Exploring Co-offending in Residential Burglary through Virtual Reality: A Novel Approach

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April 12th, 2023

Abstract

This paper aims to extend the use of virtual reality (VR) as a method to explore co-offending in residential burglary. VR has only been used to investigate solo offenders, despite a large part of burglaries being committed by multiple offenders. At the same time, co-offending can affect the behavior, cognitions, and decision-making of the burglars and exacerbate the consequences for the victims. A multi-user VR simulation was used to conduct a virtual burglary, in which participants were instructed to cooperate in couples to successfully complete the burglary. During the experiment, multiple data were recorded, such as their behavior, conversations, and heart rate. After the completion of the virtual burglary, participants completed questionnaires related to presence and cooperation.

A Friedman test revealed that, those who experience the simulation without breaks, experienced a significant increase in heart rate as a consequence of the burglary rather than the VR experience itself. Furthermore, a general linear model was used to investigate whether positive evaluated cooperation in VR was related to actual increased performance during a virtual burglary. Results indicated that positively evaluated cooperation was positively related to higher value stolen in a shorter amount of time. In contrast, this did not influence the participants to take more valuable items. Furthermore, a mixed effect model was used to examine the relationship between presence and cooperation. The results showed a significant positive relationship between co-presence and cooperation. Moreover, the differences within couples had no meaningful effect on this relationship. Further auxiliary analysis, in which participants were asked about their opinion of the virtual experience indicated that participants were positive about the immersive features and realism of the environment. On the other hand, participants indicated to be bothered by glitches and bugs the most. In summary, the outcomes revealed VR to be able to investigate co-offending in VR, however, more work is required in improving the medium to foster the need for cooperation.

Introduction

Burglary remains one of the most common forms of criminal activity in the Netherlands (CBS, 2022), and following the COVID-19 lockdowns, it is on the rise again (CBS, 2023). One of the reasons for its prevalence remains to be its low likelihood of apprehending a suspect (CBS, 2022) which contributes to the continuation of the offense over an extended period. Besides the obvious financial consequences for the victims (Nee et al., 2015), burglary may instigate an increase in fear of crime (Tseloni & Zarafonitoum, 2008), a reduction in life satisfaction (Staubli et al., 2013), and a range of short- and long-term emotional responses, such as feelings of helplessness and depression (Frieze et al., 1987).

Interviews with offenders, analysis of registered offences and experimental research have provided insight into the offending behaviour of burglars and can provide valuable guidance for prevention. Much of this research has used the burglar as expert (Nee et al., 2003), and have provided insight into burglar expertise, behaviour, individual cognitions and discission-making (e.g., Steffensmeier et al., 1991; Nee & Taylor, 2000; Bernasco & Nieuwbeerta, 2005; Meenaghan et al., 2018; 2020; Nee et al., 2019; 2020). Recently, virtual environments have been used to explore burglary behaviour more directly. For example, fully immersive VR has been tested on its availability to replicate the real world (e.g., Van Gelder, 2017) and has already been used to explore varying factors influence burglar decision-making and behaviour (e.g., van Sintemaartensdijk et al., 2021). Despite these advances in burglary research, one element of the burglary scenario remains absent, namely: the influence of others. Yet, at the same time, the prevalence of co-offending in burglary is substantial (Hochstetler, 2014). While many burglars operate on their own (van Mastrigt & Farrington, 2009), co-offending is abundant in burglary, with nearly all burglars deciding to co-offend at some point in their criminal career (Coupe, 2017). This trend is particularly pronounced among juvenile offenders, of whom the majority engage in cooperative criminal activity

(Carrington, 2009; Coupe, 2017). Most co-offending tends to be of a non-recurring nature (Reiss, 1988), however, for burglary in particular, offenders tend to stay in a collaborative relationship for a relatively long time (Carrington, 2014). Despite potential negative consequences for the offender, such as an increased risk of apprehension in the period following the burglary (McCarthy et al., 1998; Tillyer & Tillyer, 2014), co-offending may occur due to necessity, social context, or additional opportunities (Weerman, 2003; Hochstetler, 2014; van Mastrigt, 2017).

While co-offending not only occurs regularly in burglary, but it also influences the outcomes of the crime by affecting the decision-making processes of offenders. While the bulk of the criminogenic literature stems from indirect evidence, VR technology presents an opportunity to gather direct and real-time data on the influences of co-offending during the commission of a burglary (van Gelder et al., 2014). The present study aims to address this by investigating the extent to which a VR simulation can elicit a sense of presence among participants, as well as the ability to facilitate realistic collaboration in the completion of a burglary task. This will indicate the extent to which the simulation can be used to better understand the role of interaction, discussion, and influence during burglaries.

Co-offending and burglar decision-making

Earlier theories, such as the Rational Choice Theory, attempted to explain burglary decision-making as a rational consideration of costs and benefits (Coupe, 2017). The probability (e.g., guardianship) and severity of consequences and its influence of active decision-making by the individual were at the core of these theories (Coupe, 2017). However, as burglars become more experienced and develop their skills, their decision-making shifts to an automatic, and potentially unconscious, process (Nee & Ward, 2015). Experienced burglars develop *"extensive cognitive schemas"* which allow them to quickly and automatically respond to environmental and offence related cues (Nee & Ward, 2015; Meenaghan et al., 2018).

However, previous research indicates that the development of burglary expertise, as well as the relationship with decision-making may be influenced by co-offending. Following the conceptualization of Hochstetler (2014), co-offending is defined as a discrete, short-lived event in which two or more individuals engage in close collaboration while in each other's immediate proximity. This perspective attends to the various consequences co-offending have for the preparation, execution, and outcome of the burglary. For instance, expert burglars tend to engage in proactive planning of their offence and divide labour amongst group members (Weerman, 2003). Thus, behaviour and decision-making may vary in a co-offending scenario as a consequence of burglary expertise, particularly when members exhibit differing levels of knowledge and skills. Furthermore, another example, describes the decline of co-offending with age (Weerman, 2003; Mastrigt & Farrington, 2009; Lantz & Ruback, 2017), which may be due to accumulated expertise rendering co-offending unnecessary in future burglaries (Meenaghan et al., 2020; Lantz & Ruback, 2017). The accumulated expertise of one, may play a role in the acquisition of the expertise of the other.

There may be many other influences of co-offending on the burglar in varying situations that remain unknown. Other factors such as emotions and mood (Meenaghan et al., 2020), different perspectives, the nature of the relationship (McGloin, 2009), and level of deviancy (McGloin, 2009) might as well influence decisions during the burglary. By directly observing the burglar and using them as the expert (Nee, 2000), automatic responses to environmental cues and peer interaction, which would otherwise stay hidden, become apparent (van Gelder, 2014).

Virtual Reality as a method for burglary research

Direct observation of behaviour introduced in the latter paragraph has been addressed in previous research through the use of virtual reality. In this paragraph, I explore the potential of VR as a research method for investigating burglary and discuss the method in light of co-offending. Virtual reality is an immersive technology that allows for its user to interact with realistic virtual environments whilst retaining high experimental control in research (Blascovich et al., 2002; Pan & Hamilton, 2018). It stimulates the senses of its user, using a head-mounted display (HMD) and handheld controllers and offers the ability of interaction with the environment (van Gelder et al., 2014). Furthermore, VR can "[…] evoke the cognitions, emotions, and behavior commensurate with a real burglary" (p. 501) (Nee et al., 2019), while observing participants in situations that would otherwise be impractical (Seibert & Shafer, 2018). In this case, it allows to directly observe the burglary offence in diverse situations circumventing obvious ethical concerns.

