Crime Beyond Earth: An Experimental Virtual-Reality Study of Attitude, Concern, and Perceived Realism

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Abstract

Despite the increasing attention to legal and ethical issues in space as a result of recent events, there is a lack of empirical research into the perception of such behaviour in future or hypothetical contexts. This experimental study investigated the extent to which an immersive virtual reality (VR) scenario, compared to a written text, influences attitudes, concerns and perceived realism regarding space crime. The sample consisted of 66 participants who were randomly assigned to a VR condition or a written condition. They assessed their attitudes and concerns before and after the experiment, as well as the perceived realism afterwards. In addition, open-ended questions about knowledge and perceptions of the domain were analysed, and the possible moderating role of perceived realism was investigated. The results showed that participants in the VR condition reported significantly higher attitude scores than participants in the written condition, suggesting that immersive environments, through increased affective engagement, can contribute to moral evaluations of behaviour, even in abstract and unfamiliar domains. Concern about space crime increased over time, regardless of condition. The perceived realism was rated relatively low and did not differ significantly between conditions, but it did moderate the effect of condition on attitude. These findings imply that immersive scenarios have the potential to influence moral attitudes, provided that content and context are carefully matched. Future research could focus on the role of narrative coherence, domain knowledge, and repeated exposure to better understand the underlying mechanisms of moral and affective influence.

Keywords: Space, space crime, virtual reality, attitude, perceived realism, concern

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Space is no longer the exclusive domain of governments and astronauts but is developing into a dynamic field in which technology, trade, and human interaction converge (Feldman & Taylor, 2025). Since the 20th century, space travel has developed from a military and political prestige project—strongly influenced by the tensions and rivalry during the Cold War between the United States and the Soviet Union—into a domain increasingly characterised by social applications and commercial interests (McDougall, 1985). Technological breakthroughs, such as the first man in space (1961) and the moon landing (1969), marked the beginning of this development, despite the enormous costs involved. In the 21st century, this trend is accelerating, thanks in part to commercial players such as SpaceX, Virgin Galactic, Blue Origin, and Bigelow Aerospace, which are making space travel and space tourism more accessible to entrepreneurs and citizens (Wu et al., 2024). Although participation in space travel is still largely limited to the elite, technological advances and increased knowledge are opening up the domain to broader sections of the population (Carbajales-Dale & Murphy, 2022).

However, this broadening exploitation of space brings to light, both positively and negatively, the less noble sides of human nature (Feldman & Taylor, 2025). The rise of crime, corruption, piracy, and even war in space is no longer merely hypothetical, but is already beginning to manifest itself on a small scale. Although we are still at an early stage of this transition—from space as a symbol of human cooperation and progress to an arena in which unethical behaviour is also visible—the time has come to face these changes (Chrysaki, 2020). Ignoring this shift carries significant risks: without clear policy and regulation, the space sector will change from a state-managed collaborative project into a commercial battleground, where opportunistic companies and countries will have free rein to acquire monopoly positions, exploit resources, and fuel international tensions (Feldman & Taylor, 2025). Policymakers and other stakeholders who fail to recognise these drastic shifts in space travel are at significant risk (Masson-Zwaan & Freeland, 2010). Additionally, this evolution not only highlights the changing role of governments and commercial actors in regulating space behaviour but also raises questions about how individual citizens perceive and evaluate these developments.

Space travel is an extension of what humans do on Earth: discover, explore, literally push boundaries, and ‘procreate’. With this increasing human expansion in space inevitably comes human problems, including crime. Space is no exception, despite the reported cases being little to none (Hermida, 2005). Long-term space missions even predict that conflict and deviant behaviour will pose significant challenges. This prediction is supported by experiments on Earth designed to test human responses to isolation and extreme conditions, such as lengthy ‘missions’ with limited resources, also called ‘analogue astronaut missions’ (Forganni et al., 2024). One such experiment, conducted in Russia in 1999, and lasting over 100 days, shows how problematic such situations can be (Hermida, 2005). During the simulation, the commander committed several violent acts, including assault, attempted murder, and an attempted rape of a female colleague while under the influence of alcohol. A recent incident at the South African research station SANAE IV in Antarctica illustrates how extreme environments can provoke conflict and transgressive behaviour. In March 2025, a female researcher accused her male colleague of death threats and physical violence during a prolonged mission in isolation (Holmes, 2025; Savage, 2025). Independent reports point to a broader culture of stress, anxiety, and social tensions at polar stations, where hierarchies and limited privacy can lead to dangerous situations (University of Tasmania, 2025). Such cases highlight how the psychological and social risks of remote missions on Earth are also relevant for future manned space missions, where similar stressors are present.

These incidents, in particular, the one which occurred in 1999, caused a lot of controversy due to their nature and media coverage, which then played an important role in shaping the Code of Conduct for the International Space Station (ISS) (Casper & Moore, 1995). This code of conduct includes criminal provisions for dealing with criminal incidents in this unique environment. Such incidents highlight that human missions and settlements in space are very likely to carry an increased risk of conflict and criminal behaviour. This underlines the need not only to develop preventive measures, but also to understand how space crime is perceived and what factors influence it. While much information about criminal behaviour during actual space missions remains classified, rumours of similar incidents in real space flights are circulating.

Reportedly, the first case of a crime in space was in 2019, where an American astronaut, Anne McClain, was accused by her ex of looking into her partner's bank details from the International Space Station (Baker, 2020). This, according to the National

Aeronautics and Space Administration (NASA) turned out to be a false accusation, but in America, and elsewhere, newspapers wrote about the 'first space crime ever'.

The likelihood of criminal acts in space, such as: violence, theft, sexual assault, rape, and even murder in an extraterrestrial context, as well as environmental offences such as causing space debris, increases as the human presence there increases, whether for tourism, research or commercial activities (Feldman & Taylor, 2025). Unlike the first generations of astronauts, who were rigorously selected and drilled on professional behaviour and discipline, the future group of space residents is expected to come from diverse socio-economic and cultural backgrounds (Feldman & Taylor, 2025). This increases the likelihood of diverse perceptions, behaviours, and coping with stressful situations. As Sachdeva (2023) argues, humans take basic human traits such as belligerence, ego, and vengeance with them into space. These can be enhanced by unique stressors of space life, such as claustrophobic living spaces, physical discomfort due to gravitational changes, and repetitive or dangerous tasks in inappropriate work environments.

In the long run, such conditions can lead to psychological stress, frustration or even aggression, which can eventually culminate in criminal behaviour. However, the current legal framework; the best-known example being the Outer Space Treaty, hardly takes these human dimensions into account and offers few concrete tools to tackle criminal behaviour in space, yet humans have been active in space for more than 65 years. The 1967 Outer Space Treaty—which stipulates, among other things, that space may only be used for peaceful purposes and that no country may claim ownership of celestial bodies—still forms the basis for international regulations in space (United Nations, 2002). This treaty was initially drafted with only trained astronauts from national space agencies in mind, and does not provide rules for tourists, commercial employees or long-term settlers in space. At the same time, space crime remains to date, a largely under-researched topic within both public debate and academic criminology (Sachdeva, 2023). This has led to a lack of in-depth knowledge about the nature of such crime and how it can be dealt with effectively (Eski, 2023; Lampkin & White, 2023). This combination of legal gaps and scientific blind spots raises pressing questions about how space crime can be recognised, prosecuted, and prevented in the future (Mehta, 2023). A first step in answering these questions is to systematically map how people perceive, assess, and experience space crime.

While the practical and legal challenges surrounding space crime are becoming increasingly urgent, one important aspect remains conspicuously underexposed: the way people perceive and interpret these forms of crime (Eski & Lampkin, 2024). In a context as abstract, technological, and future-oriented as space, perception plays a crucial role in shaping public attitudes and levels of concern about space-related crimes (Feldman & Taylor, 2025). At present, it is practically impossible to study criminals and criminal activities in space directly. Incidents in space are rare, and as aforementioned, often classified, making it difficult to empirically research actual criminal offences. The study of public perceptions of such criminal offences therefore offers an alternative and valuable approach (Feldman & Taylor, 2025). More specifically, gaining insight into attitudes towards space crime and the degree of concern or anxiety that people experience about it can contribute to the development of effective preventive and regulatory strategies. The perceived credibility or realism of space-related scenarios also plays an important role in this: the more realistic a situation is considered to be, the stronger its impact on attitudes and feelings of concern (Feldman & Taylor, 2025). In unfamiliar or groundbreaking contexts such as space, it is precisely this interaction between attitude, concern, and realism that can guide policy-making and public acceptance.

Since the space context remains abstract and unfamiliar to most people, judgements about it are often formed on the basis of media images, technological imagination, and limited factual knowledge (Pizzolante et al., 2024). This can lead to a distorted view of the seriousness, permissibility or even possibility of criminal behaviour in space. When space is perceived as a lawless or borderless domain, this can have a direct impact on people's attitudes towards responsibility, norm-transgressing behaviour, and criminal law interventions within this context. Such attitudes are also shaped by the extent to which a scenario is perceived as credible or realistic- a concept known as perceived realism (Van Gelder et al., 2018, Feldman & Taylor, 2025). Recent research shows that immersive virtual reality can contribute convincingly to shaping or changing moral and social attitudes, especially when the content is complex or loaded, as in the case of organised crime (Frisanco et al., 2024).

In addition, public concern plays an important role in the legitimacy and effectiveness of future policy measures. If citizens consider space crime to be insufficiently regulated- or, conversely, overly restrictive- this can undermine confidence in international cooperation and commercial space initiatives. Perceptions of space crime also influence how people respond to hypothetical situations, such as cross-border behaviour or conflicts during manned missions. By systematically gaining insight into attitudes, feelings of concern, and perceived realism, policymakers can anticipate potential social tensions and normative conflicts that may arise as space exploration and colonisation progress (Feldman & Taylor, 2025; Eski & Lampkin, 2024).

