

**“It’s Better to be Alone Than in Bad Company” – Is it?  
Virtual Reality Comparison of Solo and Paired Burglars**

Julie Erber

Section of Psychology of Conflict, Risk and Safety

Behavioural, Management and Social sciences, University of Twente

Dr. Iris van Sintemaartensdijk

Dr. Steven J. Watson

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### **Abstract**

Most criminological research perceives crimes through the lens of a single victim and a single offender perspective. In reality, law enforcement organisations recognise a high prevalence of crimes committed in groups, particularly burglaries. This study examines the differences between solo and duo offenders in the success and in the moment behaviour of a burglary, as well as how the presence of an accomplice impacts risk perception. Furthermore, respective associations with the HEXACO personality model are investigated. In a virtual reality experiment, 134 students were asked to burgle a house with a partner, and 61 students were asked to burgle the identical house alone. In total, student dyads stole more items, gained higher monetary value, and took more time for the burglary. The presence of an accomplice did not affect the level of perceived risk. As for personality, only a profound analysis of the dyad data revealed that the participant's extraversion negatively impacts perceived risk in the presence of another. This study showcases important differences in the approach of solo and duo offenders to burglary. Given that dyads spent more time on the burglary, this could signal that dyads willingly take more risks. Further research on co-offending with incarcerated burglars is needed to replicate these findings in a more representative sample and to further explore the role of personality. Consequently, it would be possible to advance researchers' understanding of how solo and duo burglars behave.

*Keywords:* Virtual reality, burglary, co-offending, perceived risk, personality

### **“It’s Better to be Alone Than in Bad Company” – Is it? Virtual Reality Comparison of Solo and Paired Burglars**

Burglary is one of the most feared crimes, but still, its clearance rate is concerningly low (Cecatto, 2016). This imbalance led to a rising interest in research about the motives, behaviours, and cognitive processes of burglars (e.g., Meenaghan et al., 2020 and van Sintemaartensdijk, 2022). Recently, burglary rates in Enschede increased by 75% compared to the year before (Haverkate, 2022). This emphasises the significance of understanding burglars to increase deterrence and design preventive interventions. Research attempted to show how burglars select their targets, what routes they take within the property they are burgling, and how offenders’ behaviours are linked to personality (van Gelder et al., 2017; van Gelder et al., 2022; van Sintemaartensdijk et al., 2022b). However, existing research focuses on the single offender-single victim approach commonly used in crime research, even though especially burglaries are often committed in groups (Ashton & Bussu, 2022; Burrell, 2022).

Despite the high frequency of burglaries committed in groups, there is a significant gap in researchers’ understanding of how behaviours differ when committing a burglary in a group instead of individually. From an academic perspective, contrasting singular and duo burglars can unravel differences in decision-making, outcomes of the crime, and deterrence. Additionally, studying how personality comes into play will deepen this knowledge base offering means to avert burglars (van Sintemaartensdijk et al., 2022b). Personality has been repeatedly linked with criminal behaviour (van Gelder et al., 2017; van Sintemaartensdijk et al., 2022b). Since distinct personality traits may become central in solo and group offences, including personality adds another layer to the comparison of the two approaches to offend. Overall, gaining insights into co-offending and its association with personality advances predictions about burglars’ behaviour, paving the way to design interventions preventing burglaries and re-offending (van Sintemaartensdijk et al., 2022b).

The present study tackles the above-mentioned goals by using virtual reality (VR) to model the conduct of a burglary (the offenders’ behaviour exhibited during the crime) within a controlled virtual residence, to compare actions taken, the perception of risk, and outcomes of students burgling a house alone with students burgling in pairs. Moreover, personality will be assessed to test whether there are differences per personality type on how people commit burglary and whether some personality types do better alone than in company.

#### **Co-offending in Burglary**

The prevalence of co-offending is particularly high for burglaries and among young perpetrators (Alarid et al., 2009; Andresen & Felson, 2012; Sanercki, 2001, as cited in van Mastrigt, 2017; van Mastrigt & Farrington, 2009). Burglary is a systematic crime, meaning burglars systematically search for valuable items (Nee et al., 2015). Further, burglary is a spatial crime, meaning offenders carefully select targets and routes taken within that target (Hipp, 2016). Combined many decisions need to be taken ranging from the means used to enter the house, to which items are profitable and handy enough to carry. Arguably choices specific to a burglary are altered when offending in a group.

Researchers have widely argued that the execution of a crime and decision-making processes vary depending on the aggressors' group size (Burrell, 2022; van Mastrigt, 2017). For instance, research about robberies found that the presence of others may increase violence and uncovered a positive relationship between the number of offenders and the value of the stolen items (Burrell, 2022; Carrington, 2002, as cited in Tillyer & Tillyer, 2015; Lantz, 2021). Further, research demonstrates that decision-making strategies regarding the target selection of groups are altered compared to the target selection of lone offenders (Coupe, 2017). So far, research about burglary mostly examined how offender characteristics differ among singular versus group crimes and how this influences decisions prior to the crime, i.e., general planning and target selection (Alarid et al., 2009; Burrell, 2022; van Mastrigt, 2017). Fewer studies investigated how co-offending affects behaviour during a burglary and through which social processes these emerge (Burrell, 2022; van Mastrigt, 2017).

### **Group Dynamics in Burglary**

On the whole, criminologists do acknowledge the relevance of co-offending and for instance investigated how it affects the outcomes of a crime (Tillyer & Tillyer, 2015; Viki & Abrams, 2013, as cited in van Mastrigt, 2017). Yet, existing research does not investigate social processes coming into play shifting criminals' thinking and *how* an accomplice affects criminal behaviour in the moment of a crime or during a burglary specifically (van Mastrigt, 2017). From a practical perspective, using social psychological theories to enhance understanding of group dynamics in crimes could facilitate police investigations (Burrell, 2022; Van Mastrigt, 2017). This indicates a need to test the practicality of social psychological theories in the context of delinquency (van Mastrigt, 2017).

There are opposing predictions that could be made about group dynamics occurring during a burglary. Logically, two people can carry more items and can work in two rooms at the same time, which would lead to the assumption that they are more efficient than an

individual. Consequently, less input is needed from the individual since the offenders' combined efforts may still generate greater gains compared to a singular offender's gains. However, group dynamics make this process much more complex. On the one hand, co-offenders may experience more thrill during the offence leading to increased motivation of the perpetrators (Weerman, 2003). On the other hand, working collectively can result in a loss of coordination or even a loss of motivation (Latané & Williams, 1979, as cited in Forsyth, 2019c). Moreover, two people must communicate with one another to reach decisions. An illustration could be colleagues working on a shared project. Some people may only make minimal effort assuming other people will put things in motion. Contrary, a colleague could ignite a spark of inspiration increasing excitement experienced towards the task. Next, despite a member's level of commitment, eventually, a plan of action needs to be agreed on collectively. Coming to an agreement may also take time. In like manner, co-offending could both facilitate and impede a burglary.

Existing research by Tillyer and Tillyer (2015) inspected data from criminal reports of robbery filed by law enforcement agencies in the United States and found that even though co-offenders indeed make higher monetary gains, on average individual offenders gained less since the stolen goods need to be divided. These findings are thought to be transferable to burglary, as both robbery and burglary are instrumental crimes involving theft, posing the risk of severe penalties if offenders get caught (Salfati & Canter, 1999). Nevertheless, the study does not give transparent insights into the decision-making of solo offenders versus dyads and their underlying dynamics. Contrasting the outcomes of a solo burglary with the outcomes of a burglary conducted by a dyad will highlight whether and how the number of offenders impacts a burglar's decision-making.

### **Risk Perception and Risk-Taking Behaviours of Co-offenders**

A vital concept impacting decision-making during a criminal act is the *risky shift effect*, which describes the "tendency of groups to make riskier decisions" compared to decisions an individual would make by themselves (Forsyth, 2019a, pp. 392). The effect is explained by an illusion of invulnerability, which makes it appealing to investigate the perceived risk of offenders (Forsyth, 2019a). In the context of burglary, risk perception is relevant to decision-making as it may influence the time a burglar decides to spend in the house, how many items they are going to take, or which target they select (van Sintemaartensdijk et al., 2022b). Risk is considered a central component in prominent crime theories, like routine activity theory, and risk-gain assessment plays an important role in decisions made at the burglary scene (Coupe, 2017). Therefore, investigating perceived risk

can push towards an answer about whether an accomplice leads to enhancing or restraining social processes.

Existing research results about the risk-taking behaviours of co-offenders are ambivalent. Van Mastrigt (2017) suggests target selection between lone offenders and groups differs due to *group polarisation*. Similar to the risky shift effect, this phenomenon leads members to take on more extreme attitudes, which is induced by the need for approval and a need to conform to the group (Moscovici & Zavalloni, 1969, as cited in van Mastrigt, 2017). In the context of burglary, group polarisation may result in choosing larger and riskier targets (van Mastrigt, 2017). Moreover, even though more pronounced in larger groups, people feel more anonymous in groups. Anonymity reduces the fear of being observed or detected (Lantz, 2021). Likewise, research in adjacent fields about robbery found that groups give a reassuring comfort, which reduces the fear of getting caught (Alarid et al., 2009; Hauffe & Porter, 2009, as cited in Burrell, 2022; McGloin & Piquero, 2009). These processes together may lead an offender to perceive committing a burglary as less risky in the presence of another leading to higher risk-taking.

