla experiment," in which participants watch a video of two teams passing basketballs and are instructed to count the number of passes made by one team. During the task, a person in a gorilla suit walks through the scene (Simons and Chabris, 1999). These researchers used a variation of the selective-looking paradigm by Neisser (1979), in which participants focused on a primary visual task while unexpected stimuli were presented. The findings of this study reinforced several key principles of IB. First, the likelihood of IB increases with task difficulty: higher perceptual load leads to a higher probability of missing unexpected stimuli. Second, unexpected objects are more likely to be noticed if they share visual features with the attended task. Third, even when an unexpected stimulus passes directly through the spatial focus of attention, it can remain unseen if it is not relevant to the task at hand (Simons and Chabris, 1999).

A key factor for IB is the capture of attention towards a certain task (Mack and Rock, 1998)(Simons and Chabris, 1999)(Mack, 2003). A higher perceptual load is also associated with a higher occurrence of IB (Cartwright-Finch and Lavie, 2007) (Murphy, 2015), which is also reflected from the results of Simons and Chabris (1999), where the increased difficulty of the task increased the chances of missing the gorilla.

Overall, research on IB demonstrates a fundamental distinction between looking and seeing. Visual information may reach the eyes and even be processed at early stages of perception, yet without attention it may never become consciously experienced. This section therefore highlights the crucial role of attention in shaping what we perceive in complex visual environments.

II.A.i Salience

But what determines whether a specific unexpected stimulus captures attention? The likelihood that an unexpected stimulus is noticed during a task depends partially on its perceptual salience. In IB research, salience refers to the extent to which a stimulus stands out from its surroundings and attracts attention. Mack and Rock (1998) suggest that certain stimulus features increase salience, thereby enhancing the probability that a critical stimulus breaks through attentional filters. Their findings indicate that not all unexpected stimuli are equal, but specific characteristics make

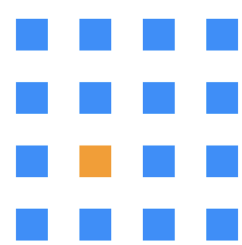


Figure I: The pop-out effect.

some stimuli more captivating.

A big factor that can influence noticing rates is perceptual distinctiveness, often described in terms of "pop-out" effects. According to research on visual search, Treisman (1985) introduce a *Feature Integration Theory* in which certain features such as color, orientation, or motion, can make stimuli stand out from their surroundings and attract attention preattentively. A good example is in Figure I in which one of the objects is distinct in color.

In principle, such perceptual salience could reduce the likelihood of IB by making unexpected stimuli more noticeable. In fact, the idea of choosing a person in a gorilla suit for the experiment by Simons and Chabris (1999) was precisely because this was an unexpected and distinctive stimulus. However, the gorilla study also demonstrated that even if an unexpected stimuli stands out and is salient, it can still go unnoticed. Therefore, making the stimulus distinctive does not guarantee that it will be noticed. However, visual similarity between the unexpected stimulus and the attended objects can also influence noticing, though the direction of this effect is not entirely straightforward. In some cases, sharing visual features with the attended objects may actually increase the likelihood that the stimulus is noticed. This pattern is discussed in variations of the gorilla experiment: when participants were instructed to attend to the team wearing black shirts, the gorilla (also black) was noticed more frequently than when attention was directed toward the white-shirted team. One possible explanation is that stimuli sharing features with the attended set receive partial processing through feature-based attention (Treisman, 1985), but the precise reason for this effect is unclear.

Additionally, there are characteristics of stimuli that do more reliably break through the effect of IB. For example:

- Personal relevance (e.g., one's own name) Participants are more likely to notice their own name compared to other names. However, even slight alterations (e.g., misspellings) substantially reduce detection rates. While this effect may be linked to familiarity or self-relevance, the precise mechanism remains inconclusive.

- Emotional valence (e.g., happy faces) Positive emotional stimuli, such as a happy face or smiley, are more likely to be noticed than neutral or negatively valenced stimuli (e.g., sad faces). This suggests that affective salience can influence perceptual awareness.

- Visual contrast (and opacity) In a modified version of the experiment, the players were made semi-transparent. Under these conditions, IB decreased. This finding suggests that visual properties such as color contrast and opacity contribute significantly to perceptual salience.

In various trials tested by Mack and Rock (1998), a substantial amount of different properties for the unexpected stimuli were tested, for example color, size and shape. From these tests, it arose that one important factor is the spatial relationship between the stimulus and the observer's focus of attention. Mack and Rock (1998) report that IB occurs more frequently when unexpected stimuli appear further away from the current zone of attention. When attention is concentrated on a specific location or object, stimuli outside this attentional focus are less likely to be noticed, even if they are clearly visible.

However, despite many experiments that try to weigh in many different characteristics of salience, research on it in IB has largely been limited to two-dimensional stimulus properties and screen-based paradigms. Stimuli are typically defined in terms of their visual features on a flat display, while their spatial characteristics are reduced to "x-y positions" within the visual field. As a result, an important aspect of real-world perception remains underexplored: how stimuli are experienced in three-dimensional space.

II.A.ii IB in Real-World Examples

Several studies have attempted to replicate IB effects in real-world settings, providing valuable insights into how the phenomenon manifests outside the laboratory. One well-known example is the study by Hyman Jr et al. (2010), in which participants walked through a city environment while using their mobile phones. During this task, a person dressed as a unicycling clown passed by in close proximity. Despite the unusual and highly visible nature of the stimulus, a substantial number of participants failed to notice it. Notably, participants were unaware that they were part of an experiment, which increased the ecological validity of the findings and ensured that attentional behavior closely resembled real-world conditions.

In another set of trials, Mack and Rock (1998) examined the role of stimulus size, with the unexpected stimulus presented in different physical sizes and at varying distances from the screen. The results indicated that detection was influenced not simply by the object's absolute size, but by its retinal size, or visual angle between the eye of the observer and the object. Stimuli that had a larger visual angle (appearing effectively larger to the observer) were more likely to be noticed, whereas those presented further away produced a smaller visual angle and were more often missed.

This early attempt to connect depth to IB is one of the few experiments that tries to weigh this in as a factor, though no real conclusive evidence points to retinal size being the critical factor of whether an unexpected object is noticed or not.

In particular, while factors such as retinal size and spatial position have been considered, the role of perceived proximity (the distance between the observer and a stimulus as experienced in depth) has not been systematically investigated. This raises the question of whether objects that appear closer to an observer are more likely to capture attention than those presented further away. Addressing this question requires moving beyond traditional 2D paradigms toward environments in which spatial relationships can be manipulated easily.