In a domain where empirical data is scarce and incidents are rare, perception research is a necessary first step in developing a scientifically grounded understanding of space crime. Such research makes it possible to uncover implicit social norms, expectations, and behavioural assumptions which—although based on hypothetical scenarios—can have a major influence on how future incidents are interpreted and addressed. Insight into the interaction between perceived realism, attitude, and concern thus not only provides a theoretical framework for further study but also contributes to the legitimacy of future legal and criminal justice structures.

The Use of VR in the Empirical Research of (Space) Crime

To reliably measure and understand perceptions of (space) crime, it is important to use research methods that are both psychologically relevant and contextually realistic. This means that the virtual environment (VE) must be capable of evoking and activating cognitive, affective and moral processes—processes that are central to the formation of attitudes, risk perceptions, and normative judgements. Virtual reality (VR) offers a promising addition in this regard (Van Gelder et al., 2014). According to Cornet and Van Gelder (2021), traditional research methods, such as the use of police and justice registration data, interviews and questionnaires among stakeholders and interested parties, have provided valuable insights into factors that may be important when investigating crime, including possible applications in other domains, thus opening doors as a viable option in researching crime in an extraterrestrial context (Cornet & Van Gelder, 2021). Nevertheless, these methods entail some limitations, including low ecological validity. This means that simulated situations do not always correspond to how similar situations are expressed or experienced in real life (Van Gelder et al., 2018). To obtain more accurate and context-specific information, it is essential to use experimental methods that provide both high control and high ecological validity.

Virtual reality (VR) has the potential to be an innovative and effective method for studying behaviour in complex and unique environments such as space. VR makes it possible to create a virtual, three-dimensional simulation in which users can enter an artificial world and have the experience of actually being in it (Briggs, 1999). Virtual reality is typically experienced using a head-mounted display (HMD), a stereoscopic device that visually immerses users in a virtual environment, enabling a more intense experience (Fox et al., 2009; Van Sintemaartensdijk. 2022). Due to these immersive system features—high-resolution images, stereoscopic sound and interactive tracking—users experience a sense of presence, i.e. the subjective experience of actually being in the virtual scene (Wilkinson et al., 2021). This technology allows users to be exposed to a variety of scenarios, including unique situations such as crime in space, and to repeat the process if necessary. This flexibility makes VR a valuable tool for experimental research (Fox et al., 2009).

Virtual reality (VR) is increasingly being used as an innovative method to study behaviour and perceptions in criminological and psychological contexts. For instance, VR has been shown in previous studies to be effective in simulating complex social situations and dangerous environments (Slater et al., 2006; Slater et al., 2013; Van Gelder et al., 2014). Examples of this are studies in which VR is utilised in investigating how individuals cope with moral dilemmas, social conflicts or threatening scenarios in controlled but real-life settings (Cornet et al., 2019). This makes VR particularly suitable for observing behaviour in contexts where traditional methods, such as interviews or questionnaires, have limited ecological validity. In the case of space crime, where actual incidents are rare, classified or physically inaccessible, VR allows researchers to realistically simulate space situations and elicit behavioural and attitudinal responses that could not otherwise (easily) be investigated empirically. In doing so, VR offers a more safe but immersive way to investigate how people perceive and interpret criminal scenarios in an extraterrestrial context (Kuhail et al., 2025).

An important feature of VR is its ability to give users a sense of presence—the subjective impression of actually being physically present in the virtual environment (Cornet et al., 2019; Wilkinson et al., 2021). Immersion, on the other hand, refers to the technological properties of the system that enable this experience, such as visual, auditory, and interactive elements. Although these concepts are closely related, the distinction between them is essential: immersion is a prerequisite, but not a guarantee, for experiencing presence. Both contribute to the degree of perceived realism, i.e. the credibility and persuasiveness of the virtual situation as perceived by the user. Although immersion is the technical prerequisite, it is presence, together with perceived realism, that determines the psychological impact.

These features are of fundamental importance, as a stronger sense of presence increases the resulting perceived realism of the virtual environment (Standen et al., 2021). In other words, the more users actually believe they are in the VE, the greater the likelihood that the behaviour exhibited will be similar to behaviour in comparable situations in the real world. This makes VR ideally suited to investigating observations, human reactions, and behaviours in unique contexts—which may include contexts such as crime in space—in a controlled and immersive way, as it can provide a credible simulation of reality. (Briggs, 1999; Fox et al., 2009).

Although VR has been successfully applied in several criminological studies, such as simulating burglary scenarios to measure the influence of guardianship (Van Sintemaartensdijk et al., 2020), its use in the context of space crime remains largely unexplored. This is remarkable, as studying perceptions and attitudes towards crime in space—and the extent to which these are perceived as realistic—is crucial to address future legal and operational issues. In a unique environment such as space, where factors such as isolation, limited resources, and long-term proximity to others come into play, traditional methods are often inadequate (Eski & Lampkin, 2024; Feldman & Taylor, 2025). Understanding these perceptions is essential, not only to prevent criminal behaviour in space, but also to inform policymakers about the social and psychological impact of space crime (Eski & Lampkin, 2024). VR offers a unique opportunity here: not only can it create realistic scenarios that immerse the user in the VE, but it also allows researchers to measure attitudes and concerns in a controlled, immersive environment, where the perception of realism may play an important role.

Purpose of this study

The aim of this study is to investigate the extent to which VR simulations can contribute to a better understanding of perceptions/views— composed of attitudes and concerns—surrounding space crime. Space crime is a topic that has so far received little attention within criminological research, despite its growing relevance due to the rise of space tourism and commercial space travel. Understanding how people perceive and respond to crime in space is crucial for developing effective preventive and regulatory strategies. Virtual reality (VR) offers a unique opportunity here to explore such perceptions and behaviours. By using a VR scenario, realistic and immersive simulations can be created in which participants can experience criminal incidents in a space environment. The sense of realism that VR simulations can evoke create makes it likely that behaviour and reactions in this virtual environment are similar to how people would react in similar situations in the real world. At the same time, this research provides a comparison with a more traditional approach, namely a written scenario describing the same incident. This comparison allows us to assess whether and how the presentation format affects participants' attitudes, perceived realism, and state of concern regarding space crime.

This research aims not only to contribute to the understanding of human perceptions of crime in a unique, extreme context such as space, but also to evaluate the effectiveness of VR as a research tool in this domain. In doing so, the research complements existing studies using VR to investigate social dilemmas, moral conflicts, and criminal behaviour in terrestrial contexts. The central premise of this study is to determine how different presentation formats, a virtual reality (VR) scenario and a written scenario, influence perceptions such as attitudes, and concerns towards space crime, which then allows us to place these individual perceptions in a broader social and legal context, in which questions about responsibility, (international) norm setting, and policy are becoming increasingly urgent.

Based on existing literature and the supposed benefits of VR, the central hypothesis of this study is: Attitudes, concerns, and overall perceptions of space crime will be significantly more strongly influenced by a VR scenario simulating a space crime compared to a written scenario describing the same incident. This implies that the presentation format (VR versus written scenario) is a determining factor in changing attitudes and concerns about space crime.

Hypotheses

H1: Participants experiencing the scenario in the VR environment will experience higher levels of engagement (presence) and realism than participants in the written scenario condition.

H2: Participants in the VR condition will show a greater change in attitude and concern towards space crime compared to the written scenario condition.

H3: Perceived realism, especially as experienced in the VR condition, will lead to a greater attitude change and concern about space crime compared to the written scenario condition.

Methods

Participants

A total of 66 participants participated in this study (Age range of 18 to 31, M_{age} = 21.71, SD_{age} = 2.82). Of these participants, 23 identified as male, 43 identified as female. Participants had to be at least 18 years old and could not have medical conditions that would prevent them from participating in a VR experiment, such as epilepsy. The sample consisted of volunteers recruited through flyers that were spread throughout: the campus of the University of Twente, an online university platform, and to additional volunteers recruited by the researchers themselves. University student participants received compensation, namely SONA credits, for their time and effort in participating.

Research Design

This study employed a between-subjects design, in which participants were randomly assigned to one of two experimental conditions: a VR scenario or a written scenario. In the VR condition, participants were presented with an immersive simulation of a space station using a VR headset. In the written condition, participants read a text version of the same scenario. The VR condition consisted of 35 participants, while the Written condition consisted of 31 participants, allowing the effects of the presentation format on attitudes, perceived realism, and concerns towards space crime to be compared.

Material

Scenario

Participants in both conditions were presented with the same scenario, in which they found themselves in an international space station-like environment (IRIS - International Research & Innovation in Space) (See Appendix A). In this scenario, the participant was introduced as a young researcher who had just arrived on board the space station to conduct experiments on artificial gravity. This scientific mission was preceded by a brief explanation of the importance of artificial gravity for long-term space missions, such as future manned trips to Mars. The event took place on the third day of the mission. The participant woke up in a sleeping cabin and was almost immediately confronted with an unexpected, confrontational situation: upon opening the door, he or she was verbally and personally approached by a fellow astronaut. This colleague, Brian— an authoritative crew member who had already been in space for almost a year— addressed the participant in an intrusive manner. His behaviour escalated into an unwanted intimidating speech, in which power and mutual dependence were explicitly mentioned. The participant was then asked to make their way through the space station to a laboratory room, where they had to perform a few simple visual inspection tasks (colour checking of objects and reporting a numerical code).