Contrasting a lowered risk perception, Cromwell et al. (1991, as cited in van Mastrigt, 2017) found that burglars make more prudent decisions in the presence of an accomplice because in sum they can identify more dangers than one person alone. Similarly, a study of US robbers found that group offenders were neither more cautious nor riskier in their real-world target selection than solo offenders (Alarid et al., 2009). Van Mastrigt (2017) proposes that increased risk awareness is counterbalanced by higher anonymity and recklessness induced by the need to show off in front of peers, leading to similar decisions as lone offenders. However, there is no evidence in research yet supporting this notion. Also, this argumentation rather applied to planning and selecting a target instead of behaviour while executing the crime (van Mastrigt, 2017).

The question remains to what extent risk perception during a burglary between individual burglars and paired burglars differs. Based on social psychological literature, it is likely that dyads perceive risks during a burglary as lower (Forsyth, 2019a). Further, the time groups need to make a careful decision in assessing risk could prolong time spent in the house, which arguably reflects a higher risk-taking (Van Sintemaartensdijk et al., 2022b). Comparing solo burglars to duo burglars concerning their risk perception and risk-taking behaviours can highlight how the perception of risk during a burglary is influenced by the number of offenders. Unravelling how solo and duo offenders appraise risks adds to the theoretical knowledge required to put forward measures to deter burglars.

### **Personality in Burglary and Co-offending**

Another fruitful avenue for uncovering differential approaches to burglary is the study of personality. Personality is not only linked to criminal behaviour but also to team performance, which makes personality particularly interesting to study in co-offending (van Sintemaartensdijk et al., 2022b; Zhong et al., 2019). Studying how burglary and personality are associated can predict actions by burglars, offering insights for designing interventions (van Gelder & de Vries, 2012; van Sintemaartensdijk et al., 2022b). Important differences in the relevance of certain personality traits on a burglar's decision-making are expected to emerge when offending in a group since personality impacts group dynamics (e.g., Barry & Steward, 1997; Bell, 2007). Hence, it is important to investigate the link between personality and co-offending burglars.

The most comprehensive model of personality predicting criminal behaviours is the HEXACO model (honesty-humility, emotionality, extraversion, agreeableness, conscientiousness, and openness to experience; Ashton et al., 2014). Unlike its predecessor, the five-factor model (FFM), this framework includes the dimension honesty-humility, which has been widely accepted as a strong predictor of anti-social tendencies (Ashton & Lee, 2020; de Vries et al., 2016; Jones, 2017; Levidi et al., 2022). The model has repeatedly found links between personality traits and involvement in crime (e.g., Ashton et al., 2014; Burt, 2020; Samenow, 2022). Work addressing the effect on behaviour during a crime is more limited.

Van Gelder et al. (2017) represent one of the scant researches examining how personality traits affect behaviour during a (solo) burglary. Drawing on a student sample, their study identified a negative correlation between conscientiousness and the monetary value of the items stolen. Notably, inspecting burglar samples frequently accentuates distinct traits as influential as student samples. Empirical evidence from such a burglar sample highlighted that burglars scoring higher on honesty-humility but lower on conscientiousness took less time scouting (i.e., traversing a neighbourhood to find a suitable target) and travelled smaller distances within the neighbourhood (van Sintemaartensdijk et al., 2022b). Simultaneously, low honesty-humility is associated with deliberate higher risk-taking, which supports the former finding as risk-taking could manifest in taking more time for a burglary. Spending more time at the scene subsequently increases the likelihood of the house owner coming back during the crime event, which heightens the faced risk (van Sintemaartensdijk et al., 2022b; Weller & Tikir, 2011, as cited in van Gelder et al., 2022).

According to phenomena like the previously introduced risky shift effect, risk perception is however generally thought to be lower when offending with an accomplice



(Alarid et al., 2009; Hauffe & Porter, 2009, as cited in Burrell, 2022; McGloin & Piquero, 2009). So even though someone higher on honesty-humility is lower in risk-taking, in a group they may express equally risky tendencies like someone lower on honesty-humility alone. As such, fluctuations in risk perception based on personality type may be less prominent in a duo burglary, which could indicate that honesty-humility has a greater impact on a solo burglar compared to a burglar dyad. Accordingly, there may only be an effect of honesty-humility on the behaviour of a solo burglar, but not on a burglar dyad.

While honesty-humility is predictive of burglary involvement, extraversion and agreeableness are linked to increased team performance which could affect co-offending (Barry & Steward, 1997; Bell, 2007; van Gelder et al., 2017). As for extraversion, Barry and Steward (1997) found that a higher proportion of extraverted group members leads to an increased group's focus on the task, and group members identified extraverted people as particularly impactful on the group. Moreover, extraverted individuals were hypothesised to be more persuasive in decision-making, which lies at the core of an efficient burglary. Further, extraverts enhance team effectiveness (Kozlowski & Bell, 2003, as cited in Macht et al., 2014).

Following a similar notion, according to Bell (2007) agreeableness has the strongest link among FFM personality traits to team performance since it facilitates cooperation and social harmony, leading to more contribution by each member. Similarly, agreeable people seem to jointly work towards a team's goals, nurturing effective teamwork (Aronoff & Wilson, 1985, as cited in Neumann & Wright, 1999; Neumann & Wright, 1999). Lastly, both extraversion and agreeableness have often been linked to improved communication, which leads to increased team cohesion and again, increased team performance (Bradley, 2013; Kozlowski & Bell, 2003, as cited in Macht et al., 2014).

Consequently, while extraversion and agreeableness may not have an impact on a solo burglary, these traits may affect how co-offenders perform. Subsequently, dyads with extraverted or agreeable partners may make more efficient decisions and spend less time in the house. Further, endorsing a strong focus on the goals (i.e., monetary gain) may combat the often-established loss of coordination in groups (Latané & Williams, 1979, as cited in Forsyth, 2019c). On the contrary, while honesty-humility affects a solo burglar, it essentially may not impact a dyad. Therefore, the question is whether the link between a burglar's decision-making and honesty-humility is only found in a solo burglary, while extraversion and agreeableness uniquely contribute to the understanding of a duo burglary.

### **The Current Study**

Practical and ethical obstacles pose a problem in studying burglary in the real world (Meenaghan, 2018; van Gelder et al., 2014). VR offers the possibility to recreate real-world settings in an immersive manner and thereby study burglars in action (Meenaghan, 2018; van Gelder et al., 2017; van Gelder et al., 2022; van Sintemaartensdijk et al., 2020). The method has been widely applied to deepen understanding of burglar decision-making, and to observe and track routes of burglars (Meenaghan, 2018; van Sintemaartensdijk, 2022). Crucially, what makes VR studies superior to vignette studies is its power to create an immersive world generating a feeling of “presence” that cannot be generated by written scenarios (van Gelder et al., 2019).

The present research uses VR to investigate how singular burglars and paired burglars differ in success and their approach to burglary and how this is impacted by social psychological mechanisms regarding risk, and personality. Participants were immersed into a virtual residential neighbourhood and guided to a house they were instructed to burgle. For the experiment, test subjects were assigned to one of two burglary type conditions. Either they completed the experiment with a partner (duo burglary), or they completed the experiment alone (solo burglary). In both trials, after finishing the experiment, participants responded to questionnaires about perceived risk and their prominent personality traits classified by the HEXACO model. Moreover, time spent in the house and monetary outcomes (items that were stolen and their value) were analysed. The outcomes of both burglary types were compared to assess differences in risk perception and (risk-taking) behaviours of solo and duo burglars. Further, the association of personality with the two types and the outcome variables was investigated.

## **Method**

### ***Participants and Design***

In total, 195 participants took part in the study in either one of two conditions (burglary type: duo versus solo). Participants were recruited by convenience sampling. Inclusion criteria were being at least 18 years of age, not suffering from epilepsy, and possessing adequate English skills. In the duo condition, 134 participants completed the experiment in pairs, resulting in 67 couples. In the solo condition, 61 participants completed the experiment in individual trials. Of the participants, 114 identified as female (59.4%; male,  $N = 73$ , non-binary,  $N = 3$ , prefer to self-describe,  $N = 1$ , prefer not to say = 1) for the overall sample, with 81 identifying as female in the duo sample (61.8%, male,  $N = 45$ , non-binary,  $N = 3$ , prefer to self-describe  $N = 1$ , prefer not to say  $N = 1$ ), and 33 in the solo sample (54.1%, male,  $N = 28$ ). Participants’ mean age was 22.6 ( $SD = 5.6$ ), with 22.6 ( $SD = 6.3$ ) in the duo

sample, and 22.7 ( $SD = 3.5$ ) in the solo sample. Data was collected at the University of Twente. Participants enrolled in the psychology track were compensated with course credit. Additional data for the duo condition was collected at the University of Portsmouth. In total, people from 33 countries took place in the study. Most people in the dyad study were from Germany (32.1%), the UK (18.3%), or the Netherlands (17.6%). In the solo iteration, the majority was from Germany (52.5%) or the Netherlands (19.7%).