A similar approach was taken by Chabris et al. (2011), where participants were instructed to jog along a predefined route while performing a cognitively demanding task. Along the route, a physical fight was staged, in which the actors were also making sound. Nevertheless, only a small proportion of participants reported noticing the fight. This finding further shows that even dynamic and multisensory events can go unnoticed when attentional resources are occupied.

In a different context, Furley et al. (2010) examined IB in a sports setting, where participants were required to monitor gameplay and identify unguarded players. Despite the task's relevance to the environment, participants frequently failed to detect critical events occurring within the scene, even if the players in this experiment were experienced.

Importantly, while these studies highlight the robustness of IB, they do not explicitly investigate the role of perceived depth, or the placement of the unexpected stimulus in a 3D space. In many cases, unexpected stimuli occurred relatively close to participants and were clearly visible, yet were still missed. This suggests that depth alone may not be sufficient to guarantee noticing. At the same time, because the spatial placement of stimuli in these studies was not systematically manipulated or controlled, it remains unclear how depth influences detection. For example, in most of these studies, the unexpected object was placed *behind* the task given to the participants. Therefore, it is unknown whether the likelihood of noticing would change if, for example, the same stimulus were presented right in front of the observer.

Moreover, the variability in findings across these real-world studies may partially stem from differences in task demands, environmental complexity, and stimulus placement. While some studies show that higher cognitive load increases the likelihood of IB, the influence of spatial factors such as distance is difficult to isolate in uncontrolled environments. As a result, although these studies suggest that IB can occur even for nearby and salient events, they do not provide a clear understanding of how proximity interacts with attention. This question points to the need for controlled experimental approaches that can isolate proximity as a variable while maintaining a realistic sense of spatial experience.

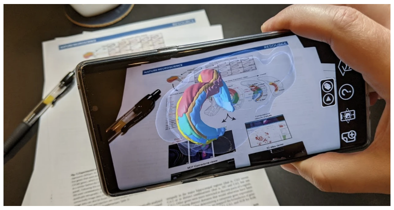
II.B Real-life Applications of VR and AR

VR, but also augmented reality (AR) are becoming increasingly demanded into a wide range of domains, including gaming, education, training, and healthcare. Among these technologies, VR has attracted particular attention due to its ability to create immersive, interactive environments that can simulate real-world experiences, as shown in Figure IIc. This is because VR is able to give the user an illusion of the sense of place and realism (Slater, 2009). These capabilities have led to a growing number of applications, ranging from skill training and therapeutic interventions to educational tools and entertainment (Hamad and Jia, 2022) (Basu, 2019). Moreover, VR can provide easy research replication (Maymon et al., 2023), making it a good tool for cognitive research.

In addition to these applications, VR is increasingly being adopted within the field of psychology. In this context, it serves not only as an experimental research tool but also as a clinical instrument for the assessment and treatment of mental health disorders (Freeman et al., 2017).

Unlike VR, in which users are immersed in a fully virtual environment, AR enhances the existing real-world environment by overlaying digital elements, as seen in Figure IIa. A good example of a relevant real-life application of AR is a head-up display (HUD), a device that presents task-relevant information on a transparent display, allowing users to view digital information while maintaining their view of the surrounding environment, like in Figure IIb. These devices are increasingly being adopted into domains like commercial vehicles or aviation, where they are intended to reduce the need to look away from the primary task. As a result, this technology has been studied extensively over the past several decades.

A classic example is the NASA study by Fischer and Haines (1980), in which pilots using a HUD during a simulated landing failed to notice an aircraft blocking the runway because their attention was captured by on-screen information. In this study, and in a similar study by Haines (1991), the effects of superimposed objects, and to some extent depth were examined. This was studied primarily in the context of commercial airplane cockpit design. The results of these studies were quite dramatic, and revealed that unexpected stimuli presented on a different visual "layer" were



(a) A screen using AR to display information, enhancing the environment. adapted from Ard et al. (2022)

(b) HUD in a cockpit, displaying information over the environment. Derived from McClellan (2021)
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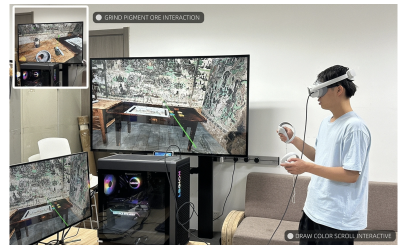

(c) A person using a VR headset to enter a simulated environment. Derived from Liu et al. (2024).

Figure II: Examples of how both AR and VR immerse the user with digital elements.

often easily overlooked, highlighting how layered or depth-related information can influence IB. More recent work by Wang et al. (2022) also found that HUDs could induce IB in cars, especially when there was no assistance with highlighting possible threats on screen. These findings suggest that immersive displays may inadvertently reduce users' awareness of unexpected but safety-critical events. As VR and AR are increasingly adopted in safety-critical applications, understanding the factors that influence inattentional blindness in immersive environments becomes essential for designing interfaces that support, rather than hinder, users' situational awareness, especially in the foveal field where unexpected stimuli might appear.

Given the increasing adoption of VR in various applications, as well as in research, understanding human perception within these environments has become increasingly important. It is therefore essential to establish whether cognitive phenomena like IB occur similarly in immersive virtual environment,. This can provide valuable insights for designing safer and more effective VR and AR applications.

Additionally, the immersive and three-dimensional nature of VR provides an interesting and perhaps new context for studying IB, as the introduction of depth adds a perceptual dimension that can possibly be compared to real-world settings.

II.C Current Research About IB and VR

Research on IB in VR is currenly relatively limited. Schöne et al. (2021) attempted to recreate the gorilla paradigm in a 3D, 360-degree VR environment. The results of this study are interesting as the noticing rate does go up, making the results similar to other studies that try to research

IB in real life (Chabris et al., 2011) (Hyman Jr et al., 2010) (Furley et al., 2010). However, this study does not examine in detail why the noticing rate increased or why the gorilla appeared to be more salient in the VR condition. The authors suggest that the perceived three-dimensional nature of VR may play a role, but other factors could also account for the effect, such as the perceived proximity of the unexpected object or simply the physical size of the gorilla. However, this possible reason is not consistent with other real-life examples of the gorilla paradigm in which IB also occurs often under similar conditions.

Moreover, in this study, both monoscopic and stereoscopic versions of the video were tested in VR. This way of testing shows that depth was initially considered in this study, but this hypothesis was however quickly dismissed due to similarity in the results between monoscopic and stereoscopic testing. As a result, the potential influence of depth is not systematically examined, despite the authors' suggestion that proximity and the three-dimensional nature of VR could affect noticing rates. This makes the interpretation of their findings unclear. This also raises the question of whether depth itself plays a meaningful role in the occurrence of IB in VR environments.