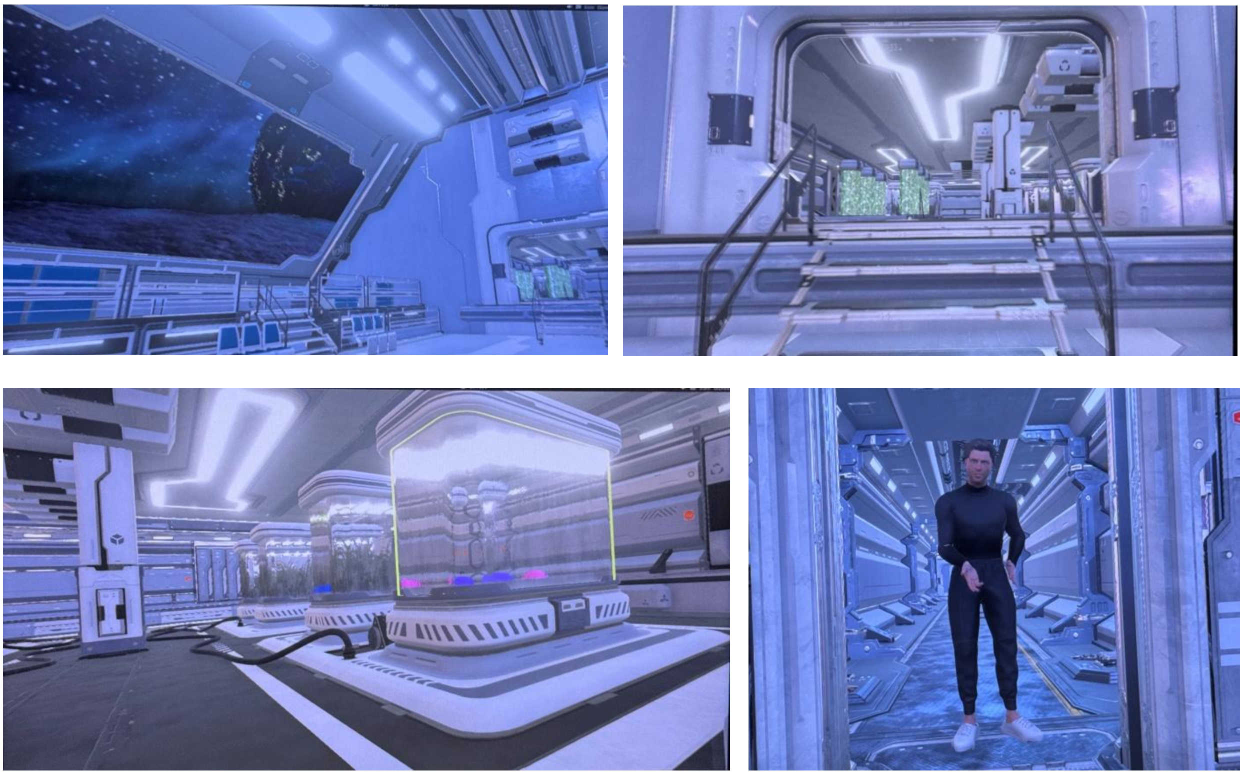
The written version contained the scenario in narrative form, while participants in the VR condition experienced this interaction from a first-person perspective in a simulated space environment. See Figure 1 for a visual impression of the VR condition.

Manipulation Check Task

Within the space station, the participants were assigned a task to be performed in a scientific workspace on board the ship, namely, to check whether the three spheres were the same colour, and an additional task to look at the board to report the number of the day. This environment/space included specific interactive elements that were crucial to the experience of the scenario and the subsequent manipulation check. For example, there was a greenhouse with plants, which contributed to the visual details of the virtual environment. In addition, there were interactive 'spheres' floating in the lab space. Participants in the VR condition had to pick up these spheres and check them for colour consistency, while also reading a number from a board. These tasks were specifically designed to stimulate interaction with the virtual environment and measure the degree of engagement with the scenario.