### ***Materials***

**Virtual Neighbourhood.** The neighbourhood was designed for the Virtual Burglary Project and programmed using the Unity Pro Engine (2021.3.4f1). The environment was designed using assets available in the Unity store. The most suitable environment was selected and adapted to a Dutch/UK-style neighbourhood by removing American flags and replacing fences with hedges to increase realism for participants. The final neighbourhood consisted of one street with five middle-class houses distributed on both sides of the street and more houses behind them. The houses differed in their looks to keep the neighbourhood from looking too uniform. Differences between the houses were, for instance, that only some houses had a chimney or a designated garage. Since pilot studies of prior research found that bare neighbourhoods are experienced as “empty”, items like trees, cars, garbage bins, and lamps in the front yards were added (van Sintemaartensdijk, 2022) (see Figure 1). The street depicted in Figure 1 was only used as a practice environment for participants to get used to VR. In later trials, floating grey cubes were distributed on the street and in the house. By putting an item in one of the cubes the chosen good was marked as stolen. The “dropzones” were added to make stealing items more realistic.

**Figure 1***Outlook of the Street*

Participants viewed the simulation using the Oculus Quest 2 VR head-mounted display with a stereoscopic view. The goggles enabled them to look in all directions to allow for instinctive movement through the environment. Game controllers were used for participants to traverse through the environment and hold on to objects when stealing items or opening doors. In the environment, participants could only enter and burgle one specific house, which was signalled by a red front door. The design choice of only enabling the entrance of one house was made to decrease noise, i.e., data of participants scouting through the neighbourhood, as this study specifically focuses on behaviour in a house when committing a burglary. Further, it ensured that all trials were comparable since time spent in the house would inevitably differ if the outlooks of the houses participants entered were different.

Figures 2, 3, and 4 show the exterior and the interior of the house participants were asked to burgle. The house consisted of a ground floor only. Entering the house, test subjects were situated in a hallway and could freely go into a storage room, office, bedroom, living room, kitchen, and bathroom. Participants could steal items differing from a computer to a TV and vases. In total, 27 distinct items could be taken (see Appendix A for a complete overview).

**Figure 2**

*House Participants Were Asked to Burgle*

**Figure 3**

*View of the Kitchen and Living Room in the House*

**Figure 4**

*View of the Office in the House*



***Time Spent in the House and Stolen Items.*** Due to programming issues, time spent in the house and movement of the participant were not tracked by the virtual environment (VE). Hence, time spent in the house was manually traced by watching screen recordings, which were saved using the Open Broadcast Software. Similarly, items stolen were noted by watching recordings of the experiment. Afterwards, the value of the items was added using a predefined assessment of the items. The time spent in the house, number of items stolen, and value of items stolen were averaged. Since spending a longer time in the house increases the chance of the homeowner returning and the chance of being caught, time was further considered an objective measure of risk (van Sintemaartensdijk et al., 2022b).

### **Questionnaires.**

***Presence.*** A 14-item scale was administered to assess presence. The first seven items measured spatial presence ( $\alpha = 0.70$ ) which reflects the extent to which participants felt present in the virtual world (e.g., “I felt like I was actually there in the virtual neighbourhood; van Sintemaartensdijk et al., 2020; see Appendix B). Additionally, four items measured social presence ( $\alpha = 0.46$ ) to assess the degree to which participants experienced they could interact with their partner in the VE (e.g., “My partner was responsive towards me in the virtual environment”) (Bulu, 2012; Molinillo et al., 2018). Lastly, three items measured copresence, i.e., the feeling of “being there” with one’s partner and having a sense of feeling or perceiving the other and being perceived by the other ( $\alpha = 0.67$ ) (e.g., “The avatar of my partner made me feel like I was in the environment with another person”; Biocca et al., 2001). Since social presence and copresence were not relevant in a solo burglary, only the first seven items of the scale were administered in the solo iteration. All items were answered on a 5-point Likert scale from “*strongly agree*” (1) to “*strongly disagree*” (5) and averaged into an overall presence score ( $M = 3.5$ ,  $SD = 0.5$ ). A higher score on the scale indicated that the participant felt immersed in the VE. According to the reliability classification of Glen (2023), reliability was acceptable,  $\alpha = .77$ . Furthermore, two open questions about how participants liked the VE and what could be improved about it were included. The open questions were not analysed for the current study.

***Cyber-sickness.*** Feelings of cyber-sickness were measured using an altered version of the Simulator Sickness Questionnaire (Kennedy et al., 1993). To compromise the questionnaire, only five items of the originally 15-item scale were used as done by van Sintemaartensdijk et al. (2020 & 2022a). The scale assessed feelings of discomfort (e.g., “The virtual environment made me nauseous”) using a 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*). Scores were averaged with higher scores indicating an increased level of

discomfort. Overall, reliability was found to be acceptable,  $\alpha = .79$  (Glen, 2023).

Additionally, an item asking about whether participants took off the goggles during the experiment was added.

**HEXACO-60.** The 60-item inventory as constructed by Ashton and Lee (2009) was used to assess six personality facets: honesty-humility ( $\alpha = .59$ ), emotionality ( $\alpha = .81$ ), extraversion ( $\alpha = .81$ ), agreeableness ( $\alpha = .68$ ), conscientiousness ( $\alpha = .77$ ), and openness to experience ( $\alpha = .52$ ). The inventory incorporates 10 items per personality facet answered on a 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*). Some items followed a reversed scoring scheme and hence needed to be reversely coded. The mean scores per personality factor were calculated to assess the final scores (e.g., “I feel reasonably satisfied with myself overall” to assess extraversion). Higher scores represented a greater disposition of a trait.

**Game Experience.** To rule out the potential influences of participants’ level of gaming experience on behaviour in the VE, participants were asked about whether they engage in video gaming. If they answered yes, they could indicate their preferred type of gaming (using controllers or a keyboard) and were presented with questions about how many hours they played with controllers a week ( $M = 2.3$ ,  $SD = 0.8$ ), in an online multiplayer mode ( $M = 1.7$ ,  $SD = 0.7$ ), and an online single mode ( $M = 1.9$ ,  $SD = 0.8$ ). Further, they were asked about how many hours they played with a keyboard ( $M = 2.8$ ,  $SD = 1.2$ ), in an online multiplayer mode ( $M = 2.3$ ,  $SD = 1.2$ ), and an online single-player mode ( $M = 2.0$ ,  $SD = 0.9$ ). Participants in the solo condition were only inquired about their single-player gaming experience. Lastly, test subjects were asked to indicate the hours they play with VR devices a week ( $M = 0.7$ ,  $SD = 0.7$ ). The items could be answered by choosing one of six predefined scales covering different ranges of hours (van Sintemaartensdijk et al., 2020).

**Additional Measures.** As this study was part of a larger study, additional measures were taken that are not of interest in the present thesis. These included heart measures that were taken using the Empatica E4 wristband tracker. Heart rates were averaged for three distinct sequences within the experiment: the start of the experiment, a training phase, and during the virtual burglary. Moreover, test subjects filled in questionnaires assessing self-control, and cooperation, which was adapted to task experience for the solo condition. Importantly, the cooperation/task experience scales incorporated the item: “I believe the chances of getting caught [together with my partner] during this task were low”. This item was also analysed independently of the scales and is referred to as the perceived risk score in the following. Participants who took part in the solo condition also filled in a perceived risk questionnaire, which was not analysed in this study given that it was only administered in one

condition prohibiting a comparison of the burglary types. A more detailed description of the additional questionnaires can be found in Appendix C.

### ***Procedure***

The research was approved by the Ethics Committee of the Behavioural Management and Social sciences at the University of Twente (approval code: 230146) and the FHSS Ethics Committee at the University of Portsmouth (reference number: FHSS 2022-025). All participants of the duo burglary were assigned a partner. Test subjects in the solo burglary completed the trial alone. Before the experiment started, participants were presented with an information sheet highlighting the outline of the study and an informed consent. At least one researcher was present who then explained the scenario of the study, in which the students burgle a house. Further, instructions were given on how to use the technical devices. Afterwards, participants were equipped with VR goggles, game controllers, an Empatica wristband, and put in the VE. To mark the start of the simulation in the heart measures, the experimenters pressed the Empaticas. Further, screen and voice recordings were started. Subsequently, participants completed a short practice phase in which they could grab a candlestand. In later trials, they could further put the candlestands in a dropzone. Hereby, participants got used to the walking motion and the notion of grabbing items.