Another relevant experiment that attempts to research IB in VR is by Hirschhorn et al. (2024) who developed a more interactive VR task in which participants rode a virtual bus while tracking moving objects. During the virtual bus ride, repeated images appeared on bus stops directly in front of them. The gaze of the participants was followed through eye Although participants often looked directly at these images, they frequently failed to report conscious awareness of them. This study is one of the few that does test to introduce depth in the experiment, because the 'salient' object is placed directly behind the task they are attending to. However, this study did not clearly differentiate between genuine perceptual failures, task-based filtering, and inattentional amnesia. The design choices embedding the "salient" object in the environment, adding background music, and implementing a complex, gamified task introduce multiple variables that complicate the interpretation of the results. The combination of these factors suggests that the task may have been excessively difficult, and the extent to which the findings reflect genuine IB rather than other cognitive or perceptual influences remains inconclusive.

Both of these studies highlight that the location in the depth of the immersive environment, as well as the type of stimulus, might still be understudied and need a systematic study to accurately assess what the impact this can have on the occurrence of IB.

II.C.i Virtual Reality and Real-World Differences

Although VR offers a highly immersive experience that can be valuable for academic research, it also introduces characteristics that may influence users' cognitive processes and behavior. Research indicates that immersive VR environments often impose a higher cognitive load than non-immersive or traditional 2D conditions (Grant Frederiksen et al., 2020). In VR, users are not only required to process the primary task or learning content, but must also navigate a three-dimensional environment, interpret spatial cues, and manage interaction mechanics. These additional demands can place strain on attentional and working memory resources. As a result, learning in highly immersive contexts does not always lead to better outcomes. In some cases, it may even reduce transfer to real-world situations, as knowledge becomes tightly based to the specific context in which it was acquired Juliano et al. (2022). This suggests that the immersive qualities of VR, while beneficial for engagement, can also introduce cognitive constraints that influence how information is processed and retained. However, these effects are not inherent to VR itself, but are strongly dependent on design choices. For example, clear attentional guidance and well-structured environments can help manage cognitive load and direct users toward relevant information (Albus et al., 2021). When designed carefully, VR can support experiential learning without overwhelming the user's cognitive resources, balancing immersion with usability. If VR environments indeed impose higher cognitive demands, this may also influence the likelihood or nature of IB compared to real-world settings. Consequently, it is important to consider how the design of VR environments (and the way stimuli are presented within them) may impact noticing rates and the occurrence of IB.

III RESEARCH QUESTION

Following the background presented in the previous section, this study builds upon the existing literature by investigating whether the depth of an unexpected stimulus influences the occurence of IB. Accordingly, the following research questions are posed:

Main research question

How does the depth of an unexpected visual stimulus affect the occurence of inattentional blindness within the foveal field in an immersive virtual reality environment?

Hypotheses:

1. The depth of an unexpected stimulus in a virtual reality environment influences the occurrence of inattentional blindness.

2. Inattentional blindness occurs less when an unexpected stimulus is presented closer to the observer than when it is presented at greater depths.

IV EXPERIMENTAL DESIGN

The approach for testing the hypothesis of this research will be similar to the original experiment by Simons and Chabris (1999), in which a participant will be tasked and subsequently exposed to an unexpected figure walking through the scene. Afterwards, the participants will be questioned in a similar fashion to assess whether they have perceived the unexpected stimulus.

For the experiment, a short game was created within a 3D environment in Unity Technologies (2023). The game that the participants must play is a rhythm-type music game. In this game, the unexpected object will be placed at three relatively different distances from the player's point of view. The goal is to test whether participants see the unexpected stimulus at different layers in perceived depth, and if there is any difference in perception between these stimuli.

IV.A Task and Environment Design

The experimental task was designed as a custom virtual reality rhythm game inspired by popular commercial rhythm-based games. Participants were required to monitor four floating cubes positioned in front of them and respond to incoming stimuli in the form of fruit objects that slowly move downward, towards the cubes. An example of such a fruit object is shown in Figure IIIb. The player could score points by pressing the corresponding button when a fruit object aligned with one of four reference cubes. In addition, bombs were presented between the fruit intermittently and were to be avoided, requiring participants to continuously discriminate between target and non-target stimuli. When the player plays the game well by hitting the objects with correct timing, points are awarded and also shown on a scoreboard, meant as a way of motivating the players. Furthermore, music was added to increase engagement and immersion in the task. The incoming objects were synchronized with the beat of the music, allowing participants to use the rhythm as a cue for timing their responses. Following the rhythm can make it easier to anticipate when objects should be hit, helping participants maintain their focus on the game throughout the experiment. A rhythm game was selected because it imposes a sustained cognitive demand throughout the duration of the experiment, much like the experiment with the gorilla from Simons and Chabris (1999) and its many variants of this paradigm. Successful performance requires participants to continuously monitor multiple spatial locations, accurately time their responses, and distinguish between the fruits and bombs. This combination of perceptual monitoring, decision-making, and motor coordination creates a relatively high cognitive load.

(a) The environment design, featuring the table with buttons and the floating cubes.

(b) An example of a fruit object aligned with one of the cubes, allowing the participant to press the button.

Figure III: The design of the environment and elements used in the game.

A second consideration in the task design was the control of participants' visual attention. To perform the task effectively, participants must continuously look at and around the four reference cubes where incoming fruits approach, while occasionally shifting their gaze to the buttons in front of them. Because of this, visual attention remains concentrated within a relatively constrained area directly in front of the participant, as well as in multiple layers in depth. This creates a predictable viewing region in which the unexpected stimulus can be presented, and the certainty that the participant's gaze is in these regions.

Maintaining a constrained and predictable gaze direction is advantageous, because it reduces the possibility that failures to detect the unexpected stimulus can be attributed to participants simply not looking in the relevant direction. By placing the unexpected stimulus within the viewing area of the participant, any failure to notice it is more likely due to limitations of attention rather than the participant's failure to look in the correct direction. This design therefore increases the internal validity of the experiment and allows inattentional blindness to be investigated under controlled viewing conditions, without the need of eye-tracking software.

Additionally, the environment in which the game is performed is a simple landscape containing buildings, vegetation, and other decorative elements, which is shown in Figure IIIa. Moreover, animations, movement, and other details were added to add realism to the scene and feedback to the game. The choice to have a filled environment was made to replicate a realistic environment, instead of a white, sterile environment in which only the task and the stimulus would be seen. By creating the game within a richer environment, the experiment provides a more ecologically valid setting while maintaining control over the task and stimulus presentation.