Following this definition, the issue that arises is the method by which one can determine how well simulation can serve as a substitute for the real world. In the context of residential burglaries, some researchers have aimed to establish this. For instance, in the study of Nee et al. (2015) two distinct groups were created, of which one consisted of 6 ex-burglars and the other of 6 university students. Both groups were tasked with participating in a mock burglary both in a physical house and a virtual house in order to identify any differences between the two methods. Results indicated minimal differences between the two methods for both groups. Additionally, the study aimed to preliminarily establish differences between expert and non-expert participants by drawing upon burglary expertise theories. When differences were observed as expected, they suggested VE's as a potential tool for examining residential burglary. Likewise, Meenaghan et al. (2018) and Nee et al. (2019) utilized non-VR virtual environments in two different ways. While participants were still able to perceive the physical world, they were able to demonstrate the potential of virtual environment as a tool for burglary research. Meenaghan and colleagues demonstrated that VE's were similar enough to increase engagement and recall during post-experience interviews, while Nee and colleagues observed differences in decision-making between burglars and other groups, in accordance with burglary expertise theories. In relation to virtual reality, van Gelder and colleagues (2016) had student participants commit a virtual burglary whilst wearing VR goggles to evaluate the validity as a research tool. In order to make objective inferences on the effectiveness of the simulation, they collected data referring the emotional state of the participant, such as heart rate. They argued that participants would have a similar physical arousal response to the virtual burglary as they would in a real burglary. Indeed, participants experienced a significant increase as a consequence of starting the burglary in contrast to no significant increase between a baseline condition (i.e., filling in questionnaires) and starting the VR simulation. This indicated that the burglary, rather than the VR simulation itself, was the trigger for an increase in arousal. Furthermore, Park & Lee (2021; 2022) investigated the potential of VR to examine users' responses to environmental factors. Although they did not sample (ex)burglars, they were able show similarities between theories relating to crime prevention through environmental design and the observed behavior of participants. Last, Sintemaartensdijk and colleagues used a virtual neighborhood and VR to experimentally study the effects of informal and symbolic guardianship (Sintemaartensdijk et al., 2021, 2022), and personality and individual differences (Sintemaartensdijk et al, 2022) on the scouting process of 181 incarcerated burglars and 172 non-offenders. They found significant different effects for guardianship and personality on the scouting process and perceptions of the neighborhood. The researchers were able to determine that the expert's were likely to be influenced differently than the layperson, potentially revealing the impact of experience and expertise on behaviour as theory suggests.

Presence in Virtual Reality

Abovementioned studies have largely relied on uncovering behavioral differences, which are mainly based in pre-existing theories, in order to establish VR as a research method and to conduct preliminary research. However, as an example, part of the study of van Gelder and colleagues (2016) focused on the technical aspect of the simulation and its ability to replicate a real-world scenario. Like other researchers that used VR, they have relied upon the presence construct. Presence has frequently been defined in straightforward terms as *"The feeling of being there"* (Schuemie et al., 2001; Slater, 2009; Skarbez et al., 2017). It refers to the users' psychological experience of existing in the VE rather than the physical environment their body is in (Weech et al., 2019; Vouzes et al., 2021). The level of presence an individual experiences within a VE may be indicative of the degree to which their actions will align with those in the physical world (Slater et al., 1996). The most common approach to asses presence has been post-hoc questionnaires (Ijselsteijn et al., 2000; Tjon et al., 2019), however, it has shown itself to be physiologically measurable, for example, by heart rate measures (e.g. van Gelder et al., 2017; Marin Morales et al., 2020) and EEG (e.g. Tjon et al., 2019; Kober et al., 2012). The theoretical basis of these latter methods suggests that the substitution of actual sensory data with artificially generated sensory data elicits bodily responses that mirror those of actual sensory stimuli (Slater, 2009). When this substitution is unsuccessful, it is indicative of the user experiencing insufficient presence.

The following section will deconstruct the concept of presence in three distinct components and I will argue for the importance of this specific conceptualization in the current study. These three components are spatial presence, copresence, and social presence. In this conceptualization, the general definition above is renamed to spatial presence like the concept Hartman et al. (2015) and Lombard & Jones (2015) use. The following two components expand on this definition by including the other user. First, copresence, bears similarity to spatial presence as it directly refers to the virtual environment and its surroundings. Simply put, copresence can be defined as the sense of being in the VE with another (Slater et al., 2000; Nowak & Biocca, 2003; Lombard & Jones, 2015). It refers to a sense of shared spatial presence and mutual awareness between users within the VE (Bulu, 2012; Skarbez et al., 2017). Second, Nowak and Biocca (2003) define social presence as the "user's perception of a medium to provide salience of another person" (p. 482). In other words, it refers to the degree to which a person feels like they are in a social situation, regardless of whether they are physically present with others or not and it focusses on the technologies (or medium) ability to psychologically create a social setting (Biocca et al., 2003; Bulu, 2012; Lowenthal & Snelson, 2017). While a medium can create a social interaction between its users, at the same time, this is not the same as being in the same virtual place as the other.

Presence and Virtual Cooperation

As the definition of presence illustrates, when participants experience high levels of presence, simulated scenarios could produce similar behavior as the real-life scenario it aims to imitate. The aim of the simulation is to foster cooperation and in doing so, it seeks to emulate real-life co-offending. Kaye (2016) conceptualized cooperative gameplay as followed: "Two or more players undertaking a task which requires complementary participation to accomplish a shared goal" (p. 287). However, at this point, there are only a few studies that have explored cooperation in VR (e.g., Weinrich et al., 2018; Casanueva & Blake, 2000). To be able to shed light on the nature of cooperation in serious games such as VR, social gaming literature is explored. In gaming, it is reported that cooperation often appears effortlessly even without the players being acquainted (Morschheuser et al., 2017). In gaming literature, several concepts have been used as indicators of effective cooperation, namely: mood of the participant (Kaye, 2015; Gajadhar et al., 2009; Kaye & Bryce, 2014), individual characteristics (Lu & Argyle, 1990; Kurzban & Houser, 2001), group flow (Kaye & Bryce, 2012), interdependence (Weinrich et al., 2018), shared goals (El-Nasr et al., 2010; Morschheuser et al., 2017; Depping & Mandryk, 2017), and trust (Depping et al., 2017).

These concepts either related to the nature of the task or the interaction itself.

While both variables have been measured in serious games, however, so far, evidence is unclear about this connection. For the individual, experiencing higher presence is likely to increase performance (Putze et al., 2020). However, it remains unclear whether this is the case for collaborative tasks. One of the objectives of Osmer and colleagues (2021) was to fill this gab in the augmented reality literature. Although similar, augmented reality with VR goggles merges virtual aspects with the physical environment, whereas a VR environment is completely digital (Osmers et al., 2021). The authors concluded that there were no studies that aimed to test this relationship, rather, they discovered co-occurrence of the two. Notably, their conceptualization of social presence included both co-presence and social presence components of this study. Nevertheless, they argued that, at this time, social presence is most likely inadequate as a predictor for cooperation quality (Osmer et al., 2021). Instead, the authors suggested that social presence leads to a positive attitude to the aspects of the simulation that increase cooperation quality, such as the avatars (Osmers et al., 2021). This suggests that social presence most likely facilitates cooperation, but that it is not a necessity for it to occur. For instance, although social presence is necessary for social interaction in a VE (Biocca, 2006), not every form of social interaction, such as having an argument, is beneficial for cooperation.