Next, participants were instructed to walk towards the designated house. The experiment started as soon as participants entered the house. At this point, the Empaticas were pressed a second time, so changes in heart rate due to the start of the burglary could easily be traced back. Test subjects could freely walk through the house, steal items, and in the duo burglary communicate with each other by their preference. Items were logged as stolen when participants grabbed an item and put it down again. Participants in later trials could steal items by putting them in the dropzones. Time spent in the house was decided upon by the participants. The experiment was done as soon as they left the house, and the experimenters pressed the Empaticas once more.

In the following, participants filled in a Qualtrics questionnaire in an individual room without any distractions. After completing the questionnaires, they were asked about their demographics in Qualtrics. Lastly, a researcher debriefed them about the goals of the study, and Psychology students of the University of Twente received their credits. The experiment took about 60 minutes per participant pair and about 45 minutes per solo trial.

## **Results**

### **Preliminary Analyses**



Table 1 highlights the means and standard deviations for each burglary type and the total sample of both conditions. Further, Pearson's correlation for all variables that were of focus in the present study is illustrated per study in Tables 2 and 3. The correlations were computed to explore the strength and direction of the relationship of the variables and to assess first differences between the samples.

**Table 1**

*Means and Standard Deviations of Time Spent in House, Number and Value of Items Stolen, Perceived Risk, Personality, and Presence for Duo Burglars, Solo Burglars and Total Sample*

	Duo Burglars	Solo Burglars	Total Sample
Time in House	687.8(370.9)	355.2(155.7)	592.5(357.2)
Number of Items Stolen	11.5(6.2)	7.4(3.7)	10.3(5.9)
Value of Items Stolen	2799.8(1262.2)	2132.0(925.3)	2608.0(1211.4)
Perceived Risk Item	2.5(1.3)	2.3(1.1)	2.5(1.2)
Honesty-humility	3.4(0.5)	3.4(0.4)	3.4(0.5)
Emotionality	3.3(0.7)	3.2(0.7)	3.3(0.7)
Extraversion	3.3(0.6)	3.5(0.6)	3.4(0.6)
Agreeableness	3.2(0.5)	3.2(0.5)	3.2(0.5)
Conscientiousness	3.5(0.6)	3.6(0.5)	3.5(0.6)
Openness	3.4(0.5)	3.4(0.5)	3.4(0.5)
Cyber-sickness	3.4(1.3)	4.0(1.3)	3.8(1.3)
Spatial Presence	3.5(0.5)	3.6(0.5)	3.6(0.5)
Social Presence	3.4(0.6)	NA	NA
Copresence	3.5(0.9)	NA	NA

*Note.* Scale of 1 (*strongly disagree*) to 5 (*strongly agree*) for all variables except time (in seconds), number of stolen items (count), and value of stolen items (in euro). The perceived risk item was administered as part of the cooperation scale.

**Table 2**

Correlations of the HEXACO Personality Traits for Duo Sample for Responses and Observations of Burglary Success

	Time	NItems	VItems	Risk	H	E	X	A	C	O
Time										
NItems	.25**									
VItems	.08	.71**								
Risk	.02	-.07	-.11							
H	-.05	-.09	-.19*	-.09						
E	.00	-.05	-.14	.07	.25**					
X	.14	.05	.00	-.18*	-.04	-.19*				
A	.06	.00	-.06	-.09	.10	-.14	.07			
C	.09	-.04	-.04	-.04	.10	.14	.20*	-.01		
O	-.04	-.15	-.18*	.07	.18*	.09	.15	.10	.18*	

*Note.* \* $p < 0.05$ . \*\* $p < .01$ ;  $N = 134$ ; Time = time spent in the house, NItems = number of items stolen, VItems = value of items stolen, Risk = perceived risk as indicated by item, H = honesty-humility, E = emotionality, X = extraversion, A = agreeableness, C = conscientiousness, O = openness to experience.

**Table 3**

Correlations of the HEXACO Personality Traits for Solo Sample for Responses and Observations of Burglary Success

	Time	NItems	VItems	Risk	H	E	X	A	C	O
Time										
NItems	.39**									
VItems	.21	.65**								
Risk	.03	.25	.09							
H	-.14	-.13	-.23	.05						
E	.28*	.05	.00	.06	.30*					
X	-.10	-.06	-.07	.00	-.03	-.26*				
A	.02	.11	.05	.04	.07	-.09	.07			
C	.13	-.20	-.22	.19	.09	.15	-.06	-.24		
O	-.02	-.08	.01	-.09	.00	.05	.16	.11	-.04	

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*Note.* \* $p < 0.05$ . \*\* $p < .01$ ;  $N = 61$ ; Time = time spent in the house, NItems = number of items stolen, VItems = value of items stolen, Risk = perceived risk as indicated by item, H = honesty-humility, E = emotionality, X = extraversion, A = agreeableness, C = conscientiousness, O = openness to experience.

### **Main Analyses**

The dependent variables were the time spent in the house, the number of items stolen and their respective value, and the perceived risk of getting caught. Multiple linear mixed models with the restricted-maximum likelihood estimation method were calculated. In the first four models, burglary type (duo versus solo) was treated as a fixed effect, trial as a random effect (trial numbers were assigned to every participant, highlighting the duos that participated in the same trial), and time in house, number of items stolen, value of the items stolen, and risk were added as dependent variables in one model each to assess differences in the behaviour and risk perception between the solo and dyad burglars. In the second four models, burglary type and the HEXACO personality traits were treated as fixed effects, trial as a random effect, and one of the dependent variables was added per model. In the third set of models, four linear mixed models per HEXACO trait were performed on the duo data to assess partner effects of personality. The participant's HEXACO score and the partner's HEXACO score were treated as fixed effects, trial as a random effect, and one of the dependent variables was added per model. To clean the data, compute correlations, and calculate Cronbach's alpha, the statistical software IBM SPSS (Version 28.0.1.0) was used. For all other analyses R studio (Version 2023.06.0+421) was used.

### **Burglary Success and Risk in the Solo and Duo Condition**

The relevant statistics for the first models are depicted in Table 4. As predicted, significant differences emerged between students who burgled the house alone and students who burgled in pairs on the number of items stolen and the value of the items stolen. The results reveal that dyads stole a greater number of items, achieving higher monetary gain compared to the solo condition.

For number of items stolen there is considerably greater variability among trials than the unexplained variability after accounting for condition and trial. Similarly, the variations for the value of the items stolen varied greatly among trials, while there was negligible variation attributed to the residual error. Hence, in both models, the trial numbers accounted for a substantial proportion of the variance within the data. Put simply, the divergence of the

scores between the couples was greater than the divergence of each couple from its predicted score, proving a good fit of the model.

**Table 4**

*Comparing Solo and Duo Burglars on Success and Risk(-taking)*

Variable	<i>F</i>	<i>p</i>	<i>SD<sub>between</sub></i>	<i>SD<sub>residual</sub></i>	<i>R</i> <sup>2</sup>
Number of items stolen	41.60	.022*	4.2	0.0	.23
Value of items stolen	10.49	.002**	1127.6	2.6	.07
Perceived risk	1.72	.191	0.0	1.2	.01
Time spent in the house	36.92	<.001**	292.6	56.5	.20

*Note.* \* $p < 0.05$ . \*\* $p < .01$ .; These and the following  $R^2$  refer to the marginal R-squared, meaning they indicate the variance that is explained by the fixed effects only.

With regards to perceived risk, no significant difference emerged between the two burglary types. Contrary to the expectations, perceived risk in the dyad condition was similar to the solo condition. Also, the markedly low explained variance signals a lack of effect of the number of people involved in a crime on perceived risk. In summary, the presence of an accomplice does not seem to impact the perception of how likely it is to be caught.

Opposed to these findings, time spent in the house significantly differed between the solo and duo conditions, revealing dyads took more time to commit the burglary. Since time spent in the house was conceptualised as an objective measure of risk, this also suggests decreased consideration of risk in group offences. Thus, while the reported perceived risk may not differ between the two groups, the actual behaviour may signify otherwise.

For perceived risk, the residual standard deviation was greater than the between trial standard deviation, suggesting the random effect of trial does not contribute to explaining the variance in the data. For time in the house, there is considerable variation between the trials, and less within trials, which shows controlling for trial proves a good fit for the analysis.

Since preliminary analyses revealed self-control and cyber-sickness significantly correlated with one or more of the outcome variables that showed a significant effect above, auxiliary analyses accounting for self-control and cyber-sickness were run. A detailed description of the analyses can be found in Appendix D, showcasing relevant statistics in Tables 13 and 14 (Appendix D). In short, the analyses disclosed that neither self-control nor cyber-sickness had a critical impact on number of items stolen, value of items stolen, or time

spent in the house. Yet, when accounting for self-control or cyber-sickness, burglary type no longer significantly impacted the number of stolen items.

### Personality in Solo and Co-offending

The relevant statistics for the second models, including standard deviations to inspect the fit of the models, are depicted in Table 5. Linear mixed models were run for each outcome variable incorporating honesty-humility, extraversion, and agreeableness while controlling for burglary type as fixed effects and accounting for trial as a random effect.