IV.B The Unexpected Stimulus

The unexpected stimulus used in this experiment was a three-dimensional model of a female police officer, as shown in Figure IVa. This stimulus was selected because it is visually salient and easily distinguishable from the other objects present in the environment. At the same time, it is entirely unrelated to the rhythm-game task and does not fit naturally within the experimental setting, making its appearance genuinely unexpected for participants. This reduces the likelihood that the stimulus would be anticipated based on the context of the task. Additionally, the selected model was fully rigged and readily available through the *Asset Store*, a native website from Unity Technologies (2023) with ready-to-use models and assets, allowing it to be integrated into the virtual environment easily.

The unexpected stimulus can be placed in 3 different positions in the depth relative to the participant. The positions can be seen in Figure IVb, in which the positions are numbered. The nearest position is right in front of the camera, marked with number 1. The middle position is between the task and the participant's button table, marked with number 2. This police officer appears in front of the cubes, without blocking the view. Finally, the furthest position is behind the task.

(a) The female police officer used as unexpected stimulus.

(b) The locations where the police officer is placed in the virtual space, and the position of the camera.

(c) The police officer scaled in size by distance.

.

Figure IV: The police officer as unexpected stimulus and how it is shown in the environment.

Moreover, in order to eliminate size as a factor of IB, the 3D model of the police officer is scaled, in order to maintain the same relative size in the view of the participant. Mack and Rock (1998) mention retinal size as a factor in IB, so by scaling the police model bigger with distance, it occludes the same area in the view of the participant. The different sizes can be seen in Figure IVc. When the participant enters the virtual environment, the police officers will appear the same size from the participant's point of view.

IV.C Pre-screening and Selection of Participants

Participants aged 18 years and older were eligible to participate in the study. No upper age limit was imposed, allowing a mixed group of participants while ensuring that every person was able to provide informed consent. Participation was completely anonymous. Before participating, all individuals completed a short screening questionnaire to identify factors that could influence performance on the experimental task. First, participants were asked about their prior experience with video games and virtual reality. Previous exposure to rhythm games, VR applications, or gaming in general can reduce the cognitive demands of the task, as experienced participants are likely to perform the game more efficiently. Since inattentional blindness is strongly associated with cognitive load, differences in gaming or VR experience could affect the occurrence of IB. Measuring these variables allows their potential influence to be considered during data analysis later.

Participants were also screened for visual impairments, including colour vision deficiencies and other eye conditions that could interfere with the perception of the virtual environment. Participants who normally wear prescription glasses or contact lenses were asked whether they would use them during the experiment.

Finally, stereoscopic vision was assessed because the experiment was conducted in an immersive three-dimensional virtual environment, with depth as a factor. Participants with impaired stereoscopic vision may perceive depth differently, which could influence their ability to detect stimuli presented at different distances. Screening for stereoscopic vision therefore helps ensure that participants perceive the virtual environment as intended and reduces the risk that differences in depth perception confound the experimental results.

The screening for stereoscopic vision was done using a simple assessment [1]. Participants hold up a finger in front of a green dot displayed on the screen, and have to shift focus with their eyes on the dot or finger, and alternate between closing one of both eyes. Even though a short assessment

[1] MediaCollege.com (n.d.)

like this can give an indication of people's stereoscopic vision abilities, it is not an objective test. However, assessing whether potentially many participants have reduced stereoscopic vision might be useful for data analysis.

IV.D Process of Testing

Before the experiment begins, the participants had to sign a consent form, and were provided an information sheet about the experiment. (see Appendix B and C). For the experiment to have a good effect, the participants should be completely surprised. Therefore, the consent form and information sheet will not disclose the fact that the topic is about inattentional blindness.

Participants first completed the pre-screening questionnaire before beginning the VR experiment. After the screening, they received a brief explanation of the task, supported by an illustration showing the game mechanics (see Appendix A1). The VR headset was then fitted, and the participant was given time to become comfortable in the VR environment before the experiment started. Next, the desired distance condition for the police officer was selected in the game editor, after which the game was started.

The rhythm game lasted approximately two minutes. Around one and a half minutes into the game, the unexpected stimulus appeared. The stimulus is the female police officer who walks into the participant's field of view from the left side, turns towards the participant, waves, and then walks off towards the right. This sequence lasts approximately five seconds. During this period, the participant was observed for any immediate behavioural response indicating that the stimulus had been noticed.

After the game ended, the VR headset was removed and the participant completed a short interview. To test whether the unexpected stimulus had been consciously perceived, participants were asked the same questions used by Simons and Chabris (1999): (i) *While you were doing the game, did you notice anything unusual on the video?* (ii) *Did you notice anything other than the fruit falling down?* and (iii) *Did you see anything else appear on the video?* If, at any point during the interview, the participant indicated that they had noticed the police officer or another unexpected object, they were asked to describe what they had seen. A verbal report during the game, or during the interview is enough to assess whether they have seen it or not. Additionally, in the experiment by Simons and Chabris (1999), an additional question is asked in the post-experiment interview: *"Did you see a gorilla walk across the screen?"* This kind of question was omitted on purpose, in order to allow another round of testing without revealing the unexpected stimulus. If the participant in this experiment did not report noticing the police officer, the experiment was repeated with the police officer presented at a different distance. This procedure continued until either the participant detected the police officer, or all experimental distance conditions had been completed.

Finally, the participant is given a de-briefing form, that explains the true purpose of the experiment and asks for the inclusion of data (see Appendix D).

In addition, the participant's playthrough was recorded using screen-recording software. These recordings were reviewed for visible head movements or behavioural responses towards the police officer, providing supplementary information alongside any verbal responses that were worth noting.

V RESULTS

The primary analyses presented in this chapter are based on participants' first playthrough of the experiment. Since IB is defined by the failure to notice an unexpected stimulus during an initial encounter, only first-playthrough observations were included in the main statistical analyses. Data from subsequent playthroughs are reported separately as exploratory results, as participants were no longer unaware of the experimental context.

V.A Participant Overview

Table I provides an overview of the participant characteristics. A total of 22 participants were recruited for the study, and only one participant was excluded due to having prior knowledge of the experiment. This results in a final sample of N = 21. Participants ranged in age from 22 to 65 years (M = 35.5, SD = 15.1). The gender distribution was relatively balanced, comprising 10 men (48%) and 11 women (52%). Participants reported a broad range of gaming experience, but 33% reported not playing video games at all. Experience with VR also varied: half of the participants reported only limited or outdated VR experience, one-third had never used VR before, and a small proportion (14%) indicated that they used VR often.

Participants were screened for visual impairments prior to the experiment. Although one participant showed difficulty on the stereoscopic vision test, this participant did not have trouble seeing the

Table I: Participant characteristics (N = 21).