The present study

The main research question formulated for this study is “To what extent can Virtual Reality be used as a research method for investigating co-offending in residential burglary?” Based on this framework, I formulated three research questions that are aimed to provide a clear picture of VR’s validity to be used as a method to explore co-offending in a residential burglary scenario.

1. To what extend does virtual reality facilitate a sense of presence so it can be used as a viable substitute for the observation of real-world residential burglaries?
2. To what extend does virtual reality facilitate effective cooperation and contribute to successful completion of a simulated cooperative burglary task?
3. Does the sense of presence experienced in VR facilitate cooperation in performing a cooperative burglary?

Method

Participants and design

In total, 80 students from the University of Twente (UT) participated in pairs. The age of the participants ranged from 18 to 29, with an average age of 20.67 (SD = 2.26). Although most of the burglars are males, we nonetheless choose to include females to reach enough participants. Of those participants, 74% were female, 23% were male and another 3% identified as non-binary. 48.57% had a German nationality, followed by 28.6% that were Dutch, and another 22.86% consisted of other nationalities. Furthermore, those below the age of 18 and those who suffered from epilepsy were excluded from participation. Furthermore, proficiency in English was a requirement as participants were instructed to communicate in English. The participants were recruited via SONA system of the UT in which students can sign-up for studies and experiments. Participating in our experiment earned them credits which they are required to obtain. 42.1% of participants were not acquainted with each other. 27.6% indicated that they were friends, another 15.8% reported being close friends (or family member or partner), and 14.5% indicated only being acquainted. The experiment had a between-subject design in which participated in self-created pairs. However, data was both collected for the analyses of pairs as well as the analyses of the individual.

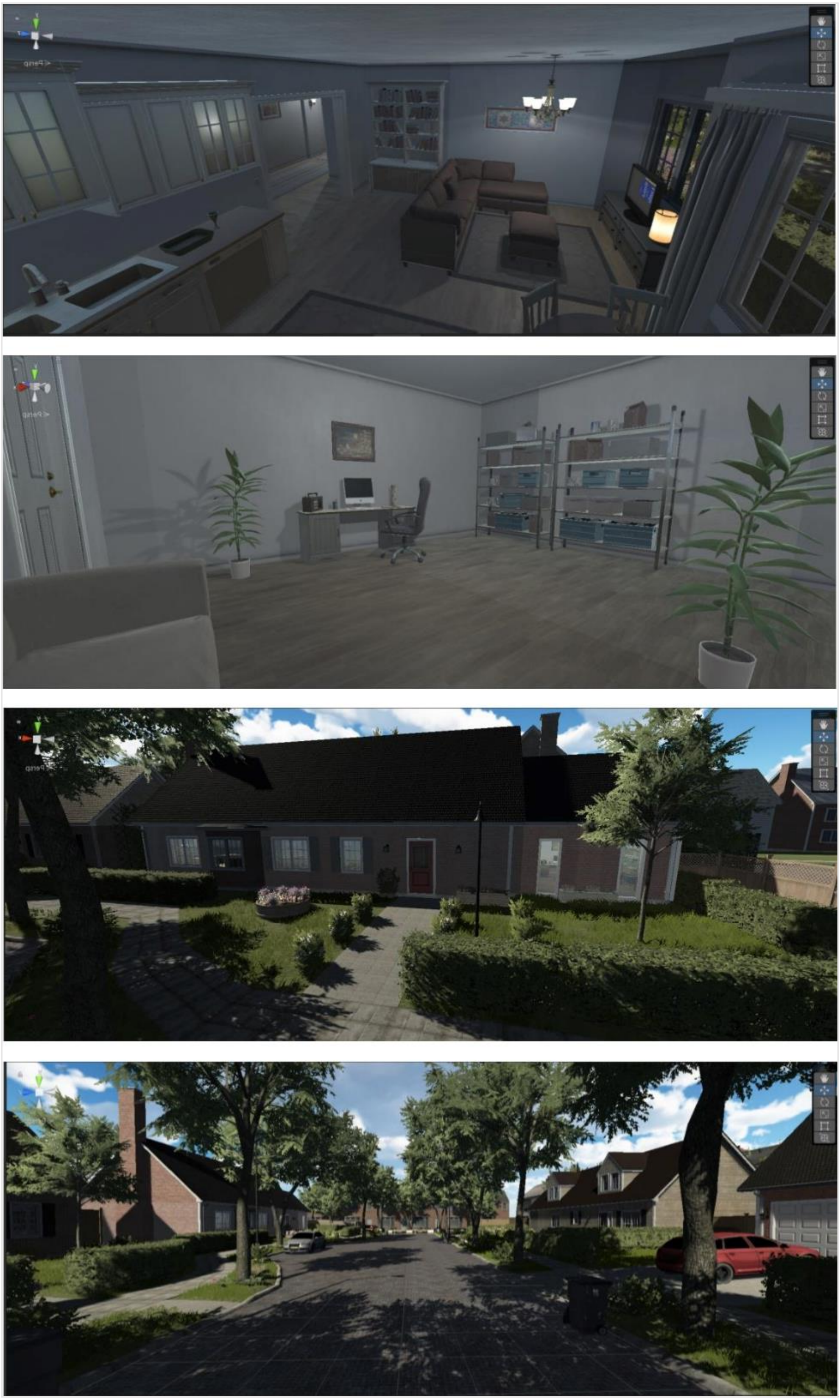
Materials

The virtual neighbourhood. The virtual environment (VE) was developed with the Unity engine (version 2021.3.4f1). A default neighbourhood that looked like an American middle/upper-class neighbourhood was adapted to resemble Dutch and British neighbourhoods more closely during the day. The layout of the neighbourhood is based on the experience of the project member living both in the Netherlands and the United Kingdom. The neighbourhood consists of one street with five detached houses of which one can be entered by the participants (figure 1). There is some overlap between the materials that are commonly used in Dutch and UK neighbourhoods and are therefore widely used in this VE (e.g., brick and concrete instead of wood). Furthermore, windows have been added to several houses for a more realistic appearance and some garages that gave an American impression have been removed. In the neighbourhood, there is ample vegetation. Additionally, in the background, rows of terraced houses (which are common both in the Netherlands and the UK) have been added. To make the environment look lively it includes objects such as lamp posts, cars, waste containers and different kinds of garden accessories. Since the focus was on the multiplayer aspect of the simulation, the choice was made to keep the house simple and only ground-level. This meant that not all cabinets, closets, crates, and items were interactable. This choice was made in a trade-off between intractability and lagging of the environment. Furthermore, the interior of the house consisted of a home office, a storage room, a large hallway, a living room, a kitchen, a bathroom, and a bedroom. The interior of the house contains valuable (and less valuable) objects which the participants could 'steal'. These items are allocated to a room of which we can logically assume to be found there (e.g., a drill is not often found in the bathroom). Moreover, participants could pick up (or steal) these objects and items and carry them to specific drop zones which were included in every room of the house. These drop zones were simple grey boxes and would simulate a bag one could use to transport stolen goods in.