The first linear mixed model did not reveal an impact of any of the three personality traits on the number of items stolen ( $R^2 = .16$ ). Likewise, the next model revealed no association between the value of items stolen and the three HEXACO facets ( $R^2 = .07$ ). Together, these results indicate no effect of personality on the success of the burglary in the present sample. Furthermore, no association was found between perceived risk and the personality traits ( $R^2 = .03$ ). The absence of effect reveals that personality does not seem to affect risk perception during a virtual burglary. Also, for time spent in the house no significant effects emerged for any personality trait ( $R^2 = .21$ ). Hence, time in the house did not differ regarding the personality characteristics of the participants. Examining the variance between the trials' and the residual's standard deviations, only for the model with risk as the outcome variable controlling for trial as a random effect does not improve the model's fit. To summarise, the results reflect that personality did not predict participants' behaviour in the current burglary study irrespective of whether someone burgled the house alone or with an accomplice.

**Table 5**

*Impact of Honesty-humility, Extraversion, and Agreeableness on the Burglary*

Variable	Beta	<i>t</i>	<i>SE</i>	<i>p</i>	<i>SD<sub>between</sub></i>	<i>SD<sub>residual</sub></i>
Number of items stolen						
Honesty-humility	0.00	0.00	0.00	1.00	4.3	0.0
Extraversion	0.00	0.00	0.00	1.00	4.3	0.0
Agreeableness	0.00	0.00	0.00	1.00	4.3	0.0
Value of items stolen						
Honesty-humility	0.68	1.10	0.61	.274	1127.7	2.7
Extraversion	0.00	0.00	0.00	1.00	1127.7	2.7
Agreeableness	0.59	0.90	0.66	.373	1127.7	2.7

**Table 5.** Continued.

Variable	Beta	<i>t</i>	<i>SE</i>	<i>p</i>	<i>SD<sub>between</sub></i>	<i>SD<sub>residual</sub></i>
Perceived risk						
Honesty-humility	-0.16	-0.88	0.18	.382	0.0	1.2
Extraversion	-0.25	-1.72	0.15	.087	0.0	1.2
Agreeableness	-0.08	-0.47	0.17	.642	0.0	1.2
Time spent in the house						
Honesty-humility	-18.96	-1.47	12.87	.145	292.6	56.6
Extraversion	12.66	1.03	12.34	.308	292.6	56.6
Agreeableness	-2.31	-0.17	0.15	.864	292.6	56.6

*Note.* Perceived risk was measured as part of the cooperation scale.

### Partner Effects of Personality in Co-Offending

The relevant statistics for the last models, including standard deviations to inspect the fit of the models, are depicted in Table 6. Although no significant effects of personality were found in the present sample, a more profound analysis of the partner effects of personality in the duo condition was pursued. It is reasonable to suggest that the personality traits of one's partner influenced the outcome variables. The partner's score may impact both the behaviour of the participant as well as the outcome variables. Hence, the analyses now included the individual's score on a personality trait and the partner's score on that personality trait. Four models per personality trait were run with one outcome variable at a time. The four models were repeated for honesty-humility, extraversion, and agreeableness. As a result, the effect of the participant's personality trait when controlling for the partner's personality dispositions could be dissected. Moreover, the effect of one's partner's score on the outcome variables was unraveled.

The linear mixed model with honesty-humility and the partner's score on honesty-humility revealed no significant effects of the participant's, nor the partner's score on items taken total, value items total, perceived risk, or time spent in the house. Despite the partner's effect on perceived risk nearing significance, given its small effect size, the partner's honesty-humility level would likely only yield a negligible impact. Thus, the (partner's) disposition of honesty-humility did neither influence the success of the burglary nor risk perception and risk-taking. Investigating extraversion in the duo sample accounting for the partner's score, a significant effect of extraversion on perceived risk emerged indicating

lower risk perception of extraverted people. The participant's extraversion score revealed no significant impact on any other of the other outcome variables. No effect of the partner's score was found for extraversion on items taken, value of the items taken, perceived risk, or time spent in the house, supporting the notion that the personality of one's partner did not substantially influence the four behavioural outcomes. Lastly, also for agreeableness no significant effects of either the participant's agreeableness score nor the partner's score on number of items stolen, value of items stolen, perceived risk, or time emerged. This result once again signals the lack of effect of agreeableness and the partner's personality score on decision-making and perceived risk during the burglary in the present study.

**Table 6**

*Impact of Participant's and Partner's Honesty-humility, Extraversion, and Agreeableness in the Dyads*

Variable	Beta	<i>t</i>	<i>SE</i>	<i>p</i>	<i>SD</i> <sub>between</sub>	<i>SD</i> <sub>residual</sub>
Number of items stolen						
Honesty-humility	0.00	0.00	0.00	1.00	4.5	0.0
H Partner	0.00	0.00	0.00	1.00	4.5	0.0
Extraversion	0.00	0.00	0.00	1.00	4.5	0.0
X Partner	0.00	0.00	0.00	1.00	4.5	0.0
Agreeableness	0.00	0.00	0.00	1.00	4.5	0.0
A Partner	0.00	0.00	0.00	1.00	4.5	0.0
Value of items stolen						
Honesty-humility	0.71	1.22	0.58	.227	1286.1	2.7
H Partner	0.00	0.11	0.01	.914	1286.1	2.7
Extraversion	0.32	0.17	1.87	.866	1286.0	2.6
X Partner	-0.59	-0.31	1.89	.757	1286.0	2.6
Agreeableness	0.39	0.32	1.20	.748	1277.0	2.6
A Partner	-0.57	-0.46	1.23	.646	1277.0	2.6
Perceived risk						
Honesty-humility	-0.16	-0.78	0.20	.438	0.0	1.2
H Partner	0.00	-1.98	0.00	.050	0.0	1.2
Extraversion	-0.42	-2.46	0.17	.015*	0.0	1.2
X Partner	0.30	1.77	0.17	.080	0.0	1.2

**Table 6.** Continued.

Variable	Beta	<i>t</i>	<i>SE</i>	<i>p</i>	<i>SD</i> <sub>between</sub>	<i>SD</i> <sub>residual</sub>
Perceived risk						
Agreeableness	-0.16	-0.74	0.21	.462	0.0	1.3
A Partner	0.14	0.64	0.21	.524	0.0	1.3
Time spent in the house						
Honesty-humility	-9.48	-0.75	12.63	.456	358.6	58.4
H Partner	-0.07	-0.36	0.20	.718	358.6	58.4
Extraversion	33.76	1.10	30.60	.272	356.8	57.9
X Partner	18.67	0.60	31.01	.548	356.8	57.9
Agreeableness	6.25	0.25	24.84	.802	362.9	58.7
A Partner	9.56	0.38	25.45	.709	362.9	58.7

*Note.* \* $p < 0.05$ .; Honesty-humility = participants' honesty-humility, H Partner = partner's honesty-humility, Extraversion = participants' extraversion, X Partner = partner's extraversion, Agreeableness = participants' agreeableness, A Partner = partner's agreeableness.

### Discussion

To date, most criminological research has focused on the single offender-single victim approach, while burglaries are frequently committed in groups (Burrell, 2022; Carrington, 2014, as cited in van Mastrigt, 2017). This study was one of the first to experimentally compare the behaviour of students burgling a virtual house alone with students burgling in pairs. Comparing the two burglary types allowed to assess respective differences in the perception of risk and the impact of personality. Students working in a dyad took more time to burgle the house, even though no difference in the perceived risk of getting caught emerged between the conditions. Besides, duos stole more items and gained higher monetary value. Contrary to expectations, personality was not associated with a burglary when looking at the combined sample of both burglary types, indicating the presence of an accomplice did not elicit differences in how specific character traits manifest. A more profound analysis of personality in a duo burglary did, however, link extraversion to lowered perceived risk.

#### The Promoting Effect of an Accomplice

Prior to this study, it was predicted that the decision-making in burgling a house alone differs from the decision-making of a dyad. However, no definite prediction could be formulated about whether a partner enhances or impedes decision-making in a burglary. The



current study establishes a difference between solo and duo offenders and found that a dyad takes more time to burgle the house compared to a solo offender. First and foremost, the duration may vary since decision-making becomes more complex the more people are involved. When committing a crime in a group, the method of approach needs to be discussed, while a lone offender only needs to consider their actions (Burrell, 2022). In the context of a burglary, approaches may for instance differ in the delegated roles (Uhnoo, 2015). A duo may e.g., assign one person to stay attentive and close to an exit to observe if the homeowner is returning, while the other person is scouting the house. Coming to this decision takes time, particularly since most dyads in the current study did not discuss their approach before entering the house.