Figure 1

First-person Images of the Interior of the Space station

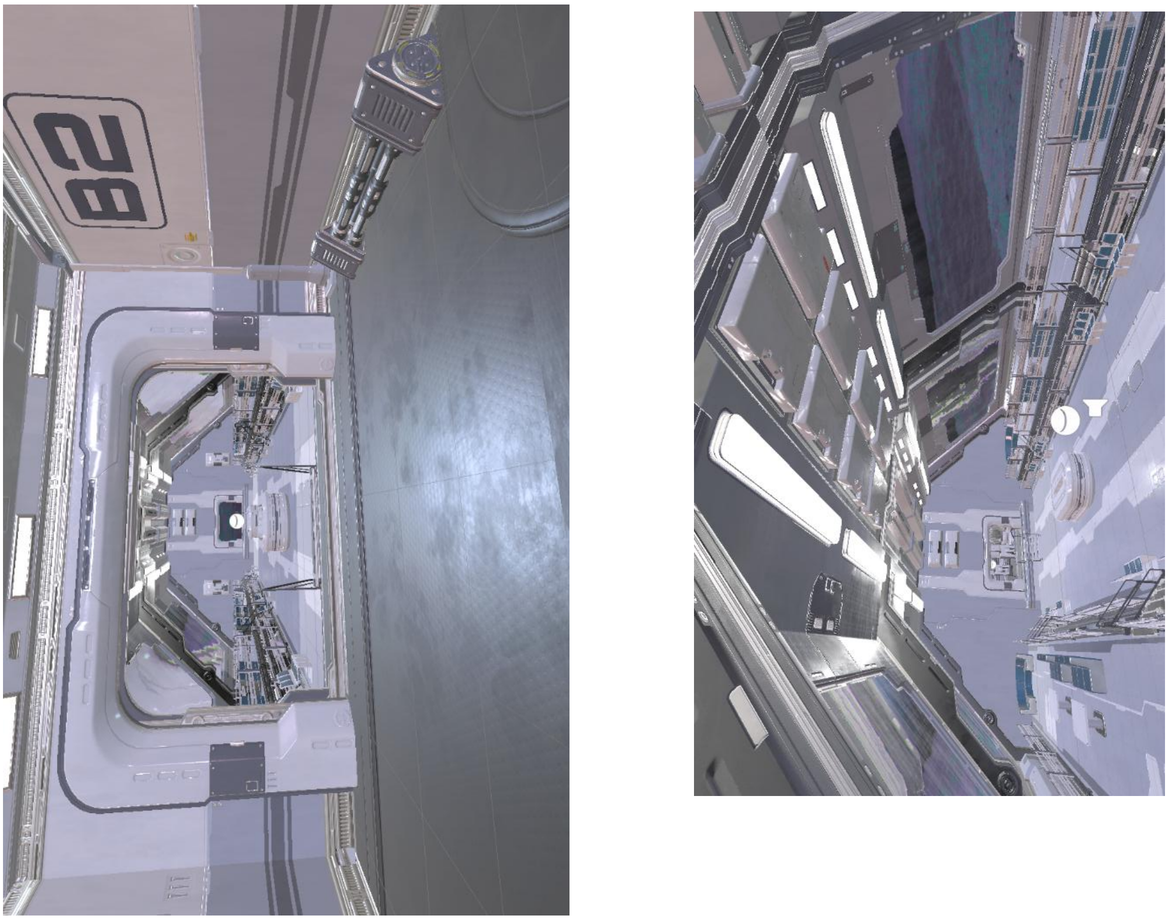


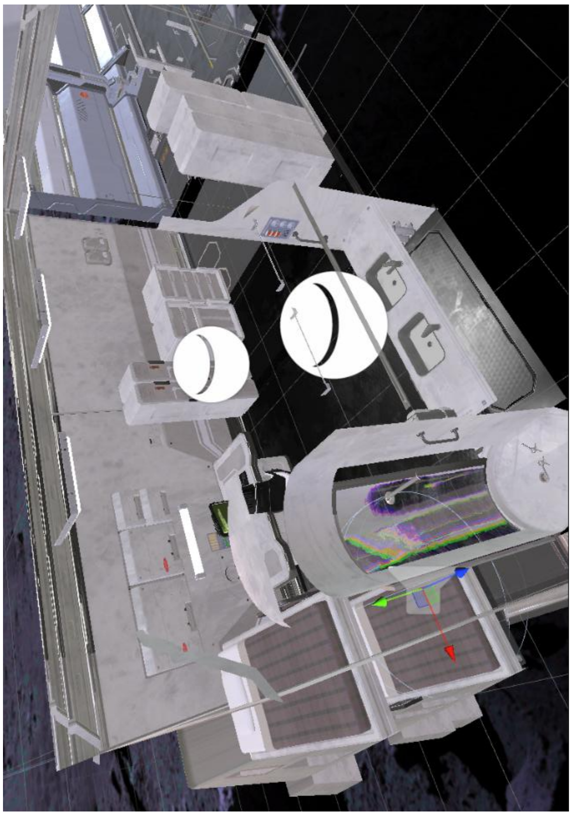
VR Scenario

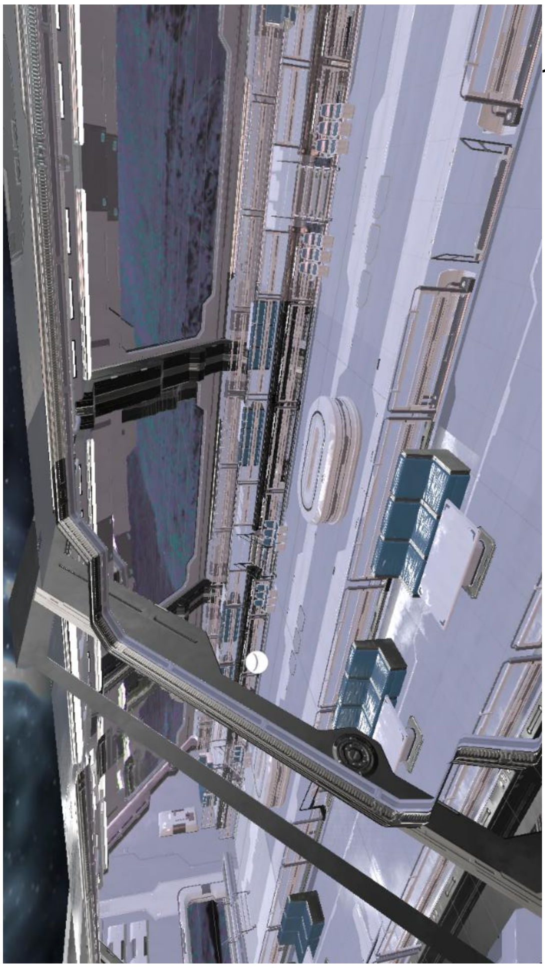
In the VR condition, this scenario was performed in an interactive Virtual Environment (VE) in which participants could freely move and interact with objects. The VE was developed and utilised using the program Unity (version Unity 2021.3.4f1), designed to resemble a space station from the inside, with an outer space view further along the spaceship, as can be seen in Figure 2. Additionally, the Oculus (Quest Rift) VR glasses were used in the VR condition. The Oculus glasses allowed for an immersive audio experience, in addition to the visual immersion. Furthermore, participants could move freely within the environment using two controllers, connected to the Oculus, allowing for active navigation. The recording of the activity within the VE by the participants was done using the Open Broadcaster Software (OBS Studio Version 31.0.3). In the written condition, the same scenario was displayed as text. The full VR scenario script is included in Appendix B.

Figure 2

Third-person Images of the Interior of the Space station







Before and after the scenario exposition, participants completed several questionnaires, each focusing on different psychological constructs. Means and standard deviations (SDs) for all scales are reported in Table 1. The self-developed questionnaires can be found in Appendix C. The questionnaires utilised in this study include the following:

Attitude towards Space Crime – Adapted Questionnaire

Attitudes towards space crime were measured to gain insight into participants' moral evaluation and perception of the seriousness of such incidents. Attitudes were measured using 7 items adapted from Entradas & Miller (2010), rated on a 5-point Likert scale ranging from 1 (completely disagree) to 5 (completely agree). An example question is: “Space crime is a serious problem that requires attention.” The internal consistency of the scale was acceptable

State of Concern – Adapted Questionnaire

To assess participants’ concern about space crime, a single-item measure was used based on Capstick et al. (2016): “How concerned are you about space crime?”, rated on a 4-point scale (1 = not at all concerned, 4 = very concerned).

PANAS – Original Questionnaire

The Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988) was administered to assess participants' overall emotional state after exposure to the scenario, in order to gain insight into the affective impact of the different presentation formats, namely both written and the VR condition. It consists of 20 items rated on a 5-point scale (1 = not at all, 5 = extremely), comprising two subscales: positive affect (e.g., enthusiasm, pride) and negative affect (e.g., fear, hostility).

Presence (VR Condition Only) – Adapted Questionnaire

In the VR condition, the degree of presence was measured to determine how strongly participants felt they were actually physically present in the virtual environment, a crucial factor for immersion. This was measured in the VR condition using 7 items based on Van Gelder et al. (2019), rated on a 5-point Likert scale. An example question is: “I felt like I was really present in the virtual environment.”

Cyber-sickness (VR Condition Only) – Adapted Questionnaire

In order to record any physical discomfort caused by the VR experience, the cybersickness scale was administered, as this could influence the experience and results. To assess discomfort due to virtual reality, participants in the VR condition completed a 6-item cyber-sickness scale (Kennedy et al., 1993). Items were rated on a 5-point scale, an example question being: “The virtual environment made me dizzy”.

Perceived Realism – Adapted Questionnaire

Perceived realism of the scenario was measured to determine the extent to which participants considered the simulated situation to be authentic and credible, which is essential for the ecological validity of the experimental manipulation. Perceived realism of the scenario was measured using 6 items (Van Gelder et al., 2018), rated on a 5-point Likert scale. An example question includes: “The situation felt realistic.”

Space Crime Knowledge – Adapted Questionnaire

In order to evaluate participants' prior knowledge and awareness of space crime, specific questions on this topic were included, as this could influence perceptions. Based on Michel et al. (2016), 11 items were used to assess participants’, these included (open) questions about familiarity, information sources, and perceived seriousness of crimes in space. An example question includes: ‘Can you name an example of a space-related crime?’

Manipulation Check – Self-Developed Questions

To verify the effectiveness of the manipulation and to assess the extent to which participants remembered the details of the scenario and the prior instructions, participants answered several questions after the scenario. These items focused on their memory of the scenario, recognition of characters, and perceptions of the offender. Specifically, questions were asked about the details of the assigned tasks within the spaceship. For example, participants had to name the specific number they were supposed to read from the board in the lab room. This number was 976. They were also asked about the colours of the three spheres they had to inspect to ensure they were of same colour. The spheres were classified as purple, blue, and pink. These questions served to verify that the participants had thoroughly read the instructions and adequately remembered the assigned task, with a focus on the specific visual and numerical details. Additional questions included for example: 'What did the other person in the scenario look like?' and 'Do you know who the person harassing you was?' (see Appendix C).

Vividness of Visual Imagery Questionnaire (VVIQ) – Original Questionnaire

To measure individual differences in visual imagery ability, the Vividness of Visual Imagery Questionnaire (VVIQ) was administered, based on Nelis et al. (2014). This questionnaire consists of 16 items divided into four mental imagination task environments (such as the face of an acquaintance or a sunset), with four questions each. The items were rated on a 5-point scale (1 = no imagery possible, 5 = image is perfectly vivid as in reality). A higher total score indicates stronger and more vivid visual imagination.

Open-Ended Questions – Self-Developed Questions

Three open-ended questions were included post-scenario, to explore qualitative reflections on space crime, as well as any additional remarks/comments on either the study or the topic of space crime: (1) 'If your view on space crime has changed as a result of this study, could you explain why?', (2) 'Do you have any additional thoughts or comments on this study or the topic of space crime?'. And lastly, a question on whether space crime laws/legislation would be needed: (3): 'Do you think special laws/legislation is needed to tackle crime in space? Why or why not?'

Table 1

Descriptive Statistics and Reliability of the Main Scales

Scale	Number of Items	*M* (SD)	Cronbach's *α*
Attitude (Pre)	7	2.50 (0.57)	.60
Attitude (Post)	7	2.47 (0.50)	.59
Concern (Pre)	1	2.54 (1.05)	–
Concern (Post)	1	3.63 (0.98)	–
Perceived Realism	6	3.92 (0.46)	.65
Presence (VR)	7	3.73 (0.65)	.81
PANAS Positive Affect	10	3.05 (0.75)	.83
PANAS Negative Affect	10	3.11 (0.83)	.87
Cybersickness	5	2.40 (0.95)	.79
VVIQ (Total)	16	3.82 (0.61)	.90

Note. M = mean; SD = standard deviation; α = Cronbach's alpha. N = 66. 'Pre' referring to Pre condition manipulation. 'Post' referring to post condition manipulation (Written or VR condition).

Procedure

The experiment was conducted in the research lab of the Faculty of Behavioural, Management, and Social Sciences, at the University of Twente. Each session of the study lasted an average of 45 minutes per participant. Upon arrival, the participant was welcomed and asked to complete an informed consent form via Qualtrics. Once the participant had given their consent by accepting the consent form, they could continue with the first round of questionnaires. The unique participation number and experimental condition were then recorded. Participants were randomly assigned to one of two conditions: the VR condition, in which the scenario was experienced within an immersive VR environment, or the written condition, in which the same scenario was presented as text on a computer screen. The researcher left the laboratory cubicle after the participant started the first round of questionnaires and gave instructions to alert the researcher once it was completed.

Written condition

Participants in the written condition were presented with the same scenario in text form on a computer screen. They were given time to read through the scenario at their own pace, without further instructions or interactions with the researcher, unless they had questions, in which case they were instructed to notify one of the researchers.

VR condition

In the VR condition, a series of instructions on how to use the VR goggles and controllers followed upon returning to the laboratory cubicle. For participants in the VR condition, the researcher first checked that the VR headset was functioning correctly. Then, these participants were instructed on how to use the virtual environment, including operating the controllers and navigating within the simulation. Participants were explained that they could move freely and that certain objects were interactive. After these instructions, they received the VR headset and controllers, after which the scenario was started, and the session was recorded using OBS software. During the VR experience, as little interaction as possible was sought with the participant unless technical issues arose, the participant experienced discomfort/unease, or the participant had questions. If a participant felt uncomfortable or showed symptoms of cybersickness, the experiment could be interrupted or terminated at any time.

Post-condition phase: written and VR condition

After completing the scenario, regardless of the condition, the participant was asked to complete a series of questionnaires. These questionnaires assessed for a second time the attitudes and concern towards space crime, and then moved on to other questionnaires, including: emotional responses (PANAS-Gen), perceived realism, and, for the VR condition specifically, the degree of presence and any symptoms of cyber-sickness. A manipulation check was also performed to verify whether the participant had perceived the scenario correctly followed by several open questions. Participants from the VR condition were checked, after having gone through the VR experience, by asking how they were feeling. Finally, the participant was thanked for participating, any compensation (e.g. credits) was provided and the session was closed

Quantitative Analysis

All data were stored anonymously- using unique participant numbers- and analysed using Excel (version 2503) and R Studio (version 2024. 12.1 + 563). Before the analyses were performed, the dataset was cleaned to ensure the quality and reliability of the data. Descriptive statistics (means, standard deviations, Cronbach's α) were calculated for each scale. Prior to the inferential analyses, the assumptions underlying the chosen statistical tests were checked to ensure the validity of the results.