Participant interacted with the VE by wearing the Oculus (or Meta) Quest 2. The device consists of a head-mounted display, with which the participant was able to view in all directions, and two controllers, which are used to move around and interact with objects and doors. Participants were able to move freely around the VE closely resembling the real world and verbally communicate with their partner. The pairs were in the same VE as well as in the same physical room. Participants were standing about one meter apart from each other with two computers and monitors in front of them. The experimenters were standing either behind or besides the computers. When instructions were given and informed consent signed, participants were asked to stand about half a metre away from the desks.

Figure 1

Images of the interior of the house and neighbourhood



Questionnaires.

Presence. Subjective presence was measured by a 14-item scale and was used to measure three concepts of presence (α = .70) (M = 3,37, SD = .43). For the first 7 items, an adaptation by Sintemaartensdijk et al. (2020) of the Spatial Presence Experience Scale of Hartman et al. (2016) was used (α = .69). This part related to environmental presence and contained items such as “I felt like I was actually in the virtual environment” and, “I felt like I could do anything I wanted in the virtual environment.” Then, the second part aimed to measure social presence (α = .35) (M = 2.98, SD = .51) and contained 4 items such as “It was easy to tell how my partner felt in the virtual environment.” The final part, measured co-presence (α = .74) (M = 3.49, SD = .91)with 3 items such as “The avatar of my partner made me feel like I was in the environment with another person.” All the items were measured on a 5-point Likert scale ranging from strongly disagree to strongly agree.

Cyber-sickness. During VR experiences it is not unusual for users to experience discomfort in the form of nausea, stomach-ache, dizziness, problems with focusing, and blurry vision. The extent to which participants suffered from one or more of these symptoms was measured via an adaptation of the Simulator Sickness Questionnaire (Kennedy et al., 1993) used by Sintemaartensdijk et al. (2020) (α = .71) (M = 4.31, SD = 1.14). Participants indicated the extend of a symptom (e.g., ‘The virtual environment made me nauseous’) on a 5-point Likert scale ranging from strongly disagree to strongly agree. Additionally, participants removal of their headset has also been counted, since most attributed this to their cyber sickness.

Game experience. For those who play games more often, the controls and interaction with the VE may be more intuitively understood, than for those who do not, because he VE and the controls resemble a video game. To establish whether outcomes were influenced by their level of gaming experience an adapted version of the scale created by Sintemaartensdijk et al. (2020) was used. Participants were asked to indicate how many hours per week they played (online single player and multiplayer) video games with a controller and a keyboard. Additionally, they had to indicate how many hours per week they played with a head-mounted display.

Cooperation scale. A cooperation scale (α =.72) was created to indicate the how the participants experienced cooperating with another person during a virtual burglary task (M = 3.07, SD = .25). The scale was created to measure several aspects that influence the rating of cooperation, including: mood of the rated success (with and without cooperation) (‘My partner and I were successful in the task we had to complete in the virtual environment’), happiness with outcome (‘I am happy with the outcome of the task we had to complete in the virtual environment’), cooperation in general (e.g. ‘I often find it difficult to work together with people’) (Lu & Argyle, 1990), group flow (Kaye, 2016) (‘e.g. I had a good idea how well my partner and I were performing the task’), mood of the participant (Kaye, 2016)(e.g. ‘I felt excited after completing the task’), shared goals (e.g. ‘I feel as if my partner and I had a shared goal in completing the task’) (Depping et al., 2017), interdependence (‘I was not dependent on my partner to complete the task) (Kaye, 2021), trust (Depping et al., 2017) (‘I trusted my partner while we were completing the task’), stress and technological capabilities. All these dimensions were measured via a 5-point Likert scale ranging from strongly disagree to strongly agree. Additionally, participants could indicate to what extend they communicated compared to their partner in percentages (e.g., 50% meant that both contributed evenly) (Gorsic et al., 2019). However, this item was beyond the scope of this study.

Other variables

Physiological measure. During the experiment participants heart rate was measured with the Empatica E4 wristband tracker. Heart rate increases due to the activation of the sympathetic nervous system as a reaction to a psychologically stressful event (e.g., a burglar may experience stress because of the threat of being caught) (Appelhans & Luecken, 2006). Van Gelder et al. (2016) used the highly accurate VU-AMS device to measure, among other variables, HRV to measure arousal. Schuurmans et al. (2020) compared the Empatica with the VU-AMS device and concluded that, for heart rate, the devices performed similar. Furthermore, the Empatica allows for the researchers to indicate time zones. In this study, the experimenters have used it to indicate different activities of the participants.

Burglary success. Burglary success was determined by two variables, namely: value per second and item value ratio. All the items within the virtual environment were valued based on their real world counterparts. Thus, at the end of the experiment, participants had accumulated a certain amount of value. Value per second describes this value when controlled for time spent in the virtual house. Spending less time than others while accumulating more value is seen as better performance. Moreover, the item value ratio describes the value accumulated divided across the total number of stolen items. Those who accumulated more value with by stealing less items are seen as performing better than those who stole many (invaluable) items.

Procedure

After participants signed their informed consent, the experimenters informed the participants on what they were about to and instructed them on how to be able to interact with the VE. Participants' were instructed to perform a virtual burglary together with their co-participant. They were encouraged to communicate and cooperate but were explicitly instructed that they could decide for themselves how to proceed. Furthermore, they were instructed that, to officially steal an item, they had to pick it up and carry them to the drop zones (which were the gray boxes). Participants were given the opportunity to ask questions. Following this section, participants entered the VE. At this time, the experimenters flagged the first event on the Empatica.

Once in the VE, participants were instructed to perform a practice exercise on the street of the neighborhood. During this exercise they practiced with picking up objects and placing them in the drop zones. Participants were told by the experimenters that this was the process of the burglary. After this, the participants were instructed on which house they were about to burgle, the experimenters flagged the burglary event on the Empatica, and the burglary started. Only when bugs and glitches with the system appeared did the experimenters interfere. Whenever participants left the house together, the experiment ended.

Following the experiment, participants were directed to separate rooms in which they completed the HEXACO questionnaire, as well as questionnaires intended to measure self-control, presence, cooperation, cyber sickness, game experience, relationship with their peer. Data for some questionnaires are beyond the scope of this study.

Results

This section is structured into four sections. First, the subjective presence will be addressed, followed by the analysis of the physiological measure. Then the relationship between cooperation and task performance will investigated. Last, the relationship between presence and cooperation will be explored. Below table 1 shows all the means and standard deviations for the outcomes of all relevant questionnaires and variables.

Table 1

Descriptive statistics for all relevant variables.

Variable	Mean	SD
Spatial presence	3.55	.52
Social presence	2.98	.51
Co-presence	3.49	.91
Cooperation	3.07	.25
Cyber sickness	4.31	1.14
Game experience (hours per week)	7.91	2.77
Value per second*	4.87	3.07
Item value ratio*	229.22	94.64

*value in euros

Subjective presence. The mean score for the subjective presence scale was 3.38 (SD = .43) out of a maximum score 5. Only a quarter of the participants (22.4%) of the mean scores were neutral or lower.

Furthermore, there was no significant correlation between total level of presence and gaming experience (r = .105, p = .369). Indicating that gaming experience did not influence how participants reported their levels of presence. Additionally, a weak correlation emerged between copresence and gaming experience (r = .218, p = .059). However, this relationship was non-significant. Noteworthy, participants reported relatively high levels of cyber sickness (M = 4.31, SD = 1.14), however, presence was not significantly correlated with cybersickness (r =. -006, p = .962) (table 2 includes a correlation overview). The level of cybersickness participants reported to experience was not related to how they would evaluate their presence during the simulation. Because of their cyber sickness, some participants removed their headset (N = 25). Nevertheless, an independent sample t test indicated that pairs in which at least one participant removed their headset did not report significantly lower subjective presence, *t*(33) = 1.22, *p* = .166[1]. Furthermore, participants themselves did not report lower presence scores as a consequence of removing their HMD, *t*(74) = .98, *p* = .166.