Second, group offenders may be more motivated to commit the crime. Situational circumstances are an important determinant in decision-making (Wikström, 2006, as cited in Lantz, 2021). The presence of another may increase the excitement experienced during the offence possibly extending the duration of the crime and increasing the thrill to steal more (Katz, 1988; Weerman, 2003). Similarly, according to McGloin and Thomas (2016), present peers prompt a higher priority of reward. Both rationales would also support the finding that dyads took more items and gained higher monetary value. Hence, given that dyads were more successful, the prolonged time spent in the house may negate the hypothesised loss of coordination but may signify increased ambition.

Third, according to situational action theory, moral context is crucial in anticipating behaviour (Wikström, 2004, as cited in McClanahan, 2020). People are likely to engage in a behaviour when they believe it is adequate to perform that behaviour and refrain from it if not enforced (McClanahan, 2020). The presence of another may serve as an enforcer offering the individual a social norm justifying to engage in the behaviour and soothing feelings of guilt (e.g., “It’s more okay to do this since the other person is engaging in delinquent behaviour as well”, “My social group approves of this behaviour”) (Rothgerber & Rosenfeld, 2021). Witnessing the support from an accomplice may thus reinforce delinquency leading to an extended period in the house and striving for higher gains. Particularly, in a student sample the moral context is important considering that participants engage in an activity they would usually refrain from.

The promoting effect of an accomplice increasing time spent in the house also distinguishes solo and duo offenders on the objective risk measure. Accordingly, spending more time at the crime scene increases the chance of being caught (van Sintemaartensdijk et al., 2022b). The shift to riskier decisions in groups is in line with the findings of numerous

previous studies (e.g., Bougheas et al., 2013; Wallach et al., 1964). Wallach et al. (1964) explain the shift to riskier decisions in groups by a diffusion of responsibility. Individuals in a group share responsibility for the group. Hence, no single person feels obligated to combat the possibility of failure. Decisions are viewed as a group product, which makes it easier to tolerate possible failure (Wallach et al., 1964). Diffusion may further be enhanced in the current study since no leader was designated. Therefore, students burgling the house may not have felt responsible for acting to alleviate the group's chance of getting caught.

Furthermore, the demonstrated higher risk-taking in groups may highlight that groups make less weighted decisions. Facilitating more extreme decisions would also underscore group polarisation. Van Mastrigt (2017) proposed polarisation may contribute to groups selecting riskier targets. Corresponding with that, the presence of another may have provoked dyads to strive for higher gains irrespective of possible costs resulting in prolonged time spent in the house. Hence, making more extreme decisions not only impacts risk-taking but also directly translates into decision-making determining the success of the burglary. Additionally, even though likely less impactful in a group of two, individuals feel more anonymous in groups and accomplices offer comfort (Hauffe & Porter, 2009, as cited in Burrell, 2022). The created sense of safety may further endorse recklessness exhibited by groups (Alarid et al., 2009). Altogether, the presence of another may contribute to more daring decisions leading duos to take more risks.

While taking more risks was believed to go hand in hand with lower perceived risk, no association was found between perceived risk and the burglary types. The indifference of perceived risk regardless of burgling solo or in a dyad supports van Mastrigt's (2017) idea that a group can simultaneously trigger risk-taking and risk cautiousness. Although the presence of another can induce a need to show off, two people can observe more cues of risks. Combined the level of perceived risk is counterbalanced (van Mastrigt, 2017). Therefore, given the influence of a partner on perceived risk can go both ways, a dyad might near similar levels of perceived risk as a solo offender.

The lack of effect of the number of offenders on perceived risk may also be explained by the fact that risk was not explicitly manipulated in the current study. The VE did not contain valid risks of getting caught. The neighbourhood participants traversed was empty (e.g., no guardians were present), there were no visible safety measures like security cameras, and participants could enter the house through an unlocked front door which may have signified low risk. Furthermore, according to rational choice theory, offenders rationally outweigh the costs and benefits (Coupe, 2017). The rational consideration of risk (costs) was

equal in both conditions of the study. Hence, rationally the confronted risk was consistent, no matter if one was with an accomplice or not. Future studies may put the presented rationales about perceived risk to the test by embedding clear signals of risk in the VE.

Another explanation is that multiple participants indicated to experience the study as a game instead of an actual threatening situation, which questions the ecological validity (Jackson, 2012). In criminological theories incarceration is central to the perceived risk for an offender and the consequences of punishment are important to conceptualising risk (van Gelder & de Vries, 2012). Contrary, participants knew they were taking part in a research study so no actual punishment would be awaiting them. Even more importantly, since test subjects essentially fulfilled a requested task, they possibly did not conceive the possibility of being caught. Consequently, participants indicating low chances of being caught irrespective of burgling solo or in a dyad may be attributed to the game-like experience.

In conjunction, the question remains why the objective and subjective measures of risk signified opposing appraisals. Possibly, although participants did not assert to feel at risk of being caught, they unconsciously became less cautious in the presence of another. This unconscious bias would also correspond with the group-induced illusion of invulnerability (Forsyth, 2019a). Further, the discrepancy between the reported perceived risk and the actual behaviour aligns with the findings of van Sintemaartensdijk et al. (2022a), who explored the effect of neighbourhood watch signs on deterrence. In their study, burglars did not assert to be deterred by neighbourhood watch signs, but still selected “safer” targets that were closer to the exit of the neighbourhood.

Moreover, the divergence of the risk measures can be disentangled by group influence. Van Gelder (2013) augments rational choice theory by introducing the differentiation of *hot and cool cognitions*. Accordingly, cool cognitions are based on systematic considerations of probabilities and long-term consequences. Hot cognitions avert rational choices and lead criminals to take actions that could be detrimental to themselves. Thus, while the cool cognition of assessing the risk in a post-questionnaire may prompt participants to indicate risk as low in both conditions, hot cognitions during the burglary may have been influenced by an accomplice leading to riskier decisions (McGloin & Thomas, 2016; van Gelder, 2013). Consequently, while the self-reported perceived risk did not differ between solo and duo burglars, dyads took longer to burgle the house.

Not only the timing of measuring risk may account for the discrepancy in perceived and objective risk, but also how the measures are conceptualised plays a critical role. Perceived risk was measured using a single item inquiring about the chances of being caught

post-experiment. By contrast, Schwind (2019) recommended implementing questionnaires into VR rather than administering them afterwards. While their study focuses on measuring presence, similar pitfalls may become important for risk. For instance, hindsight bias describes the fallacy that “an event was more predictable after it was known than it was before it was known” (Roese & Vohs, 2012, p. 411). Since after the experiment participants already knew they were not caught, they may also claim to have anticipated that during the burglary. Hence, incorporating a perceived risk questionnaire within the VE may provide more valid results. Further, the fact that people take longer in a dyad does not mean they perceive risk as low, it only means they *take* more risk. This does not imply they actively consider the higher chance of being caught. Conceivably they take longer because they are with someone else, or they enjoy the thrill of offending in the presence of another (Weerman, 2003). In short, the distinct outcomes of the measures may not point to opposing views. The divergence may predominantly demonstrate that the measures must be viewed from distinct angles.

### **Personality Expression in a (Duo) Burglary**

Honesty-humility, extraversion, and agreeableness were predicted to be distinctively associated with solo and duo burglaries. However, none of these personality traits were associated with relevant outcomes when looking into the combined sample of both burglary types. Certainly, the lack of effect could be due to the sample, which included students instead of burglars. A great body of literature highlights differences in the behaviour and personality between burglars and student samples (Levidi et al., 2022). Accordingly, studies comparing both samples came to distinct conclusions per population, and effects of personality identified in earlier studies were mostly found within burglar samples (e.g., van Sintemaartensdijk et al., 2022b). Hence, the absent effect of personality noted in this study may take form when studying burglars.

Also, studying personality in duos without considering how personality dispositions interact paints an incomplete picture. In theory, personality traits of people influence one another. Van Sintemaartensdijk and Righetti (2019) found people scoring high on self-control work harder to compensate for partners scoring low on self-control. Additionally, personalities can clash prohibiting productive collaboration (Lykourantzou et al., 2016). Statistically, however, it was not possible to account for that in the current study. Participants in the duo condition had arbitrary roles, therefore, no meaningful variable distinguished the data of both subjects. The consequence of this “indistinguishability” is that no analysis which depends on the arrangement of the data could be run (Nestler et al., 2015). To illustrate, if

participants were assigned roles like leader and follower, they could neatly be identified in the data. Without these roles, however, X and Y must be assigned arbitrarily. Differences in how the scores could be assigned would lead to different results, posing a problem for conclusive data analysis (Kashy & Snyder, 1995). Hence, including partner effects was the most feasible way to account for this interaction. The results showed no significant impact of a partner's effect, increasing confidence that in this study a partner's score did not alter the outcomes of the study. Nevertheless, it cannot be ruled out that the impact of another's personality dispositions may have resolved effects of honesty-humility, extraversion, and agreeableness on offending.