Characteristic	Value
Participants recruited	22
Excluded participants	1
Final sample size	21
Age (in years), Mean (SD)	35.5 (15.1)
Age range	22–65
Gender (Male/Female)	10 (48%) / 11 (52%)
Gaming experience (hours/week)	
0	7 (33.3%)
Between 0 and 1	3 (14.3%)
1–5	2 (9.5%)
6–10	7 (33.3%)
11–20	2 (9.5%)
VR experience	
Never	7 (33%)
Limited / Long ago	11 (52%)
Often	3 (14%)

police officer. Therefore, this data is included. Sixteen participants (66.7%) reported wearing corrective lenses, but all also chose to wear them during the experiment so they were not in any way impaired. No participants reported any other visual impairments. A full overview of the results can be found in Appendix A, Table A2.

V.B Results of Experiment and Statistics

Table II: The amount of participants who notice the police officer, for every distance condition.

Distance	Noticed	Missed	Noticing rate
Near	6	1	85.7%
Middle	7	0	100%
Far	4	3	57.1%

The results of all participants are presented in Appendix A1.

Table II presents the noticing rates for each distance condition. The highest noticing rate were observed in the middle condition (100%), followed by the near condition (85.7%) and the far condition (57.1%).

To determine whether the depth of the police officer influenced noticing rates, the following hypotheses were tested. The null hypothesis (H_0) stated that the proportion of participants who noticed the police officer was independent of its depth placement. The alternative hypothesis (H_1)

stated that the proportion of participants who noticed the police officer are dependent of its depth placement. These hypotheses were evaluated using the Fisher–Freeman–Halton exact test, using an online calculator (Soper, 2026).

For the statistical analysis, we take a contingency table of 2x3 rows and columns respectively, using the values in the 'Noticed' and 'Missed' columns. To examine whether notice outcome was associated with depth placement, a Pearson chi-square test of independence was initially considered, as it is the standard statistical test for assessing associations between categorical variables. However, several cells in the contingency table contained very small expected frequencies due to the low number of missed observations (5 and lower), violating the assumptions required for the chi-square approximation. Therefore, the Fisher–Freeman–Halton exact test, an extension of Fisher's exact test for larger contingency tables was used to test the association between viewing distance and noticing outcome. This exact test does not rely on large-sample assumptions and is therefore more appropriate for this dataset.

Using this test, the outcome was $p = 0.26 > \alpha = 0.05$. As the test did not yield a statistically significant result, the null hypothesis could not be rejected. This indicates that no statistically significant association was found between the depth at which the police officer was displayed and the notice outcome.

V.C Additional Data and Participant Reports

In the post-experiment interview, participants who reported noticing the police officer were also asked to describe her appearance. This was done to assess whether participants not only noticed the police officer but also recollected physical details about it. The participants had to at least be able to identify the police officer specifically as a *police officer* for them to have correctly recalled it. Comparing this recall data across the different presentation distances revealed notable differences. Of the six participants who noticed the police officer at the nearest distance, four were unable to accurately describe her appearance. At the middle distance, only one participant who noticed the police officer was unable to describe her appearance, while every participant with the furthest condition correctly recalled her appearance.

Table III suggests a possible relationship between the distance at which the police officer was noticed and participants' ability to accurately recall. To test this, a Fisher–Freeman–Halton exact test was performed. The null hypothesis (H_0) stated that recall accuracy is independent of the

Table III: Recall accuracy of the police officer's appearance among participants who noticed the unexpected stimulus.

Distance	Noticed	Correct recall	Incorrect recall
Near	6	2 (33.3%)	4 (66.7%)
Middle	7	6 (85.7%)	1 (14.3%)
Far	4	4 (100%)	0 (0%)

distance at which the police officer was placed, whereas the alternative hypothesis (H_1) stated that recall accuracy is associated with depth placement. The test yielded a non-significant result, p = 0.06 $>$ α = 0.05. Therefore, the null hypothesis could not be rejected, indicating that the present dataset provides insufficient evidence for an association between depth and recall accuracy.

VI DISCUSSION

The aim of this study was to investigate whether the placement of an unexpected stimulus in different depth layers influences the occurrence of IB during a cognitively demanding task. Although the observed noticing rates differed across the three police officer placements, the statistical analyses did not provide sufficient evidence that depth significantly influenced the occurence of IB. Nevertheless, an interesting pattern emerged in the descriptive data.

The strongest IB effect was observed when the police officer was placed at the furthest distance, where 3 out of 7 participants (43%) missed the unexpected stimulus. In contrast, only 1 out of 7 participants (14%) missed the police officer at the nearest distance, while all participants noticed the police officer at the middle distance. Although these differences were not statistically significant, they suggest a possible trend that may warrant further investigation with a larger sample.

Additionally, the data from the four participants who initially failed to notice the police officer provided limited insight. All four participants detected the police officer in subsequent testing rounds, and only one of them continued to recall the officer's appearance inaccurately. However, given the very small sample size (n = 4), these observations are insufficient to draw any meaningful conclusions or identify reliable patterns.

When comparing the data with existing IB studies, the observed miss rate for the farthest police officer (43%) is comparable to the 42-46% reported in the original gorilla experiment (Simons and Chabris, 1999). However, both the middle and nearest police officer produced substantially lower miss rates in this experiment. Other IB studies have reported different noticing rates depending on the experimental context. For example, the unicycling clown experiment found a miss rate of approximately 75% (Hyman Jr et al., 2010), whereas a stereoscopic VR replication of the gorilla experiment reported that around 30% of participants failed to notice the unexpected stimulus (Schöne et al., 2021). These findings suggest that, while the farthest condition in the present study produced levels of IB comparable to previous work, the closer conditions do not. Several factors may have contributed to these findings.

VI.A Salience

The nearest and middle police officer were noticed the most, by almost all participants. One possible explanation is that the police officer was simply too salient to be overlooked, due to several characteristics that may have increased its ability to attract attention. First, the police officer was almost entirely dressed in black, making it one of the darkest objects in the environment. As mentioned before, highly distinctive visual features can produce a pop-out effect, automatically attracting attention (Treisman, 1985). However, previous IB studies, including the gorilla study and similar experiments, demonstrate that even visually distinctive stimuli can remain unnoticed when they are unexpected. Therefore, while colour may have contributed to the visibility of the police officer, it is unlikely to fully explain the high noticing rates.