Currently, it indicates that removing ones HMD did not influence their self-reported presence.

Table 2

Pearson's correlations presence

	Spatial presence	Social presence	Copresence
Spatial presence			
Social presence	.188		
Copresence	.308**	.251*	
Game experience	-.039	.218	.123
Cyber sickness	-.120	.193	.004
Relationship			

Note: *p <. 05, **p < .001

Physiological measure. First, of the 88 participants for the heart rate measure 24 were excluded because time zones were not flagged correctly. Furthermore, one participant was excluded because they had unreasonably high heart rate (200 bpm at rest).

Since the sample size was small, determining the distribution of the mean heart rate (HR) for all three timeframes was needed for the appropriate statistical method. A Shapiro-Wilk test was performed (Yazici & Yolacan, 2007) and did show evidence of non-normality for Mean HR Introduction (W = .931, p = .002), for Mean HR Training (W = .936, p = .003),

[1] Independent sample t tests were also performed for the three subscales of presence; however, all of these indicated a non-significant difference.

and for Mean HR Burglary ($W = .890$, $p < .001$). The data for all three variables were positively skewed. Based on these outcomes, there is not enough evidence to assume normality of the data. For this reason, a non-parametric test was used to analyze the heart rate data.

The following analysis aimed to test whether HR burglary was significantly higher than HR training. Additionally, HR training should not be significantly higher than HR training to confirm my hypothesis. A Friedman's two-way ANOVA by ranks (Pereira et al., 2015) revealed a significant effect of timeframe on mean HR χ^2 (2, n = 63) = 6.558, $p = .038$. To explore to origin of this effect, post hoc pair wise comparison with Bonferroni correction revealed that, contrary to my expectation, that decrease between HR introduction and HR training was significant (*p* = .031). Furthermore, heart rate increased between HR training and HR burglary, but this was not significant (*p* = .055). The difference between HR introduction and HR burglary was non-significant as well (*p* = .50). Noteworthy, there was no significant increase in heart rate as a consequence of starting the simulation.

When only those who did not remove their HMD were analyzed (n = 43), a Friedman test again revealed a significant effect of timeframe on mean HR χ^2 (2, n = 43) = 8.573, $p = .014$. Additionally, post hoc analysis with Bonferonni correction revealed similar results between HR introduction ($M = 89.12$, $SD = 9.65$) and HR VR training ($M = 83.26$, $SD = 13.22$) (*p* = .011). However, the increase in heart rate between HR VR training ($M = 83.26$, $SD = 13.22$) and HR VR burglary ($M = 88.87$, $SD = 12.21$) was revealed to be significant (*p* = .031). However, excluding those who removed their HMD from the analysis only led to a small difference in the data. Nonetheless, these findings, although not completely as expected, point in the direction of arousal increasing as a result of the burglary rather than the VR experience itself.

Table 3

Mean and SD for HR timeframes

Timeframe	Mean	SD	N
HR Introduction	89.5	9.73	63
HR VR Training	84.43	13.19	63
HR VR Burglary	88.43	10.69	63

Cooperation and presence. First, overall, the mean corporation was 3.06 (SD = .24) out of 5 and indicates participants not necessarily evaluated their cooperation as positive or negative. 28.9% of the participants reported a negative score (lower than 3) for their mean cooperation. Table 4 is an overview of all correlation for cooperation.

Table 4

Pearson's Correlations for cooperation

Variable	Correlation
Spatial presence	.304**
Social presence	.260*
Copresence	.441**
Game experience	.108
Cyber sickness	-.050
Relationship	.270*

Note: p* < .05, ** p < .001

Since the data of the couples are not independent of each other, a linear mixed model was fit to the data (Hox, 2002; Signmann & Kellen, 2019), including fixed effects[2] for the spatial presence, social presence, and copresence and a random effect for the couple the participant was a part of. Results are shown in table 5. The model showed copresence to be a positive significant predictor of cooperation ($\beta = .097$, $t = 3.18$, $p = .002$). Additionally, the model revealed a non-significant relationship between spatial presence ($\beta = .069$, $t = 1.44$, $p = .154$) and social presence ($\beta = .086$, $t = 1.55$, $p = .126$). Furthermore, the results of the model indicated that the estimated variance within couples was .041 (SE = .010) and was significant ($t = 4.34$, $p < .001$), while the estimated variance between couples was .009 (SE = .008), however, this was nonsignificant ($t = 1.01$, $p = .312$). This indicated that there was no meaningful effect of how the participants were grouped (i.e., couple) (Hox, 2002).

These results point in the direction that those who felt present within the VE with the other participant evaluated their cooperation more positive. Notable, however, the result indicated no influence of the simulation's ability to create a social situation on the evaluation of the cooperation.

[2] Game experience and relationship were also added as fixed effects, but these did not lead to any significant relationships.

Table 5

Results LLM for the relationship between presence and cooperation.

Variable	β	SE	t	Sig
Intercept	2.243	.207	10.86	<.001
Spatial Presence	.071	.049	1.44	.154
Social Presence	.078	.050	1.55	.126
Copresence	.097	.029	3.33	.002
Gaming experience	.000	.010	.03	.977
Relationship	.044	.024	1.82	.076

Cooperation and performance. Additionally, the following paragraph investigates whether a positive evaluation of the cooperation by participants was associated with better performance. In this case, performance of the pairs was indicated as the value stolen per second. A general linear model was used like Miller & Haden (2006) proposed, to examine the relationship between value per second and the interaction effect between cooperation score of participant A and B[3]. The model results indicated that the interaction effect was a significant predictor of value per second, F (1, 28) = 6.759, p = .015. The model accounted for 19.4% of variance in the value per second. These results indicate that those who positively evaluated their cooperation used less time to steal more valuable items together, but this depended on how the other evaluated the cooperation. Further, a different indicator of performance was analyzed using a general linear model. This time, the average value per item (Item value ratio) was put into the model as a dependent variable. Again, the cooperation of participant A and B were added as an interaction effect. The results of the model revealed

[3] Initially the interaction effect of presence and the main effect for relationship were added, however, these were revealed to be non-significant.

that the interaction effect of cooperation did not predict a higher item value ratio F (1, 33) = .819, p = .372. When we correct for the number of items taken, participants did not accumulate more value as a consequence of more positive experienced cooperation.

Auxiliary analysis: Open presence items. The data were imported into ATLAS.ti coding software and then analyzed using thematic content analysis (Braun & Clarke, 2008). The data were handled by means of inductive coding, in which the data were examined for patterns or repeated themes within the units of analysis (Thomas, 2006). Table 6 illustrates the results when asked what the participants liked about the virtual experience. Table 7 presents all suggestions for improvement. Both include the code, total amount participants mentioned this specific code, a description, variations, and an example quote. In the following section I will provide a short analysis of the data from both questions.

First, the focus will be directed towards all codes associated with the question "What did you like about the simulation?"