To test H1, an independent t-test was conducted to determine whether there were significant differences in perceived realism between the VR and written conditions. Engagement (presence) could only be evaluated within the VR condition, as this variable was not measured in the written condition.

To test H2, a mixed ANOVA was conducted for both attitude and concern, with "time" (pre- vs. post-measurement) as the within-subjects factor and "condition" (VR vs. written) as the between-subjects factor. This analysis examined the mean differences in attitude and concern between conditions, the change over time, and the interaction between time and condition.

Lastly, to test H3, the mixed ANOVA used to test H2 was expanded by adding perceived realism as a covariate. This allowed us to investigate the moderating role of realism on the relationship between condition, time and the dependent variables (attitude and concern).

Additional Qualitative Analysis of Open Questions (VR and Written condition)

In addition to the quantitative analyses, a deductive thematic analysis was also carried out on the open questions that participants answered after the scenario. The purpose of this analysis was to gain additional insight into how participants experienced the situation and to gather information about participants' perceptions of space crime, with a particular focus on involvement (perceived realism) and presence. For this qualitative analysis, open answers were analysed from both the VR condition (condition = 1) and the written condition (condition = 2). For each condition, different questions were analysed, tailored to the content of the scenario and whether the questionnaire in question was part of one of the conditions.

The thematic analysis was performed in ATLAS.ti (version 25.0.1). The data were coded by theme, after which descriptive patterns in the responses within and between conditions were identified. Quotes from participants are presented with a reference to the corresponding participant number.

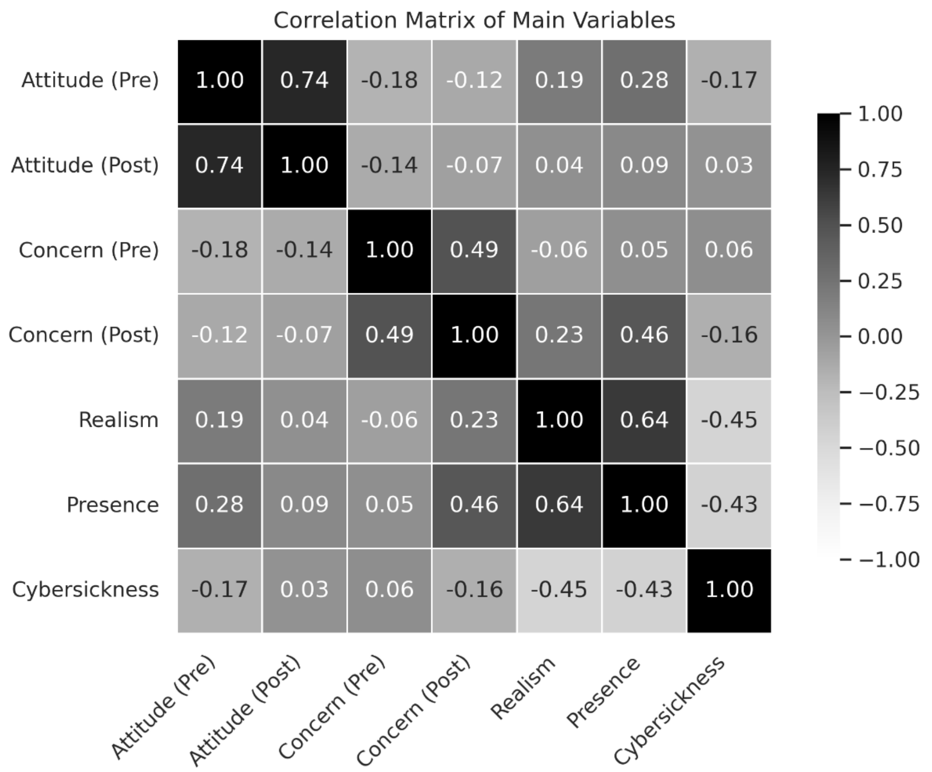
Results

Preliminary analyses: Correlations between variables

The results are presented in line with the hypotheses and analyses described in the analysis plan. As a first step in data exploration and in preparation for the main hypothesis tests, the correlations between the most important variables were examined. A summary of the descriptive statistics and reliability of the scales used is shown in Table 1. The correlation matrix of the main variables can be found in Figure 3. Attitude before and after manipulation were highly correlated (*r* = .74). There was a positive correlation between perceived realism and presence (r = .64), and a negative correlation between realism and cybersickness (*r* = -.45). Cybersickness also correlated negatively with presence (*r* = -.43). No significant correlations were found between cybersickness and attitude or concern.

Figure 3.

Correlation Matrix of Main Variables



Note. Values closer to 1 or -1 indicate stronger relationships. Black-gray gradient reflects direction and strength of the correlation. N = 66.

Manipulation of realism and engagement: Testing Hypothesis 1

To test whether the manipulation of the conditions was successful in eliciting differences in realism and engagement (in this study measured as presence), and thus to test Hypothesis 1, we first investigated whether the perceived realism differed significantly between the VR condition and the written condition. In this study, engagement was partly interpreted on the basis of perceived realism and presence. However, presence was only measured among participants in the VR condition, which meant that this variable could not be directly compared between conditions. An independent t-test was performed for perceived realism.

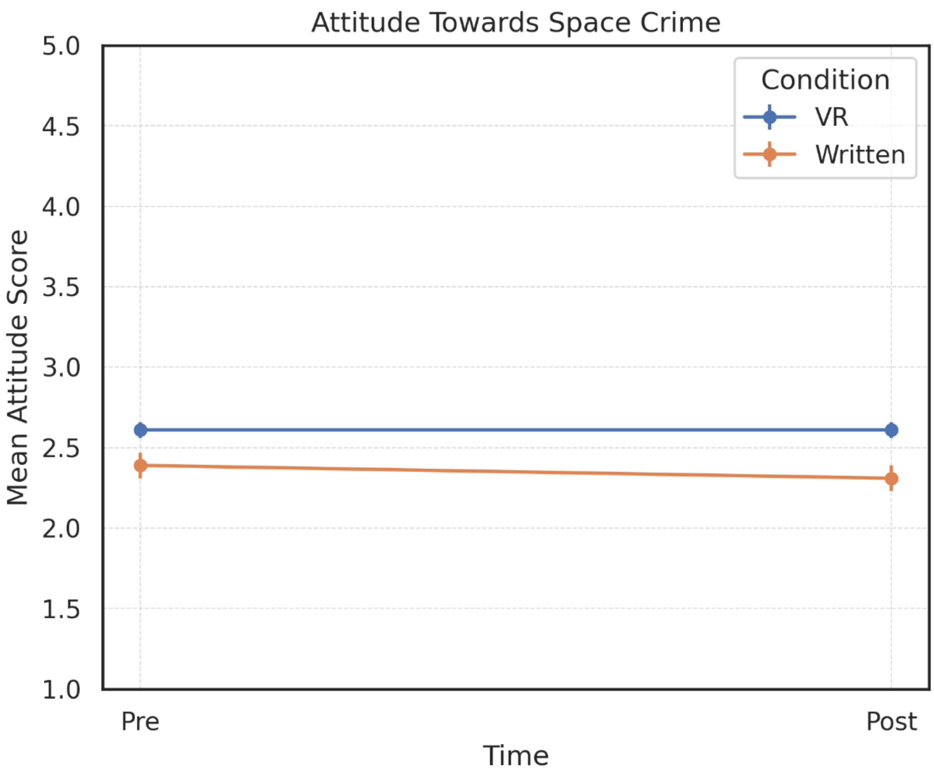
The results showed that participants in the VR condition (M = 3.93, SD = 0.46) did not report significantly higher realism scores than participants in the written condition (*M* = 3.97, *SD* = 0.46), $t(63.55) = 0.31$ $SE = 0.11$, $p = 0.75$, $\eta^2 = .002$. The manipulation of realism can therefore be considered ineffective, as no significant differences between the conditions were found. Furthermore, differences in engagement could not be formally tested between the conditions, as presence was only measured in one condition, which means that Hypothesis 1 is not supported.

Effect of the manipulation on attitude and concern: Testing Hypothesis 2

To investigate the effect of the manipulation on attitudes towards space crime, a repeated measures ANOVA was conducted with attitude as the dependent variable, time (before vs. after) as the within-subjects factor, and condition (VR vs. written) as the between-subjects factor (see Figure 4). The analysis showed a significant main effect of condition, $F(1, 64) = 4.43$, $p = .039$, indicating that participants in the VR condition reported higher attitude scores on average than participants in the written condition. However, no significant main effect of time was found, $F(1, 64) = 0.48$, $p = .49$, indicating that attitudes remained stable overall from before to after the manipulation. The interaction between time and condition was also not significant, $F(1, 64) = 0.20$, $p = .66$. This indicates that the manipulation did not influence the extent to which posture changed over time.

Figure 4

Average attitude scores regarding space crime before and after manipulation, broken down by condition (VR vs. written scenario).