The size of the stimulus may also have played a role. Mack and Rock (1998) suggest that larger retinal angles may increase noticing rates. Because the police officer occupied a relatively large portion of the participant's visual field, its retinal angle may have been sufficiently large to increase its detectability. As a result, the stimulus may have covered a substantial portion of the foveal region, making it more difficult to ignore. However, Mack and Rock (1998) simply make an assumption, and do not provide real evidence supporting this theory. For this research, it is therefore not possible to draw a conclusion based on this theory.

In addition, the police officer may have held too much emotional valence. A police officer is generally associated with authority, vigilance, or potential danger, which could unconsciously increase attentional priority. Although this explanation is speculative, it is possible that the meaning of the stimulus contributed to its relatively high detection rate.

Finally, the police officer momentarily waved towards the participant. This animation may have attracted considerably more attention than intended. Several participants reported after the experiment that they found the waving police officer distracting. Furthermore, observations from the recorded gameplay showed that some participants shifted their attention towards the police officer during the waving sequence, causing them to miss fruit objects and temporarily perform worse on the primary task. This suggests that the movement of the unexpected stimulus may have drawn attention away from the game, reducing the occurrence of IB.

VI.B Depth and Relative Distance

Although no statistically significant association was found between depth and the occurrence of IB, a possible explanation is that it might actually be the placement of the unexpected stimulus and the primary task that contributed to these differences. The nearest police officer appeared in front of everything, including the task, the middle police officer was positioned right in the middle of the task, and the farthest police officer appeared behind it. Consequently, the experimental conditions varied not only in absolute distance but also in placement relative to the primary task. This could suggest that the distance between the participant and the unexpected stimulus may not be as significant, and the importance may lie in the distance between the unexpected stimulus and the primary task instead.

Although the game was intentionally designed to encourage participants to distribute their attention across multiple depth layers, it is possible that the relative placement of the unexpected stimulus influenced its salience independently of its physical distance from the participant. The nearest police officer may have attracted participants' attention because it appeared prominently in the foreground, making it more likely to be noticed. However, because it was not in the same depth layer as the primary task, participants may have processed it only briefly, resulting in a general awareness that something was present without having enough visual detail to accurately recall its appearance. In contrast, the middle police officer occupied the same depth layer as the primary task, where participants were likely directing most of their visual attention, which may explain why it was both noticed and recalled more accurately. Finally, the task did not require participants to direct their visual focus beyond the task itself, meaning that the police officer positioned behind it may have received little or no visual attention and was therefore more likely to be missed altogether.

VI.C Participant Pool

The characteristics of the participant pool may also have influenced the results. Most participants reported prior gaming experience, and a few had previous experience with VR. Interestingly, The four participants who did not notice the unexpected police officer shared several characteristics. All were at least 43 years old and reported no prior experience with VR or video games. Although not all participants in this age group missed the police officer, every participant who did miss it also belonged to this age category. The remaining participants aged 43 years or older either encountered the police officer at a different distance or had some prior gaming experience. Previous research has reported age-related differences in IB (Stothart et al., 2016), although the small number of missed observations, as well as the non-significant result from the statistical analysis prevents any meaningful conclusions regarding this relationship.

The gameplay recordings support this observation. Participants with limited gaming or VR experience appeared to devote most of their attention to controlling the game itself. They frequently looked down at their hands, struggled with hand-eye coordination, and had difficulty keeping up with the pace of the game. In contrast, experienced gamers generally performed the primary task with little difficulty and rarely needed to look at their controllers or hands. This suggests that experienced players may have had greater attentional capacity available to process unexpected events in the environment, increasing the occurrence of noticing the police officer. It would be valuable for future research to develop an experimental design in which the cognitive demand remains consistently high across all participants, for example by implementing a dynamic difficulty adjustment system that adapts the primary task to individual performance. This would help ensure that attentional load is more uniform between participants, reducing variability caused by differences in skill level and potentially providing a more accurate assessment of IB. Furthermore, the participant pool was relatively small, making it difficult to draw strong conclusions or generalize the findings. The combination of a limited sample size and a participant pool with relatively high gaming experience may therefore have influenced the observed noticing rates.

VI.D Other Factors

Another potential issue concerns participants' prior knowledge of IB. Several previous studies, including both the original gorilla experiment (Simons and Chabris, 1999) and its VR replication (Schöne et al., 2021), excluded participants who were already familiar with IB. In this research, this was not controlled for. After completing the experiment, many participants either mentioned the gorilla or unicycling clown experiment before the purpose of the study had been explained, or confirmed their prior knowledge of the phenomenon after being told what the study was about. Excluding all of these participants would have resulted in the removal of most of the collected data, making such an exclusion impractical. Nevertheless, prior knowledge may have increased participants' expectation of encountering an unexpected stimulus and therefore reduced the IB effect. An obvious way to address this issue would be to exclude participants with prior knowledge of IB. However, screening for such knowledge is challenging, as directly asking participants about the concept before the experiment could reveal the purpose of the study and thereby introduce bias into their responses.

Finally, the VR environment itself may have affected the results. Although VR offers a controlled and immersive setting for studying attention, relatively few studies have investigated IB in immersive virtual environments. Similarly, real-world IB studies that take place in the natural environment rather than being studied on 2D-based computer screens remain relatively scarce. As a result, it is currently unclear to what extent the use of VR, stereoscopic depth perception, or other characteristics of immersive environments influence IB. Future research should further investigate whether these factors systematically affect noticing rates.

VI.E Limitations

This study has several limitations that should be considered when interpreting the findings. First, the participant sample was relatively limited and included individuals with varying levels of prior experience with video games, virtual reality, and IB. Recruiting participants without any prior exposure to these factors proved challenging. Future studies could benefit from a larger and more homogeneous sample consisting of participants who have little or no experience with video games or virtual reality and who are unfamiliar with the concept of IB. Such a participant pool would reduce the influence of prior knowledge and experience and allow the effects of stimulus depth to be examined more independently.

Furthermore, the relatively small sample size may have limited the statistical power of the study, making it more difficult to detect subtle effects of stimulus depth on IB. Although no statistically significant relationship was found, a larger sample may provide greater sensitivity to identify effects that could not be detected in the present study.

A second limitation concerns the absence of eye-tracking data. Although eye tracking was originally intended to be incorporated into the experimental setup, technical difficulties prevented its use. As a result, it was not possible to determine precisely when participants first fixated on the unexpected stimulus, how long it was viewed, or whether participants briefly looked at the police officer without consciously processing its presence. Eye-tracking data would have provided valuable insight into participants' visual attention throughout the task and allowed for a more detailed analysis of their gaze behaviour during the police officer sequence.