Realism. This code relates to how well certain aspects of the simulation resemble reality according to the participants. Variations of this code include realism in general, realism of the movement and behavior, realism of the environment, and the realism of the items. For example, a participant of couple 19 clarified: *"Everything in the environment looked very real, I actually had the idea that I was in someone's house."* Of all variations, participants most often mentioned the realism related to their movement and behaviour, for example: *"I liked the different possibilities of movement, like grabbing onto things, turning, and walking."* In essence, many participants were surprised by how the simulation was able to replicate the real world and "[…] *made me feel as if I really was inside of a house"* (participant from couple 15).

Interactivity. Furthermore, participants cited that they liked the possibility of interacting with the doors and items: While others especially liked the collaboration aspect of the study, for example like a participant from couple 37: *"I did like that you could talk to the other person and share what you are seeing."*. These specifically indicated the simulation to include interactivity both in terms of objects and items and allow them to socially interact with their peer as well.

Presence and Immersion. This code includes all direct mentions of immersion and feelings of presence in the virtual environment. Participants from couple 33 described how they sometimes forgot the location of their physical body. While others simply described feeling immersed in the environment: *"*[…] *It is quite unbelievable how much you can immerse in this world"* (participant from couple 14).

Graphics and details. This code was only applied when participants only mentioned the visual aspects of the simulation. It this sense, it differs from the code realism as these participants did not mention the visuals to influence their sense of realism. For instance, participant from couple x mentioned the following: *"I liked the attention to detail throughout the entire environment."*

Behavior. Some participants described the simulation as a way to behave in a way they normally would not. Participants from couples 10 described excitement due to the simulation's resemblance to real criminal activity.

The following section includes the codes that refer to the question "What could be improved about the simulation?" These codes include recommendations that refer to existing or missing aspects of the simulation.

Technical aspects. The units of analysis that belong to this code refer to the technical functioning or the capabilities of the simulation. Participants most often mentioned specific bugs and glitches as one of the most important factors to be improved. These glitches ranged from not being able to grab and hold objects to floating through the environment and vibrating screens. Some participants even attributed discomfort to these malfunctions.

Furthermore, many participants experienced cybersickness as a consequence of the sensitivity of the analog sticks. For example, one participant from couple 10 mentioned: *"I got easily motion sick, because I did not move in the real world but in the VE, this happened especially when moving fast."* Moreover, some participants advised to use avatars that would more closely resemble real persons. These participants merely mentioned the representation of the avatar rather than the quality of the interaction achieved via these avatars. For instance, participant from couple 25 explained: *"I think it would be closer to reality if the other person would have a more real appearing avatar."* Lastly, only a few participants mentioned that the inclusion of environmental audio would enhance their experience.

Interactivity. While many participants liked the interactivity present within the simulation, others mentioned a lack thereof. Several participants have mentioned that allowing all doors and cabinets to be openable would improve the simulation. For instance, participants of couple 7 and 19 wanted to open cabinets whereas participant of couple 5 wanted to open the fridge. Similar to this, others also mentioned a lack of interactive stealable items. For example, one participant from couple 10 explained the following: *"Adding more items could also be interesting so that the user actually has a debate between the items he wants to steal."* This participant specifically describes why having more stealable items would benefit the simulation. Like this participant mentioned, several participants mentioned the scare quantity of stealable items and recommended adding more.

Miscellaneous. Belonging to this category were codes referring to the physical room, the task in general, and the absence of guardians in the neighbourhood. Participant of couple 34 mentioned not being able to move around freely because of the limited space, while participant of couple 11 stated the tables to be in their way. Furthermore, some participants indicated that guardianship would increase the perceived risks of the burglary. Moreover, some participants stated that the way in which they had to commit the burglary was unrealistic to them, like participant of couple 3 explained: “ […] *it was also weird to just picking things up and dropping them again which does not seem that realistic.”*

Instructions. Some participants indicated not receiving sufficient instructions before starting their virtual burglary. For example, one participant from couple 10 mentioned: “*It was not clear to me which items I could pick up and which not.”*

Table 6

What did you like about the simulation?

Code label	Frequency	Description	Variation	Example quote
Realism	49	Resemblance to real life or reality	General	*"It was a very realistic and interesting experience. It was stunning to see that VR really feels like an actual place and experience."*
			Realism movement & behavior	*"I liked that I could be able to feel present in the environment and that it felt real to move around the house."*
			Realism environment	*"Everything in the environment looked very real, I actually had the idea that I was in someone's house."*
			Realism items	*"The items also looked quite realistic, so it made me feel as if I really was inside of a house."*
Interactivity	27	The intractability of the simulation	Interaction with environment & items	*"I really liked that we were able to roam around the house and open and close doors which made everything more realistic."*
			Interaction with partner	*"I really liked the concept of doing the virtual experience with another person, this enhances the experience and makes it more realistic since you are not doing it alone."*

Presence & Immersion	7	Feelings present in the environment	*"On moments I even forgot that there are other things around me in the real world."*
Graphics and details	7	Visual representation of the simulation	*"I liked the attention for detail throughout the entire virtual environment."*
Behaviour	4	Being able to behave different than in real-life	*"I really liked the feeling of being able to try out something that I would never do in real life."*

Table 7

What could we improve about the virtual experience?

Code label	Frequency	Description	Variation	Example quote
Technical aspects	57	Processes and operating of the simulation	Bugs and Glitches	*"As soon as I grabbed an item it started vibrating and sinking. If I was not fast enough to fit the item into the box, the item would fall."*
			Characters/Avatars	*"Think it would be closer to reality if the other person would have a more real appearing avatar."*
			Sensitivity of the controllers	*"The turning of the head made me quite dizzy, so slowing that down would be helpful."*

			Audio	*"If audio that was reflective of the environment was included, I would feel more aware of myself, my surroundings and actions."*
Interactivity	28	Interaction capabilities of the simulation	Interactivity objects and environment	*"As well as opening the fridge, the drawers, the closet and a few more things so that it felt more real."*
			Interactivity items	*"Adding more items could also be interesting so that the user actually has a debate between the items he wants to steal."*
Miscellaneous	12	Few addressed topics	Physical room	*"More room for the actual person to move in the real world. Often, furniture like the table and chair were a hindrance when moving in the virtual world."*
			Task in general	*"I felt like I did not have a lot of freedom to do stuff and also it was weird just picking things up and dropping them again which does not seem that realistic."*
			Guardianship	*"It felt like there were not really things at stake since there wasn't anybody around or no real danger or consequences to anything."*
Instructions	5	Instructions given by the experimenters		*"Maybe explain a bit more as to what objects can and which can't be picked up."*

Discussion

This study aimed to understand whether virtual reality is a suitable method in order to explore co-offending in residential burglary. In order for the simulation to be deemed suitable, participant's sense of presence was reported both subjectively and physiologically. Furthermore, whether the simulation was suitable for cooperation was evaluated exploring the relationship between experienced cooperation and burglary performance. Lastly, since this is a proof of concept, this study sought possible avenues for improvement for further application of a cooperative VR simulation.