To additionally examine the singular traits, the absence of a significant correlation between (one's partners') honesty-humility and the outcome measures supports the notion suggested by van Gelder et al. (2017) claiming while honesty-humility is predictive of the involvement of crime, it may be less influential in the execution of a crime. Further, van Sintemaartensdijk et al. (2022b) found that honesty-humility leads people to be less susceptible to perceiving risk. After all, participants perceived risk as low in this study. Consequently, finding an effect of honesty-humility reducing perceived risk was unlikely.

With respect to extraversion and agreeableness, both traits were included due to their impact on group dynamics. The impact on group dynamics was anticipated to affect a duo burglary. However, performing as a team was not explicitly investigated in the present study. Hence, while extraversion and agreeableness may positively affect team performance or communication, this does not necessarily reflect in the profit of a burglary (Barry & Steward, 1997; Kozlowski & Bell, 2003, as cited in Macht et al., 2014). An extraverted member may, for instance, facilitate the group's focus on the task, but that does not imply the group steals more items than other duos. Likewise, agreeable members may facilitate cooperation, but that rather shapes the experience of the burglary for the dyad instead of the burglary's success.

Moreover, interpreting evidence of personality in the context of group dynamics and burglary is not straightforward. For extraversion specifically, also other studies could not demonstrate a direct link between extraversion and team performance (Macht et al., 2014). Further, extraversion is also related to excitement seeking (Nguyen et al., 2013). It could therefore be that dyads with someone scoring high on extraversion may come to a decision more easily, but they still stay at the scene for longer to expand the thrill experienced during a burglary resulting in similar outcomes as other dyads. As for agreeableness, no distinct rationale can be given to explain the missing effect. Further work is needed to understand the role of extraversion and agreeableness in duo burglary.

Besides, analyses specifically looking into the duo sample showed that extraverted people working in a dyad perceived the chances of being caught as lower when the partner's influence is taken into account. Extraverts tend to be less introspective and are more action-oriented (Chauvin et al., 2007). Accordingly, extraverts may not have actively assessed the risk of adverse consequences. The fact that this was only found in the duo sample may relate to the social nature of extraverted people (Chauvin et al., 2007). The presence of another may make the burglary more fun for them, shifting their focus further away from thoughts about getting caught (Weerman, 2003). Alternatively, the combined effect of comfort offered by an accomplice and the outward-oriented perception of extraverts may lead to lower perceived risk for extraverts in dyads (Chauvin et al., 2007; Hauffe & Porter, 2009, as cited in Burrell, 2022). In sum, extraverts in a burglar duo may particularly focus on the offence rather than reflecting on their actions' consequences possibly explaining reduced perceived risk.

Another personality trait that was not of primary focus in this study is self-control. Self-control is widely linked with criminal behaviour, especially with engagement in criminal behaviours (van Gelder et al., 2017). Even though there was no significant effect of self-control on the outcome variables, accounting for self-control diminished the relationship between burglary type and the number of items stolen. Thus, different levels of self-control may regulate how the effect of whether someone burgles alone or in a dyad on the number of items stolen develops. For instance, while conscientiousness drives people to ascertain whether they covered everything, self-control may bolster withstanding this urge since spending more time at the scene increases the likelihood of getting caught (van Gelder et al., 2017). Hence, investigating the impact of self-control more thoroughly could enrich the understanding of personality in co-offending.

### **Strengths and Limitations**

An important strength of this study is the use of VR to study delinquent behaviour. VR allows to observe burglars in real time, overcoming memory and question biases of interview studies, and ethical deliberations that prevent to study burglars in the real world. Not only is the relationship between a burglar's behaviour in the real world and a VE established in literature, but also the physiological reaction to the virtual burglary is indicative that the behaviour of a virtual burglary seems to resemble a burglary in the real world (Meenaghan et al., 2018; Nee et al., 2015; van Gelder et al., 2017; van Gelder et al., 2019; van Gelder et al., 2022; van Sintemaartensdijk et al., 2020). Furthermore, this study makes use of triangulation by combining different data streams, i.e., survey data,

physiological data, movement data, and audio data, which strengthens confidence in the present findings.

Some limitations must be noted. The student sample may not be representative of a burglar sample (Jones, 2017). Many studies demonstrated the dysfunctional expertise of burglars (Nee & Meenaghan, 2006; Nee & Ward, 2015; Taylor & Nee, 1988). Accordingly, burglars differ in their decision-making compared to less experienced groups (Clare, 2011). Experienced burglars are more efficient in their scouting process, spend more time in high-value areas, and identify more high-value items (Meenaghan et al., 2018; van Sintemaartensdijk et al., 2020; van Sintemaartensdijk et al., 2022b). Additionally, as aforementioned, burglars differ in their personality dispositions compared to student samples, which certainly impacted the results of this study (Samenow, 2022; van Sintemaartensdijk et al., 2022b). Nonetheless, this study served as an important proof of concept, establishing differences in the conduct of solo and group offences. This is an important first step giving reason to replicate similar studies with incarcerated burglars.

Additionally, the utilised technologies leave room for improvement. The VE entailed many glitches hindering participants from grabbing items, which required restarts or participants having to name items to log them as stolen. Consequently, participants may have felt less immersed in the VE, and naming items instead of putting them in a box also affected the time spent in the house. Further, many participants experienced cyber-sickness, i.e., discomfort experienced due to movement in the real world that conflicts with the visual input from the virtual world (van Gelder et al., 2017). Cyber-sickness could have also been enhanced by the glitches and may have caused fluctuations in the heart rate data. Moreover, the heart rate data was negatively impacted by the used devices, which frequently disconnected leading to missing data. Nevertheless, by, e.g., incorporating a training phase to get used to VR and restarting the experiment in the exact position where the participants stopped when taking breaks, every effort was made to keep the impact of these limitations low. Additionally, the results suggest that participants still felt sufficiently immersed in the VE and experienced the experiment as realistic, which affirms the reliability and validity of the data.

## **Conclusion**

The presence of another is considered crucial in many crime theories, but in practice, its influence has hardly been studied. The present research underscores the relevance of an accomplice in the dynamics of burglary in a student sample. Dyads stole more items, achieved higher monetary gains, and spent more time on the burglary, which further suggests

dyads willingly take more risks than individuals. No difference, however, was found between the burglary types on perceived risk. Concerning personality, extraversion and lowered perceived risk were only linked after a profound analysis of the duo sample. When looking into the combined samples of both solo and duo burglary, personality did not predict burglary outcomes. Nevertheless, it would be premature to assume there is no difference in perceived risk between solos and dyads and no influence of personality in the solo sample, given the support from existing literature. This first comparison of solo and duo burglars established an important proof of concept, demanding a need for further research about co-offending with actual burglar samples. Disentangling the influence of an accomplice can potentially explain how dyads differentially approach burglaries, offering a more holistic foundation for preventive measures that are urgently needed given the high prevalence of burglaries society is confronted with.



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## Appendix A

### Items to be Stolen in the Virtual Environment and Their Assigned Value

**Table 7**

*Stealable Items and Their Assigned Value*

Item	Value (in euro)
Carkeys	1500
Computer	800
Guitar	500
Xbox console	300
Amplifier	200
PSP console	200
Tablet	175
Wallet	150
TV	100
Electric drill	75
Xbox controller	35
Radio	20
Axe	15
Casserole dish	15
Vase (x2)	10
Candlestand	10
Lamp	10
Hammer	10
Screwdriver	5
Wine glass	3
Bowl	3
Plate	0
Yucca plant (x2)	0
Soap	0
Shampoo	0
Picture (x2)	0
Newspaper	0



## Appendix B

### Modified Spatial Presence Experience Scale

Below, please rate your experiences with the virtual environment.

#### Spatial Presence

1. I felt like I was actually part 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 like I could be active in the virtual environment.
6. I felt like I could move the items in the virtual environment.
7. I felt like I could do anything I wanted in the virtual environment.

#### Social Presence<sup>1</sup>

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

#### Copresence Scale<sup>1</sup>

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]

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<sup>1</sup> Excluded for solo condition since there was no content validity to measure social or copresence in a solo burglary.

## Appendix C

### Elaboration of Additional Measures

#### Self-control

Since past research repeatedly linked self-control to behaviour during a burglary, self-control was assessed. Test subjects filled in the Brief Self-Control Scale (e.g., “I am good at resisting temptation”; Tangney et al., 2018). The scale consisted of 13 items that could be answered on a scale of 1 to 5 (*strongly disagree* to *strongly agree*). Some items followed a reversed scoring scheme and hence needed to be reversely coded. Scores were averaged with higher scores indicating higher levels of self-control ( $M = 3.1$ ,  $SD = 0.6$ ). The reliability of the scale was acceptable,  $\alpha = .80$  (Glen, 2023).