Finally, the design of the unexpected stimulus was constrained by the limited availability of suitable three-dimensional character models. Because creating a custom animated character was beyond the scope of this project, the experiment relied on freely available assets. More choice in the appearance of the unexpected stimulus would have allowed for more systematic manipulation of stimulus properties, such as salience and realism, and could improve experimental control in future research. In addition, the experiment employed only a single type of unexpected stimulus, namely a police officer. As a result, it is unclear whether the observed findings would generalize to other unexpected stimuli that differ in appearance, movement, semantic meaning, or visual salience. Future research could investigate a wider range of unexpected stimuli to determine whether the influence of depth on IB is consistent across different stimulus types.

VII CONCLUSION

This study investigated whether the depth of an unexpected stimulus influences the occurrence of IB in a virtual reality environment. Although IB was observed, the results did not provide statistically significant evidence that depth influences noticing rates, or accuracy of recalling the physical appearance of an unexpected stimulus. Nevertheless, descriptive trends suggested that both the closest and farthest stimuli were recalled less accurately, or even completely missed, compared to those presented at intermediate distances. These findings indicate that the relationship between IB and depth, and specifically the spatial placement of the unexpected stimulus in relation to the primary task, may be more complex than initially expected. Future research with larger sample sizes, improved participant screening, different stimuli characteristics, and more controlled experimental conditions are needed to further investigate the role of depth in IB within immersive virtual environments.

VIII Acknowledgments

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Appendix

A Additional Tables and Figures

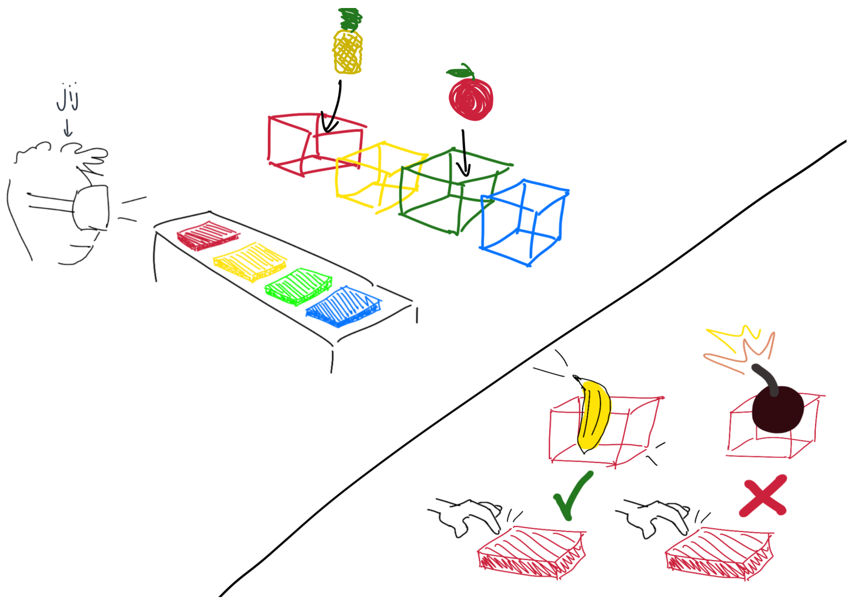

Figure A1: Image used to explain the mechanics of the game.

Table A1: Participant esults for the stereoscopic assessment, inattentional blindness task, and police officer identification.

Participant	Stereoscopic assessment	1st condition	1st result	2nd condition	2nd result	Police officer identified
1	Yes	3	No	2	Yes	No
2	Yes	3	Yes	1	–	Yes
3	Yes	2	Yes	3	–	Yes
4	Yes	1	No	3	Yes	No
5	Yes	2	Yes	1	–	No
6	Yes	1	Yes	3	–	No
7	Yes	3	Yes	2	–	Yes
8	Yes	2	Yes	1	–	Yes
9	Yes	1	Yes	2	–	Yes
10	Yes	3	No	1	Yes	No
11	Yes	3	Yes	2	–	Yes
12	Yes	3	Yes	2	–	Yes
13	Yes	1	Yes	2	–	No
14	No	2	Yes	3	–	Yes
15	Yes	1	Yes	3	–	Yes
16	Yes	1	Yes	3	–	No
17	Yes	2	Yes	1	–	Yes
18	Yes	1	Yes	2	–	No
19	Yes	3	No	1	Yes	No
20	Yes	2	Yes	3	–	Yes
21	Yes	2	Yes	3	–	Yes

Table A2: Participant demographics and screening questionnaire responses.

ID	Age	Gender	VR exp.	Gaming (hours/week)	Epilepsy/ photosensitivity	Visual impairment	Color vision	Stereo vision
1	60	M	No	0	No	Yes	No	No
2	22	F	Yes	6–10	No	No	No	No
3	26	M	Yes	11–20	No	No	No	No
4	57	F	No	0	No	Yes	No	No
5	65	M	No	Between 0–1	No	No	No	No
6	28	F	No	6–10	No	No	No	No
7	28	M	Yes	6–10	No	Yes	No	No
8	26	M	No	6–10	No	No	No	No
9	45	M	Yes	Between 0–1	No	No	No	No
10	43	F	No	0	No	No	No	No
11	27	M	Yes	6–10	No	Yes	No	No
12	22	F	No	0	No	No	No	No
13	26	F	Yes	11–20	No	Yes	No	No
14	26	M	No	6–10	Yes	No	No	No
15	22	F	Yes	6–10	No	No	No	Unsure
16	29	M	Yes	1–5	No	No	No	No
17	24	F	No	Between 0–1	No	No	No	No
18	62	M	No	0	No	Yes	No	No
19	57	F	No	0	No	Yes	No	No
20	25	F	No	0	No	Yes	No	No
21	25	F	No	1–5	Yes	No	No	No

B Informed Consent Form

<u>Informed Consent Form</u>

For participating in Media Technology MSc graduation project research conducted by Annefie Tuinstra, supervised by Maarten Lamers at Leiden University.

I confirm that I have been clearly informed about the nature and method of the research, as described in the information sheet. My questions have been answered satisfactorily.

I agree to participate in this research freely. I know that I can stop my participation at any time. If my research results are to be used in scientific publications, or made public in any other way, this will be done completely anonymously, unless I give my consent to exceptions below by marking the checkboxes.

Eye Tracking
I hereby consent to having eye tracking data anonymously collected during the experiment. ☐

I hereby consent to the eye tracking data being used in subsequent presentations and the thesis of this research. ☐

Quotes
I hereby consent to having my answers quoted in research publications. When quotes are used, my (real) name and other direct identifiers will not be mentioned. ☐

If I would like any further information about the study, now or in the future, I can contact Annefie Tuinstra (a.w.tuinstra@umail.leidenuniv.nl, +316 36545351) or Maarten Lamers (m.h.lamers@liacs.leidenuniv.nl, Gorlaeus Gebouw, Einsteinweg 55, 2333 CC Leiden, Room BE3.12)

If I have any complaints about this research, I can contact the supervisor of this research (Maarten Lamers, m.h.lamers@liacs.leidenuniv.nl) or the secretary of the Ethics Committee for Mathematics and Natural Sciences of Leiden University (ethicscommittee@science.leidenuniv.nl).