Presence during a virtual burglary

First of all, of the three presence components, co-presence received the highest score, followed by spatial presence, and social presence. Participants subjective evaluation of experienced presence was not influenced by the level of cyber sickness experienced. Likewise, removing the VR goggles did not influence evaluated presence. Furthermore, the findings indicated the sense of co-presence to be related to spatial presence and social presence, while spatial presence and social presence were not related. These results suggest that participants who felt present in the virtual environment were more likely to experience a sense mutual awareness with the other. Additionally, those who felt present with the other perceived social interaction to be possible with their peer. Notably, it appears that high subjective spatial presence is not a necessary condition for social interaction to occur in the simulation, which may be due to the physical presence of participants in the same room. When all participants were included into the analysis, the physiological measure was unable to reveal a significant increase between the heart rate during the VR training and the burglary itself. On the other hand, heart rate did not increase as a consequence of the simulation. When those who removed their VR goggles at some point during the simulation were excluded from the analysis, results did in fact show a significant increase in heart rate as a consequence of starting the burglary. These latter results were in line with van Gelder and colleagues (2016), who were able to show a significant increase in heart rate when the burglary started. Contrary to the results from the subjective measure of presence, removing the VR goggles likely interfered with the presence experienced. As the main reason for removing the headset was cyber sickness, it is likely that this interfered with emotional response to presence but not with their subjective experience.

Cooperation and burglary performance

Participants' evaluation of their cooperation was not influenced by relationships, gaming experience, and cyber sickness. This indicates that cooperation is able to occur between unfamiliar participants and (online) gaming experience is likely not important for the simulation to foster cooperation. Furthermore, participants who reported their cooperation more positive than others exhibited a higher overall value accumulation, after accounting for the time invested in the burglary. However, the same did not lead to a higher total value per item when accounting for the number of items the participants stole. The first outcome fits within one of the reasons for burglars to co-offend in the physical world. Namely, burglars that co-offend can be more efficient with a decreased likelihood of apprehension at the time of the burglary (Lantz & Ruback, 2017). The absence of the relationship between item value ratio may have been influence by the unlimited time participants had to complete their burglary. For instance, participants' cue to end the simulation may have been when they were unable find any more stealable items rather than perceived time limits. In reality however, burglars who perform well are typically the one who take less time to accumulate more value (Meenaghan et al., 2018). Furthermore, the post hoc evaluation might have been influenced whether participants were successful or not in completing their task. For instance, if both participants adopted an individual approach and succeeded in reaching their individual goal, they might have evaluated the cooperation more positively simply because they were successful. However, in that case, the participants were not working cooperatively towards a common goal, rather, they worked independently towards their own goals. Based on the relationship between cooperation and value per second, it is likely that the simulation is able to foster effective cooperation in a VR burglary scenario.

Cooperation and Presence

Furthermore, results indicated that, of the three components of presence, only copresence was a positive predictor of the post hoc evaluation of cooperation. When participants felt present with the other in the virtual environment, they were more likely to evaluate their cooperation more positive. Furthermore, this relationship was not affected by the presence of the other participant. It is worth noting that the participants' assessment of the cooperation was not influenced by their perception of the simulations' ability to foster a social setting. It implies that, when participants have a shared sense of presence, it leads to better cooperation. However, the perceived ability to have a face-to-face interaction via the simulation is likely not essential for cooperation to occur effectively. The concept of presence is often seen an indication of immersion and behavioral involvement (Witmer & Singer, 1998), thus describing its effectiveness (Slater et al., 1996). The results from this study were able to establish a connection between co-presence and cooperation, indicating that its participants that felt immersed and involved with the other, perceived their cooperation to be more positive than those who were not. Although the two have never been related to each other, increasing the sense of co-presence may be helpful in fostering cooperation in the form of co-offending.

What did the user think?

As this study was on of the first to explore co-offending by means of VR, participants' opinions of the simulation were collected as well. When participants were questioned about the positive aspects of the simulation, they most often referred to the simulation as being highly realistic. Several directly indicated that the environment and their own behavioral capabilities via the simulation would resemble the real world closely. Some mentioned the VR simulation could be a substitution for the real world in which there were no consequences to behavior. Furthermore, many participants liked how interactive the environment was and were positive about the ability to work together in a burglary team.

When participants made suggestions for improvement, they often mentioned improving the technical aspects of the simulation, such as reducing bugs and glitches. Some of the participants even attributed discomfort to result from these aspects. This finding is in line with the high scores on the cyber sickness scale and provides a possible explanation for the occurrence. Improving these aspects may in the future improve the experiences of the participants. Moreover, while many participants mentioned the interactivity to a like aspect, however, about the same number of participants indicating a lack thereof. Several participants suggested adding more items which would be hidden in cabinets and closets. Some participants also mentioned adding dilemmas and risk in order to create the sense of a real burglary. These suggestions included adding more items or guardians into the environment. Other participants suggested more minor improvements such as clearer instructions, more space in the physical room, and adding environmental audio.

Limitations

As already alluded to in prior sections of this paper, although promising, this research is prone to limitations being a proof of concept. First, the virtual experience suffered from quite a lot of malfunctions. Experimenters had to intervene and help the participants regularly. Input coming from someone who is not in the simulation may have affected their feelings of immersion and presence as well as their ability to cooperate. Furthermore, the social presence subscale may have influenced the outcomes, as it had low internal consistency despite being a previously validated questionnaire by de Kort and colleagues (2007).

Second, although not an unknown phenomenon, participants experienced considerable discomfort. Cybersickness is a common occurrence in VR research, and it is suggested to be produced, among other things, by time delays between actual head movements and the movement of the virtual scene (Chang et al., 2022). Additionally, participants also mentioned, unnatural movement, like the sensitivity of the analog sticks and the glitches, to be at the root of their discomfort. Although the findings did not suggest interference from cyber sickness, it is nonetheless important for future application. Finding solutions to reduce cyber sickness by, for example, excluding those with a susceptibility to motion sickness (Chang et al., 2022), or providing enough space to move the body around freely (Chang et al., 2022), as well as more technical improvements (e.g. adapting the sensitivity).

Third, noteworthy was the low social presence score measured. There are a couple of plausible explanations to what may have caused this. First, one of the most mentioned topics by the participants were the virtual bodies of them and their peers. Having avatars has been shown to increase (social) presence rather than no avatars (Benta et al., 2008). There is, however, an indication that the user can experience high levels of social presence and copresence when they interact with non-human like characters (Nowak & Biocca, 2003), and floating heads and bodies (Heidicker et al. 2017; Dubosc et al, 2021). Additionally, humans expect highly realistic human-like avatars to mimic human behaviour, however, when it fails to do so, leads to adverse outcomes (Pan & Hamilton, 2018). When the focus of the interaction is on verbal communication, simple characters used in this research might be sufficient (Greenwald et al, 2017). On the other hand, when the interaction necessitates non-verbal communication, when the virtual burglary requires silence, for example, a more human-like avatar needs to be considered (Greenwald et al., 2017).

Second, there was a limited need for cooperation and collaboration during the virtual burglary. For example, in a small study, Casanueva & Blake (2000) explored social presence in a collaborative task within a virtual environment. They concluded that the level of co-presence was depended on the level of collaboration needed to complete a task. In other words, those who had to collaborate with their peers felt more present in the VE with the other participant. In our case, no particular strategy is needed in order to avoid failure to complete the task. A real burglar, for instance, may employ strategies to avoid apprehension (i.e., failure). Participants themselves specifically mentioned the lack of stealable items, carrying limit, time pressure, or consequences. Sintemaartensdijk and colleagues (2020), for example, previously demonstrated that simulated consequences are able influence participants. For instance, they showed, by adding simulated guardians into the simulation, that (ex)burglars perceived the neighborhood to be a less lucrative target. In the end, this may have limited them in their necessity to collaborate letting them to experience less social presence. More broadly, participants may experience more social presence in situations that refer attention toward their co-participant (Oh et al., 2018).