#### Cooperation

To measure cooperation, a new scale was developed. The items of the scale covered different components of other studies that examined how an individual experiences cooperation with another person. Specifically, the measured constructs were rated success (of the burglary), anticipated success without one’s partner, happiness with the outcomes, general cooperative tendencies, flow during the burglary, mood after cooperation, interdependence, the perception of a shared goal, trust, stress, evaluation of the VR devices, and the chances of getting (e.g., “My partner and I were successful in the task we had to complete in the virtual environment”, “I feel as if my partner and I had a shared goal in completing the task“, see Table 8) (Depping & Mandryk, 2017; Kaye, 2016; Kurzban & Houser, 2001; Lu & Argyle, 1991). The scale included 17 items, that could be answered on a scale from 1 (*strongly disagree*) to 5 (*strongly agree*). For the total scale, all item scores were averaged. A higher score indicated higher perceived cooperation between the partners ( $M = 3.4$ ,  $SD = 0.4$ ). The reliability of the scale was acceptable,  $\alpha = .76$  (Glen, 2023). Since this study investigated risk perception, the inquiry about the chances of being caught was also analysed separately. To further investigate cooperation, open-ended inquiries that sought to understand the participants’ engagement level in the conversation, their contribution, and their familiarity with their partner were included (Gorsic et al., 2019).

**Table 8**

## Cooperation Scale

Number	Item
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 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.	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)?
16.	How well did you know the other person with whom you did the experiment before the VR experience?
17.	I think the quality of the communication with my partner while completing the task was low.
18.	I felt stressed out due to the actions of my partner during the task.
19.	The technology enabled my partner and me to collaborate effectively.
20.	I believed the chances of getting caught together with my partner during this task was low.

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*Note.* The prompt before the items were displayed was “We would like to know how you experienced the task of the virtual burglary.”; Items 15 and 16 are referred to as open-inquiries in-text.

### **Task Experience**

For the solo condition, items measuring cooperation with others were excluded from the cooperation scale. The remaining items measured rated success, happiness with the outcomes, mood after the task, and the chances of getting caught (Kaye, 2016; Lu & Argyle, 1991). Items that e.g., related to success were adapted to the setting of an individual burglary (e.g., “I was successful in completing the task in the virtual environment”; see Table 9). In total, six items measured on 5-point scales (*strongly disagree-strongly agree*) were administered but not averaged into a scale since there was no content validity to create the scale.

**Table 9**

#### Task Experience Scale

Number	Item
1.	I was successful in the task I had to complete in the virtual environment.
2.	I am happy with the outcomes of the task I had to complete in the virtual environment.
3.	I had a good idea how well I was performing the task.
4.	I felt excited after completing the task.
5.	I felt frustrated after completing the task.
6.	I believed the chances of getting caught during this task was low.

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*Note.* The prompt before the items were displayed was “We would like to know how you experienced the task of the virtual burglary.”

### **Perceived Risk**

An 8-item perceived risk scale was added for the solo condition (van Gelder & de Vries, 2012). Items were adapted to the setting of the virtual burglary and reflected two constructs, namely perceived probability of risk (two items, e.g. “How likely was it that you were going to be caught during the burglary?”) and expected severity of the punishment (two items, e.g. “How serious do you consider the possible consequences of being caught to be?”).

Participants could answer on 7-point Likert scales that were tailored to each item (see Table 10). The items per construct were averaged and multiplied. Higher scores indicated higher perceived risk with the maximum possible score being 49 ( $M = 20.8$ ,  $SD = 13.1$ ). The reliability of the adapted scale was acceptable,  $\alpha = .70$  (Glen, 2023). Importantly, as the overarching study compared the results of the duo and solo trials and this scale was only assessed in the solo condition, perceived risk was nonetheless investigated using the risk item of the task experience scale, and this perceived risk scale was omitted.

**Table 10**

## Perceived Risk Scale

Item	Response options						
How likely was it that you were going to be caught during the burglary?	Very unlikely	Unlikely	Somewhat unlikely	Neutral	Somewhat likely	Likely	Very likely
How big do you think the change is that you will be found out to having committed the burglary?	Very small	Small	Somewhat small	Neutral	Somewhat large	Large	Very large
How serious do you consider the possible consequence of being caught to be?	Not at all serious	Not serious	Somewhat not serious	Neutral	Somewhat serious	Serious	Very serious
How annoying to you find the potential negative consequence of being charged for committing the burglary?	Not at all annoying	Not annoying	Somewhat not annoying	Neutral	Somewhat annoying	Annoying	Very annoying

*Note.* The prompt before the items were displayed was “Please read the questions below and answer them using the provided scales”.

### Appendix D

#### Auxiliary Analyses: Controlling for Self-control and Cyber-sickness

Preliminary analyses revealed significant correlations of self-control and cyber-sickness with one or more of the outcome variables that revealed a significant effect (i.e., number and value of items stolen, and time spent in the house; see Tables 11 and 12 for correlations). Therefore, self-control and cyber-sickness were added as covariates to the affected models. Linear mixed models were run with condition and one of the covariates at a time (self-control, cyber-sickness) as fixed effects, trial as a random effect, and one of the dependent variables (number of items stolen, value of items stolen, time in house) per model.

**Table 11**

*Extended Correlation Matrix for Duo Sample*

	Time	NItem	Value	Risk	Pres	Cyber	SelfC	HrCon	Coop
Time									
NItem	.18*								
Value	.05	.75*							
Risk	0.12	.02	.04						
Pres	.04	-.02	-.40	-.03					
Cyber	-.12	-.19*	-.24**	-.12	-.05				
SelfC	.05	-.06	-.11	-.04	.28**	.04			
HrsCon	-.08	-.12	.01	.16	-.07	-.11	.33**		
Coop	-.05	-.04	.01	.05	.46**	-.08	.28**	-.22	

*Note.* \* $p < 0.05$ . \*\* $p < .01$ ;  $N = 134$ ; Time = time spent in the house, NItem = number of items stolen, Value = value of items stolen, Risk = perceived risk as indicated by item, Pres = total presence, Cyber = cyber-sickness, SelfC = self-control, HrCon = hours played with controller, Coop = cooperation.

**Table 12**

*Extended Correlation Matrix for Solo Sample*

	Time	NItem	Value	Risk	Pres	Cyber	SelfC	HrCon
Time								
NItem		.39**						
Value		.21	.65**					

**Table 12.** Continued.

	Time	NItem	Value	Risk	Pres	Cyber	SelfC	HrCon
Risk	.03	.25	.09					
Pres	.12	.01	-.10	.09				
Cyber	.15	.08	-.29*	.11	-.07			
SelfC	-.03	-.32*	-.31*	.05	.04	.13		
HrCon	-.06	.23	.53*	-.04	.11	.02	-.03	

*Note.* \* $p < 0.05$ . \*\* $p < .01$ ;  $N = 61$ ; Time = time spent in the house, NItem = number of items stolen, Value = value of items stolen, Risk = perceived risk as indicated by item, Pres = spatial presence, Cyber = cyber-sickness, SelfC = self-control, HrCon = hours played with controller.

The outcomes for the covariate analyses are displayed in Tables 13 and 14. For number of items stolen, there was no significant difference between the solo and duo conditions after controlling for self-control. The effect of self-control was also non-significant. In like manner, there was no significant effect of condition on number of items stolen after controlling for cyber-sickness, but also no significant effect of cyber-sickness on number of items stolen. For value of items stolen and time spent in the house, the significant effect of condition remained. In other words, after controlling for self-control or cyber-sickness, there were significant differences between a solo and a duo burglary regarding the value of items stolen and how long the burglary took. Examining the influence of self-control and cyber-sickness, neither variable significantly impacted the value of items stolen or time spent in the house per se.

For all of the above models, the standard deviations of the fixed and random effects proved a good fit for including trial as a random effect. In sum, the analyses show that neither self-control nor cyber-sickness had a critical impact on number of items stolen, value of items stolen, or time spent in the house. However, when controlling for the influence of self-control or cyber-sickness, whether someone burgled the house alone or in a dyad had no longer a significant effect on the number of items stolen.

**Table 13***Effect of Condition when Controlling for Self-control*

Variable	<i>F</i>	<i>p</i>	<i>SD</i> <sub>Between</sub>	<i>SD</i> <sub>Residual</sub>
Number of items stolen				
Condition	29.12	.055	4.26	0.00
Self-control	0.00	1.00	4.26	0.00
Value of items stolen				
Condition	10.49	.002*	1127.64	2.67
Self-control	0.01	.914	1127.64	2.67
Time spent in the house				
Condition	36.65	<.001**	292.49	57.47
Self-control	0.69	.408	292.49	57.47

Note. \* $p < 0.05$ . \*\* $p < .01$ .

**Table 14***Effect of Condition when Controlling for Cyber-sickness*

Variable	<i>F</i>	<i>p</i>	<i>SD</i> <sub>Between</sub>	<i>SD</i> <sub>Residual</sub>
Number of items stolen				
Condition	29.35	.056	4.26	0.00
Cyber-sickness	0.00	1.00	4.26	0.00
Value of items stolen				
Condition	10.49	.002*	1127.63	2.67
Cyber-sickness	0.00	.993	1127.63	2.67
Time spent in the house				
Condition	36.95	<.001**	292.19	57.86
Cyber-sickness	0.02	.894	292.19	57.86

Note. \* $p < 0.05$ . \*\* $p < .01$ .