Name, Surname: ……………………….

Location and date: …………………………………………………………………….

Signature

Figure A2: Informed consent form for participants.

C Information sheet accompanying the informed consent form

Introduction This study investigates how individuals perceive and respond to visual information in immersive virtual reality (VR) environments. Participants will engage in an interactive task that requires attention and coordination, while their responses to visual elements within the environment are measured. The research aims to contribute to a better understanding of how attention and perception operate in dynamic and immersive settings. As VR is increasingly used in research, training, and entertainment, it is important to understand how individuals process information. Some aspects of the study cannot be fully explained in advance, as this could influence participants' natural responses. A full explanation of the research purpose will therefore be provided during the debriefing after participation.

Purpose of the research The purpose of this study is to investigate how individuals perceive and respond to visual information while performing a task in an immersive virtual reality (VR) environment. VR is used as a controlled and interactive setting in which perceptual and attentional processes can be studied in a consistent and measurable way. This research aims to contribute to a better understanding of how people process and respond to visual stimuli during task performance. Such insights are relevant for research on human perception and attention, as well as for the effective use of immersive technologies in experimental settings.

Voluntary Participation Participation in this research is voluntary. There is no pressure for any participant to comply or to be forced to participate. It is allowed to stop participation in any point of the experiment without any questions asked.

Right to Withdraw You have the right to withdraw your consent to use the personal data within one month after providing it. You do not have to justify your decision to withdraw your consent and there are no consequences for withdrawing your consent.

Procedures The experiment will take approximately 10–20 minutes to complete. During this time, you will first receive instructions on how to use the virtual reality (VR) equipment, followed by an explanation of the task. You will then participate in the experiment by wearing a VR headset and engaging in an interactive task. After completing the task, a debriefing will take place, during which you may be asked additional questions about your experience. In some cases, you may be invited to complete an additional trial; participation in this is entirely optional. At the end of the session, you will have the opportunity to ask questions or request further clarification about the study.

Potential Risks and Discomforts This study involves the use of an immersive virtual reality (VR) headset, which may be associated with certain risks or temporary discomforts. Potential risks include minor physical injury due to reduced awareness of the surrounding environment, symptoms of motion sickness (often referred to as "cybersickness"), and visual fatigue or eye strain. To minimize these risks, the experiment will be conducted in a safe and controlled environment (standalone, no movement/teleportation), and the researcher will closely monitor participants throughout the session. The VR headset will be adjusted to ensure a comfortable fit, and participants will be regularly asked about their well-being during the experiment. Participation is entirely voluntary, and you are free to pause or withdraw from the study at any time without providing a reason, particularly if you experience any discomfort or adverse effects. The participant may verbally request to end the experiment, and the headset will be removed immediately. A comfortable place to sit and some water will be provided in case the participant does not feel well.

Reimbursements For participating in this research, reimbursement will be in the form of a homemade sweet snack. Additionally, if you are interested in trying some games and/or experiences, I will be happy to let you show you.

Privacy All data collected in this study will be processed in accordance with the General Data Protection Regulation (GDPR) and handled to ensure your anonymity as much as possible. No directly identifiable personal data (such as your name or contact details) will be collected or linked to the research data.
Only limited personal data will be recorded, namely your age and prior experience with virtual reality.

Eye-tracking technology will be used to measure gaze behaviour within the virtual environment; this involves only positional data (i.e., where you are looking on-screen) and does not include facial images, photographs, video, or audio recordings. The researcher may also note relevant participant remarks (e.g., reactions or suggestions), which will be recorded anonymously on paper. All data will be used solely for academic research purposes and stored securely. You have the right to access, correct, or request deletion of your data in accordance with applicable data protection regulations.

Retaining and Sharing data Following data collection, all research data will be pseudonymised, meaning that any potentially identifiable information will be replaced with codes and stored separately from the dataset. If the results of this study are published or presented, this will be done using fully anonymised data, ensuring that individual participants cannot be identified. Upon completion of the project, the research data will be securely transferred to the Media Technology archive for storage and potential future reference. The data may also be shared with other researchers for the purposes of follow-up studies or academic publication. In such cases, only anonymised data will be shared, unless explicit additional consent has been obtained from participants.

Sharing the Results The findings of this study will be primarily communicated to scientific peers through the publication of a bachelor's/master's thesis. This document will describe the research design, methodology, results, and interpretation in a structured and academically rigorous manner. In addition, the results may be presented in academic settings, such as seminars or conferences, and may form the basis for a future scientific publication in a peer-reviewed journal.

Who to Contact

Annefie Tuinstra (main researcher) a.w.tuinstra@umail.leidenuniv.nl | +316 36545351
Maarten Lamers (1st supervisor) - m.h.lamers@liacs.leidenuniv.nl, Gorlaeus Gebouw, Einsteinweg 55, 2333 CC Leiden, Room BE3.12

D De-briefing Form

De-briefing

Thank you for your participation in this research. The aim of this study is to investigate how individuals perceive and respond to visual stimuli while engaged in a cognitively demanding task. In particular, it examines whether unexpected stimuli that are within a participant's field of view are nevertheless not consciously perceived, otherwise known as "inattentional blindness".

Right to withdraw data

You may choose to withdraw the data you provided during the research. If that is the case, please contact me not later than 1 month after participating in this research.

If you have questions

The main researcher conducting this study is Annefie Tuinstra. This research is supervised by Maarten Lamers at Leiden Institute for Advanced Computer Science (LIACS), Leiden University. Please ask any questions you have now. If you have questions later, you may contact Annefie Tuinstra at a.w.tuinstra@umail.leidenuniv.nl or at +316 36545351.

If you have any questions or concerns regarding your rights as a research participant in this study, you may contact the supervisor (Maarten Lamers, m.h.lamers@liacs.leidenuniv.nl) or secretary of the Ethics Committee for Mathematics and Natural Sciences of Leiden University (ethicscommittee@science.leidenuniv.nl).

If you would like to receive a copy of the final report of this study [or a summary of the findings] when it is completed, please feel free to contact the student.

Your signature below indicates that you have been debriefed, and have had all of your questions answered.

________________________	______________________	_________
Name of Researcher	Signature	Date
________________________	______________________	__________
Name of Participant	Signature	Date

Please sign both copies, keep one and return one to the researcher.