Directions for further research

Further research should obviously aim to improve the technical functioning of the virtual environment as well as aim to reduce cyber sickness. I expect that these malfunctions interfered with the outcome of this research as participants mentioned to be the main contributor to cyber sickness or restarts. However, even with its shortcomings, the outcomes suggest VR to be a valid way to investigate co-offending. In the future, it may provide the ability to study co-offending, burglary expertise can be observed, and difference in cooperative styles and decision-making may be uncovered. Nevertheless, for the creation a simulation suitable for co-offending research, there are several issues to consider.

First, further research should focus on the influences of the avatars on communication and cooperation. Simple avatars as used in this simulation might not be sufficient in varying burglary scenarios. Additionally, research has shown the influence of guardians in real life (e.g., Wilcox et al., 2008) as well as in VR (Sintemaartensdijk et al., 2020). Therefore, adding non-human avatars may influence the experienced realism as well. In addition, this enables the researcher to observe behaviours relating to guardianship, occupancy of residences, and detection risk and how co-offending fits into this process.

Second, adding interactivity, consequences, and dilemma's may be able to increase collaboration and social presence. At this point, our simulation may have been "to empty" for the need to cooperate. Indeed, Ijselsteijn and colleagues (2000) argue that increasing the intractability of objects, items, the environment, and actors will increase the experienced presence. For instance, adding more openable cabinets and closets in which participants can search for items may already improve this. Further research may, for example, add a more realistic way to handle the items. In this simulation there were no real consequences (only perceived consequences) to taking every item in sight.

Third, participants partook in the experiment in the same room and were communicating like they normally would. However, further research should test whether presence and cooperation are affected by participation in different rooms. It might be the case, for example, that this influenced their presence in a negative way as part of the sensory information originated from the physical environment rather than from the VE. Furthermore, sharing a physical space with the other might negatively influence performance on a cooperative task (Born et al., 2019).

Conclusion

To conclude, this study investigated whether VR is a suitable method investigate co-offending in residential burglary. As a proof of concept, despite its glitches and bugs, this paper already demonstrated promising results. The simulation was able to foster cooperation among participants while also increase their performance on the burglary task. Furthermore, the study preliminary establishes that the sense of being present with a peer in the VE can enhance the perceived cooperation. Finally, the participants perceived the simulation to be realistic and provided mainly technical improvements as suggestions. In the future, VR can be used to explore co-offending in residential burglaries in order to fill the gap that currently resides in burglary research.

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Appendices

Appendix A: Informed consent sheet

Participant Consent Form

Brief Summary of Project

Research into burglars using VR has only used simulations where one person could break into a house. However, most burglars do not work alone. In this research, two participants will be in the simulation at the same time and will be working together instead of one.

After an instruction, you put on the VR goggles and take the controllers. With these, you will be transported to a virtual environment where you will burgle a residence. You will have limited time to search for objects together with your fellow participant and take them with you. While you are doing this, several things will be measured like your heart rate and the value of the items you took.

After completing your time in the simulation, you will be given questionnaires that measure your immersion, presence (feeling of 'being there'), personality and that evaluate the interaction with your peer

In order to participate in this sturdy, we need to ensure that you understand the nature of the research, as outlined in the participant information sheet. Please tick the boxes to indicate that you understand and agree to the following conditions:

I confirm that I have read the participant information sheet for this study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

I understand that in order to take part in this study, I should be at least 18 years old and have no epilepsy. ☐

I understand that personal data about me will be collected for the purposes of the research study (e.g., name, gender and audio recordings), and that these will be processed in accordance with data protection regulations. ☐

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected. ☐

I understand that my data is anonymous and will be stored on secure university servers. I understand that I will only be used by the investigators for research purposes and that there is a possibility this research will be presented to other researchers or staff members. ☐

I understand that an audio recording will be made during this research. ☐

I agree to take part in this study. ☐

Participant's name

Participant's signature

Date

For any additional information or questions, please ask the researcher present or contact a member of the research team:

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Appendix B: Questionnaires

Presence

1. I felt like I was actually in the virtual environment
2. I felt like I was part of the virtual environment
3. It felt like I was physically present in the virtual environment
4. The items in the virtual environment gave me the feeling I could use them
5. I felt I could be active in the virtual environment
6. I felt I could move around the items in the virtual environment

7. It felt like I could do anything I wanted in the virtual environment
8. I was easily distracted during the interaction
9. It was easy to tell how my partner felt in the virtual environment
10. My partner was responsive towards me in the virtual environment
11. My partners behaviour was often a reaction to my own behaviour in the virtual environment
12. I felt as if my partner was actually in the virtual environment
13. The avatar of my partner made me feel like I was in the environment with another person
14. My own avatar made me feel like I was in the environment
15. What did you like about the virtual experience? [open question]
16. What could we improve about the virtual experience? [open question]

Cybersickness

1. The virtual environment made me nauseous
2. The virtual environment gave me a stomach ache
3. The virtual environment made me dizzy
4. The virtual environment made it hard for me to focus
5. My vision was blurry in the virtual environment
6. Did you take off the VR goggles during the experiment? Was it the beginning, middle or end of the VR experience?

Game experience

1. How many hours per week do you play games with a controller?

2. How many hours per week do you play games with a keyboard?
3. How many hours per week do you play (online) multiplayer games with a controller?
4. How many hours per week do you play (online) multiplayer games with a keyboard?
5. How many hours per week do you play (online) single player games with a controller?
6. How many hours per week do you play (online) single player games with a keyboard?
7. How many hours per week do you play VR games with a head-mounted display?

Cooperation

1. My partner and I were successful in the task we had to complete in the virtual environment
2. I believe I would have been more successful without my partner in the task we had to complete in the virtual environment
3. I am happy with the outcome of the task we had to complete in the virtual environment
4. I often find it difficult to work together with people
5. Teamwork is always the best way of getting results
6. I contributed more then my partner to achieve the task
7. I perceived my partner to be the leader while we were cooperating
8. I had a good idea how well my partner and I were performing the task
9. My partner had relevant knowledge and skills about the task we had to perform
10. I felt excited after completing the task
11. I felt frustrated after completing the task
12. I was not dependent on my partner to complete the task
13. I feel as if my partner and I had a shared goal in completing the task

14. I trusted my partner while we were completing the task
15. I think the quality of the communication with my partner while completing the task was low
16. I felt stressed out due to the actions of my partner during the task
17. The technology enabled me and my partner to cooperate effectively
18. I believed the chances of getting caught together with my partner during this task was low
19. What percentage of the time during the times you and your partner spoke during virtual Did you contribute (50% being you and your partner spoke equally, 10% means mostly partner talking and 90% mostly you talking)

Demographics

1. What is your age
2. What is your gender?
3. What is your highest level of completed education or education you are currently completing?
4. What is your country of origin?
5. What is your native language?
6. How would you rate your understanding of the English language
7. How well did you know the other person with whom you did the experiment before the VR experience? [see also Yuan et al, 2007 for reasons why it is important to ask]
8. What was the colour of your avatar?
9. What was the colour of the avatar of your partner?
10. How do you rate your knowledge of burglary prior to starting the experiment?
11. Did you follow the module 5 “Psychology of Safety” elective, and saw the lecture “Inside the mind of a burglar”? [will only be displayed if location = Twente]