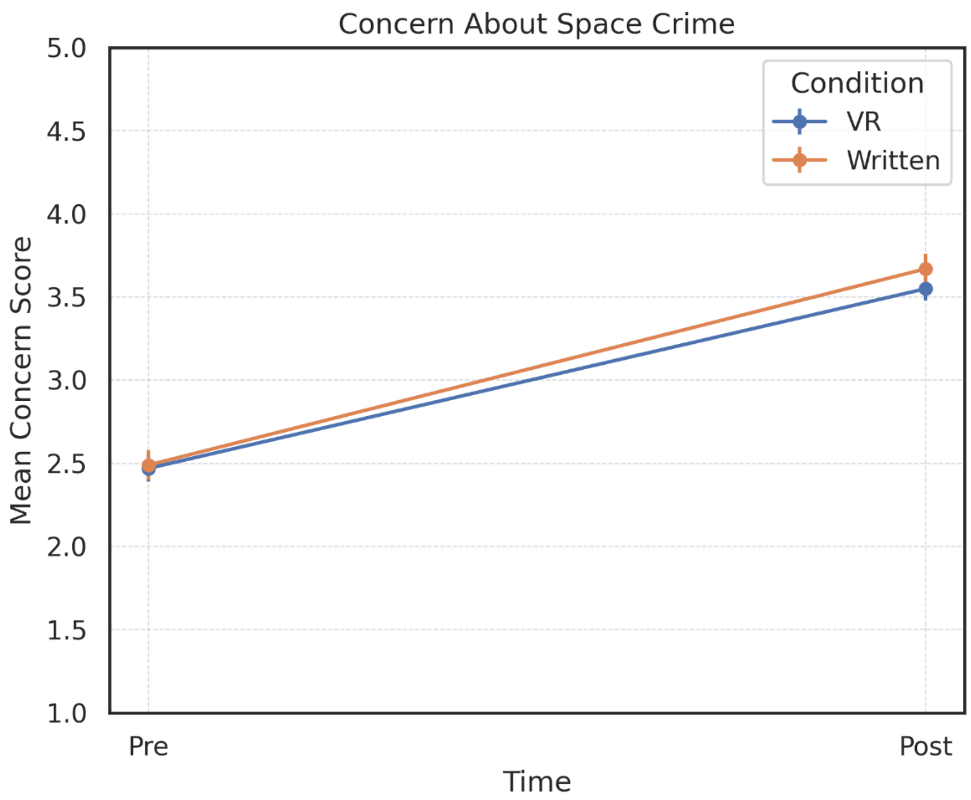


***Note*.** Average scores for attitude towards space crime before and after manipulation, broken down by condition (VR vs. written scenario). Error bars indicate the standard error of the mean. Scores are measured on a scale from 1 (very low) to 5 (very high).

Another repeated measures ANOVA was conducted for concerns about space crime (see Figure 5). This revealed a highly significant main effect of time, $F(1, 64) = 86.19$, $p < .001$, $\eta^2 = .57$, meaning that concerns about space crime increased significantly after the manipulation, regardless of condition. No significant main effect of condition was found, $F(1, 64) = 0.71$, $p = .40$, nor was there a significant interaction between time and condition, $F(1, 64) = 0.19$, $p = .66$. This suggests that both the VR and written conditions led to a similar increase in concern.

Figure 5

Average concern scores regarding space crime before and after manipulation, broken down by condition (VR vs. written scenario).



Note. Average concern scores towards space crime before and after manipulation, broken down by condition (VR vs. written scenario). Error bars indicate the standard error of the mean. Scores are measured on a scale from 1 (very low) to 5 (very high).

In sum, Hypothesis 2 was partially supported: although attitude differed on average between conditions, it did not change significantly over time. Concern about space crime did increase, but this was equally true for both conditions.

Moderating Role of Perceived Realism: Testing Hypothesis 3

To test Hypothesis 3, which assumed a moderating role for perceived realism, an extension of the previously conducted repeated measures ANOVAs was carried out, adding perceived realism as a covariate to the models for both attitude and concern.

Attitude and realism

The analysis of attitudes towards space crime with perceived realism as a covariate was conducted using a mixed ANOVA (see Table 2). This analysis showed no significant main effect of condition, $F(1, 62) = 3.30$, $p = .074$. The main effect of time was also not significant, $F(1, 62) = 2.48$, $p = .120$, indicating that the average attitude did not change significantly between the two measurement moments. Furthermore, there was no significant effect of perceived realism, $F(1, 62) = 0.18$, $p = .676$. No significant interactions were found within the model between time and condition ($F(1, 62) = 0.07$, $p = .789$), time and realism ($F(1, 62) = 2.76$, $p = .102$), or between time, condition and realism ($F(1, 62) = 0.05$, $p = .832$).

However, a significant interaction between condition and perceived realism was found, $F(1, 62) = 4.26$, $p = .043$ (see Table 3). This interaction indicates that the relationship between perceived realism and attitude differed depending on the experimental condition (VR versus written scenario).

Table 2

Within-subjects effects of the repeated measures ANOVA for attitude with realism as a covariate

Effect	***SS***	***dF***	***MS***	***F***	***P***	***ηp²***
Time	0.19	1	0.19	2.48	.120	.038
Time * Condition	0.01	1	0.01	0.07	.789	.001
Time * Realism	0.21	1	0.21	2.76	.102	.043
Time * Condition * Realism	0.00	1	0.00	0.05	.832	.001
Residual	4.74	62	0.08			

Note. Time = Attitude Pre measurement and Attitude Post measurement

Table 3

Between-subjects effects of the ANOVA for attitude with realism as a covariate

Effect	***SS***	***dF***	***MS***	***F***	***p***	***ηp²***
Condition	1.47	1	1.47	3.30	.074	.051
Realism	0.08	1	0.08	0.18	.676	.003

Condition * Realism	1.90	1	1.90	4.26	.043	.064
Residual	27.65	62	0.45			

Note. Time = Attitude Pre measurement and Attitude Post measurement

An additional simple slopes analysis showed that the effect of condition (0 = written scenario, 1 = VR scenario) on attitude depended on the perceived realism (centred on M). At low realism (M – 1 SD), there was no difference in attitude between the two conditions. At medium realism, the difference was significant, and at high realism (M + 1 SD), this difference increased further. In short, the more realistic participants perceived the scenario, the greater the impact on attitude in the VR condition compared to the written scenario condition (see Figure 6 and Table 4).

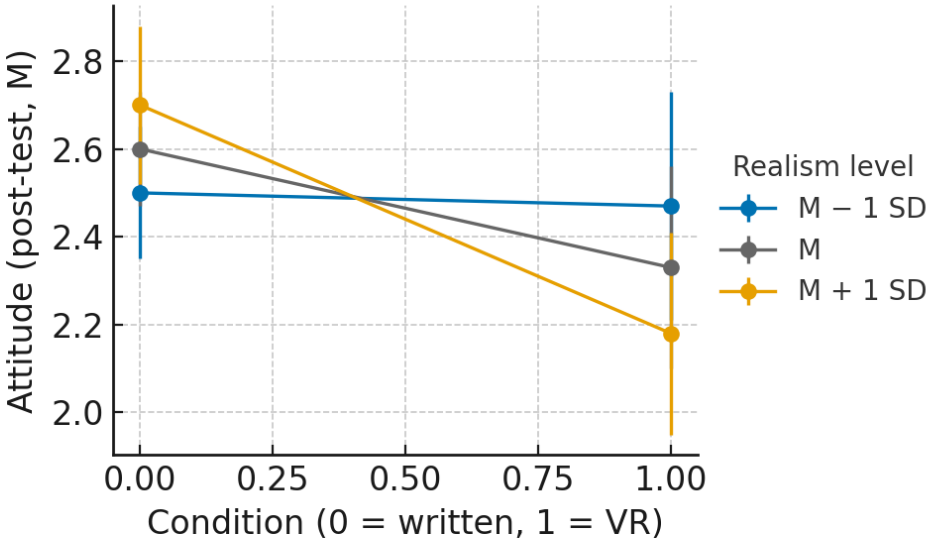
Table 4

Simple slopes analysis for Hypothesis 3 (attitude)

Realism	***b*** **(1 − 0)**	***SE***	***t*****(df = 62)**	***p***	***F*****(1, 62)**	$\eta^2 p$
M − 1 SD	−0.034	0.169	−0.20	.840	0.04	.001
M	−0.275	0.118	−2.33	.023	5.42	.080
M + 1 SD	−0.515	0.172	−3.00	.004	9.00	.127

Figure 6

Post-test attitude as a function of condition (0 = Written scenario, 1 = VR scenario) at three levels of perceived realism (M – 1 SD, M, M + 1 SD). Error bars represent ± 1 SE



Concern and realism

For concern about space crime, the analysis showed a strong significant main effect of time, $F(1, 51) = 54.11$, $p < .001$, indicating a clear increase in concern after manipulation, independent of condition or realism (see Table 5 and Table 6). The main effect of condition was not significant, $F(1, 51) = 0.40$, $p = .53$, as was the effect of realism as a covariate, $F(13, 51) = 0.84$, $p = .61$. No significant interactions were also found: the interaction between condition and time was not significant, $F(1, 51) = 0.21$, $p = .65$, and the interaction between time and realism was not significant, $F(13, 51) = 1.26$, $p = .27$.

Table 5

Within-subjects effects of the repeated measures ANOVA for concern with realism as a covariate

Effect	***SS***	***dF***	***MS***	***F***	***P***	***ηp²***
Time	24.11	1	24.11	54.11	< .001	.515
Time * Condition	0.10	1	0.10	0.21	.646	.004

Time * Realism	0.56	1	0.56	1.26	.266	.024
Residual	22.73	51	0.45			

Note. Time = Concern Pre measurement and Concern Post measurement

Table 6

Between-subjects effects of the repeated measures ANOVA for concern with realism as a covariate

Effect	***SS***	***dF***	***MS***	***F***	***p***	***ηp²***
Condition	0.57	1	0.57	0.40	.528	.008
Realism	1.19	1	1.19	0.84	.613	.016
Condition * Realism	1.90	1	1.90	1.35	.250	.026
Residual	71.86	51	1.41			

Note. Time = Concern Pre measurement and Concern Post measurement

Additional Qualitative Analyses

The analysis was performed deductively, based on predetermined themes derived from theories about engagement and presence in media experiences. These themes were specifically chosen because they directly relate to the core concepts of VR research and the psychological effects of immersive media, as described by Cummings & Bailenson (2015); Skarbez et al. (2017); Slater & Sanchez-Vives (2016); Van Gelder et al. (2019) on the perception of virtual environments, and (Green & Brock (2000); Nash (2017); Van Laer et al. (2013) for textual scenarios. For example, “Person” and “Environment” focus on the credibility of elements within the scenario, while “Task” and “Personal” (Latter for the written condition only) measure the participant's active and emotional engagement.

The following themes were identified within the VR condition (N = 35):

- PersonVR (perception of the virtual person)
- EnvironmentVR (perceived realism of the environment)
- TaskVR (task involvement)

For the written condition (N = 31), the open answers were grouped into:

- PersonWritten (experience of the main character)
- EnvironmentWritten (perception of the environment)
- TaskWritten (involvement in the scenario)
- PersonalWritten (emotional or personal involvement)

Within each theme, patterns were identified in how participants described their experience of the scenario (see Table 7). Quotations were provided with corresponding participant numbers.

VR

Theme 1: PersonVR - Experience of the virtual person

Within this theme, the virtual person was frequently described through external features, clothing and appearance. Some participants indicated that the person appeared convincing, for example through comments such as ‘he was handsome, dark hair, black clothes, looked real’ (U16) or ‘He was a muscled man with black clothing on, and a serious face’ (U15). Characteristics such as ‘tall man with brown hair’ (U12) and ‘average height, brown hair, some space like uniform’ (U17) were also mentioned. At the same time, some participants named less vivid or vague descriptions, such as ‘male, with brown hair’ (U9), saying little about behaviour or human expression, which may indicate limited presence or involvement.

Theme 2: EnvironmentVR - Perceived realism of the environment

Descriptions of the virtual environment ranged from concise to detailed. Several participants described the space as convincing, e.g. ‘The inside of some sort of spacestation where stuff was floating’ (U17) or ‘white and grey with a lot of tubes and tanks, really immersive’ (U14). Others gave a more global impression such as ‘A space station’ (U9) or ‘grey, cold’ (U10). This shows that some participants actually felt immersed in a futuristic environment, while others experienced it less visually or emotionally involved.

Theme 3: TaskVR - Engagement with the task

In terms of task experience, most participants were asked to interact with objects such as coloured spheres. Some participants reported a clear task structure: ‘moving three coloured balls. There was a number on the wall’ (U13) and “I checked the colour of some orbs and threw one on the ground” (U17). On the contrary, others mentioned technical or functional limitations, such as ‘i had to pick up balls but that didn't work’ (U16) or ‘couldn't finish because of technical problems' (U20). This suggests differences in task engagement, partly influenced by technical performance and personal interpretation of the task.

Written

Theme 1: PersonWritten - Perception of the protagonist

Responses to the protagonist ranged from detailed and recognisable to more detached and unclear. Some participants described the protagonist in a detailed manner: 'white, tall, male, brown hair, blue eyes, in his 40s (participant U37) 'Since I am a male, I was imagining the person to look like a gay guy, since their name was Brian.' (participant U31). In contrast, others reported difficulty with empathy or a lack of specificity: 'I did not ascribe a lot of looks to the protagonist as well as Brian as I was mostly caught up in the scenario. If i had to imagine a physical appearance it was probably a blend of common movie trope astronauts, such as seen in the Martian. short brown hair, in shape or rather healthy enough to be considered physically eligible to be an astronaut.' (participant U39).

Theme 2: EnvironmentWritten - Perceived environment

Descriptions of the environment similarly ranged from vivid and detailed to vague or stereotypical. Some participants had a clear mental representation: 'like the inner workings of a space station. Nothing sci fi, but rather like a crammy high tech student dorm. (U39). 'Like the inside of a space craft in a movie.' (participant U32), 'Industrial, how you'd imagine a rocketship.' (participant U11). Others found the environment too narrowly defined or less convincing: 'No space for privacy, very small.' (participant U19), 'Grey, cold.' (participant U35)

Theme 3: TaskWritten - Involvement in the task

The level of involvement in the task or situation varied widely. Some participants indicated active thinking: 'I think every person in space should have the option of contacting someone/sending an alert to someone on earth and be able to leave the spaceship. I also think this should be enforced/protected by law (U69)'. 'i think the laws in space, should be the same as the laws on earth, since its not about the ground its about the people who commit crime (U67)'. Others found the scenario less immersive or difficult to take seriously: 'something with colours and the number 976' (participant U75), 'I wanted to get up and check hemisphere colours (U49)

Theme 4: PersonalWritten - Emotional or personal involvement

This category explored whether participants were emotionally affected by the scenario. Some respondents reported indicators of having strong feelings towards the scenario/experience: '-in my eyes certain crimes such as sexual harassment or rape would be much more serious when they occur in an enclosed environment in space than on earth. In space, it is very difficult for the victim to leave the dangerous environment, because this is quite literally not possible when in a spaceship, which can lead to recidivism a lot faster..' (participant U73), 'I think the scenario was realistic but is surprised me that no further questions were asked about sexual harassment or assault. Otherwise I believe that the topic is really interesting.' (participant U67)

Table 7

Frequency of coded themes within the VR condition (N = 35) and Written-condition open answers (N = 31)

Themes	***f***
PersonVR	41
EnvironmentVR	60
TaskVR	39
PersonWritten	62
EnvironmentWritten	84
TaskWritten	23
PersonalWritten	40

Note. Counts (*f*) indicate the total number of discrete text segments that were coded with each theme across open-ended answers from both the VR and the Written condition. A single participant could contribute more than one segment per theme.

Discussion

Interpretation and Relevance of the Findings

This research was conducted against the backdrop of a rapidly changing space landscape, in which commercial space flights and space colonisation are becoming increasingly realistic. Although space crime was largely considered hypothetical until recently, the increase in private space activities and the lack of a universal legal framework are making this topic increasingly urgent in scientific and societal discussions (Eski &

Lampkin, 2024; Feldman & Taylor, 2025). Given the crucial role of perceptions in risk assessment, moral judgements, and policy acceptance, it is important to systematically map these perceptions (Capstick et al., 2016). Virtual reality (VR) offers an innovative and context-sensitive method for simulating hypothetical scenarios in a realistic way. This research thus contributes to the emerging literature within space criminology and VR research in the behavioural sciences.

The results of this study show that the presentation format (VR versus written scenario) partially influences participants' perceptions and responses to crime in space.

The manipulation of realism proved ineffective, as no significant difference in perceived realism was found between the conditions. Furthermore, engagement could only be partially evaluated using “presence”, a variable that was only measured in the VR condition and therefore could not be compared between conditions.

Concern about space crime increased significantly after exposure to the scenario, but this increase was similar in both conditions. With regard to attitude, a significant difference between the conditions was found, with participants in the VR condition reporting higher attitude scores on average, but no significant change in attitude over time was found.

Although no significant main effects or two-way interactions with realism were found for attitude, the analysis showed a significant interaction between condition and perceived realism. This interaction indicates—in line with what was hypothesised— that the relationship between realism and attitude differed significantly depending on the presentation condition, in this case the attitude change was significant in the VR condition. However, perceived realism did not play a moderating role for concern, as no significant interactions with realism were found.

Attitude towards space crime

Although it was expected that attitudes towards space crime would increase more strongly in the VR condition (Hypothesis 2), the analysis showed no significant main effect of time, nor a significant interaction between time and condition. This indicates that the average attitude did not change significantly between the two measurement moments, and that this change did not differ significantly between the conditions. A general main effect of condition was also not significant, suggesting that participants in the VR condition did not report significantly higher attitude scores overall than participants in the written condition.

However, participants in the VR condition did report higher attitude scores, on average, than participants in the written condition. While attitudes are often understood as evaluations of behaviour or situations on a scale of good versus bad, in some contexts they touch on deeper moral convictions. This is particularly true for topics linked to normative frameworks or fundamental values, such as crime (Frisanco et al., 2024). When a phenomenon occurs in a new and unfamiliar domain—such as space—where formal norms are still lacking, moral intuitions become particularly relevant to how behaviour is evaluated (Scully, 2014). In such contexts, attitudes are often not based solely on practical considerations or knowledge but can also function as expressions of moral evaluation; judgements about what constitutes morally acceptable, just or responsible behaviour (Scully, 2014). For example, when participants judge space crime more negatively in a VR environment, this may indicate a heightened moral response due to the increased intensity of the medium's experience (Frisanco et al., 2024). This moral dimension of attitude formation requires further attention, especially given the absence of explicit regulations and shared norms in the space context. This suggests that VR may contribute to enhanced moral evaluation of space crime even in the absence of actual attitude change.

The analyses show that the higher attitude score in the VR condition is not a time effect but already existed before the manipulation: the results show that VR participants were slightly more positive from the outset than the written group. Attitudes towards hypothetical space crime therefore appear to be stable and only moderately influenced by a single scenario exposure. They seem to be rooted in existing beliefs about ethical behaviour in space, fuelled by societal debates about technological expansion and transgressive behaviour (Eski, 2023; Carbajales-Dale & Murphy, 2022), and are therefore more ideological than situational.

This interpretation is consistent with previous research in which immersive virtual reality was used to activate moral engagement in situations where human rights were violated. Seinfeld et al. (2018) found that participants who witnessed violence against civilians in VR rejected the behaviour shown more strongly and felt more empathy for the victims compared to participants who saw the same scenario via a two-dimensional video. This effect was partly attributed to the increased sense of presence in VR—the feeling of actually being “there” —and the possibility of perspective-taking, whereby participants were able to put themselves more in the shoes of those involved.

A similar mechanism also appears to have played a role in the current study. The scenario contained elements of violence, abuse of power, and legal ambiguity—morally charged themes that may have been experienced more intensely in VR. The increased immersion and sense of reality can make participants feel more emotionally and morally engaged, which influences their attitude towards the behaviour depicted in the scenario. This was also reflected in the open responses of participants in the VR condition. One participant commented: "*No, I think everyone should abide by the laws of the country that is active in space. But in general, it would be very good to introduce human rights as a form of legislation. I think crimes in space should be punished just as severely as on Earth, and sexual harassment and abuse should be punished more severely both on Earth and in space*."

This response illustrates how moral beliefs—in this case about universal human rights—can be activated by a scenario that feels more credible or confrontational in VR. The affective impact, or the emotional charge experienced by participants, seems to go hand in hand with a stronger moral evaluation of the behaviour shown. This dynamic is characteristic of VR contexts in which users can become not only cognitively but also emotionally involved in ethically charged content. Additionally, according to affective heuristics (Slovic & Peters, 2006), emotion acts as a cognitive shortcut when factual knowledge is lacking; in an abstract domain such as space crime, attitudes are then mainly driven by feelings of injustice, threat or empathy rather than by rational legal analysis.

The scenario in this study contained explicit moral dilemmas such as abuse of power and sexually transgressive behaviour. Participants in the VR condition were virtually in the same space as the victim and the perpetrator, which presumably enhanced the affective experience and moral urgency of the scenario. According to the mechanism of affective heuristics, this intensification of moral emotions may have directly contributed to a sharper moral evaluation and a more positive attitude towards the need for legal enforcement in the space.

Although the affective charge was not measured quantitatively in this study, qualitative responses suggest that participants were emotionally affected. The responses of VR participants referred, among other things, to universal human rights and stricter punishment for transgressive behaviour, which is indicative of morally charged affective judgements. Future research could build on this by, for example, explicitly measuring moral emotions such as anger, disgust or compassion or integrating physiological responses as possible indicators of affective involvement. Additionally, follow-up research could compare the impact of different presentation modalities, such as text/written, video, and VR, on moral evaluations, as well as the role of social cues or group norms within VR environments.

In addition to affective involvement and perceived realism, self-relevance may also play a role in explaining the differences in attitude scores between the VR and written conditions. Self-relevance refers to the extent to which a situation or experience is perceived as personally meaningful and thus directly affects an individual's self-image, moral beliefs and values. Previous research has shown that when a situation is perceived as highly self-relevant, this leads to more intense mental imagery, increased affective responses, and greater behavioural intentions (Jang & Kim, 2024). Although self-relevance was not directly measured, some indications point to its influence. VR participants reported higher attitude scores, suggesting that the scenario was experienced as more personal and morally relevant due to the increased telepresence and empathy. Immersive VR increases vividness and interactivity, allowing users to link the scenario more quickly to their own moral compass (Skard et al., 2021; Somarathna et al., 2022). The fact that several VR respondents cited universal human rights or personal norms in open responses confirms that VR brings moral issues closer to the individual frame of reference and thus elicits stronger emotional judgements, even without substantial attitude change.

The lack of significant changes in attitudes over time can be understood by previous studies suggesting that attitudes change only to a limited extent after single and brief exposure to ethically charged scenarios, especially when the topic aligns with pre-existing beliefs or moral orientations (Vela et al., 2022). In the current study, the scenario involved a hypothetical situation with elements of justice, power and ethics in a futuristic context. Such themes may already be morally framed prior to participation in the experiment by broader societal discussions about technology, regulation and safety. This implies that many participants may have approached the scenario with pre-formed norms and beliefs, leaving little room for attitude change. As one participant noted: "*I think laws for space crime are needed. While I do believe that all astronauts and researchers sent into space get their history checked enough, it is better to ensure that there are laws protecting all participants, in case anything happens. i think research in space has to follow its own ethics and moral, but it also has to cover laws we have on earth*" This statement illustrates how attitudes in this domain may already be firmly anchored in a broader moral worldview. Future research into attitude changes in a VR (space) crime study could explore whether attitude change does occur when participants experience multiple scenarios, for instance, or when they discuss these with others, or when the narrative is deepened to stimulate reflection.

Previous research within the context of climate change and ocean acidification suggests that people form attitudes towards abstract threats mainly based on media representations, narratives, and emotional imagination (Capstick et al., 2016). It is therefore possible that attitudes about space crime are not merely a product of factual information processing, but rather of affective framing, in which VR may play a greater role than written text.

Concern about space crime

Whilst attitudes mainly reflected moral judgements of behaviour, analysing concerns provides additional insights into the affective impact of the scenario and the perceived urgency of space crime. Although VR was assumed to lead to a stronger increase in concern about space crime than a written scenario, no significant interaction effect was found. However, concern did increase significantly over time, regardless of condition. This finding suggests that the scenario itself, regardless of modality (VR vs written), was sufficient to elicit an affective response. The increase in concern can possibly be explained by the content characteristics of the scenario, which includes transgressive behaviour, danger to crew members and legal ambiguity-elements that—as also discussed in the introduction—can strongly activate moral intuitions and risk perceptions (Eski & Lampkin, 2024; Feldman & Taylor, 2025). The absence of an interaction effect with condition is remarkable, given previous findings in which VR-based simulations actually evoked stronger affective responses than written scenarios. In the study by Van Gelder et al (2016), for example, participants in a virtual burglary simulation were found to report higher levels of arousal and engagement than in traditional research designs. In this study, that affective intensification does not seem to have translated into a differential increase in concern, which may indicate that the content severity of the scenario outweighed the form in which it was presented. Both the VR and Written scenario proved effective in triggering concern about the incident shown, suggesting that the moral and threatening nature of the scenario was decisive in initiating emotional processing.

The consistent level of concern across conditions may point to a distinction between cognitive evaluations (attitude) and emotional-affective responses (concern): whereas attitude appears to be sensitive to immersion (as suggested by the higher mean in the VR condition), concern may be more primarily fuelled by the substantial threat itself. Moral framing research shows that abstract scenarios evoke concern as soon as they are presented as ethically urgent and socially relevant, regardless of the medium (Capstick et al., 2016; Brugman, 2024). The space attack in this study took place within a legal and normative vacuum, allowing participants to activate their own moral compass—driven by intuitive schemas rather than formal rules—and thus develop equal levels of concern in both the VR and written conditions.

It is possible that concern as a variable is less sensitive to differences in modality when the subject—such as space crime—is relatively unknown and normatively "open". In such cases, participants seem to be guided primarily by the moral implications and potential risks of the behaviour outlined, rather than by the specific way in which that behaviour is presented. The scenario contained elements such as abuse of power, legal uncertainty and threats to safety in a context without established norms—themes that people naturally evaluate morally, even when they have no direct experience of them or limited knowledge (Carbajales-Dale & Murphy, 2022). In light of this, it is not unexpected that no difference was found between VR and the written condition in terms of increased concern in this study. At the same time, one might expect VR, due to its increased sense of presence, to elicit a stronger affective response. Previous research shows, for example, that immersive VR can lead to more intense feelings of fear in threatening scenarios than less immersive media (Standen et al., 2021). However, this effect does not appear to be present in the current study. One explanation for this is that the scenario did not contain sufficient immediate threat to activate a strong affective defence mechanism. Participants perceived the events from a passive, observing position and were not themselves in acute danger. As Cummings and Bailenson (2015) argue, physical involvement is often a prerequisite for experiencing increased presence and affective impact in VR. In this case, that active involvement may have bene lacking, which then may have prevented the amplification of concern via VR.

An alternative explanation for the lack of significant differences between the conditions lies in the nature of the measurement itself. The lack of difference between conditions may also indicate a ceiling effect in the measurement of concern: participants reported relatively high scores on average, making any additional effects of VR difficult to detect (Salman et al., 2020). This is consistent with previous findings that emotions such as worry and anxiety in some domains (e.g. crime or climate change) quickly reach high levels when the content implies a clear threat, even without sensory or immersive enrichment (Slater et al., 2006). Although there may be serious ethical limitations involved, future research could experiment, where research ethical committees allow so, with more direct threat, longer exposure or repeated measurements, to more sharply dissect the nuances of media use and emotional response (Karagiannopoulos & Winstone, 2019).

Perceived realism

In addition to moral and emotional responses, the extent to which the scenario was perceived as realistic also plays a crucial role in understanding the psychological impact of the different conditions. Contrary to expectations, no significant difference was found in perceived realism between the VR condition and the written scenario condition. This finding deviates from previous research in which VR systems are generally associated with an increased perception of realism and situational credibility (Slater & Sanchez-Vives, 2016; Van Gelder et al., 2016).

However, a significant interaction effect was found between realism and condition on attitude, indicating that the relationship between perceived realism and attitude differed depending on the presentation form. This finding suggests that realism in VR may have had a stronger influence on attitude formation than in the textual condition. This result is consistent with previous research showing that perceptual realism in VR plays a crucial role in the psychological impact of an experience, as participants feel physically present in the simulated environment (Slater, 2013).

The absence of a significant difference in realism suggests that VR does not guarantee credibility on its own; the perceptual, cognitive and affective layers of realism depend mainly on content and technical execution (Slater, 2013). The abstract theme of “space crime” offered participants few concrete points of reference, so that both modalities scored similarly on subjective credibility. Moreover, the VR environment was austere: a simple, grey-themed space station with a few visual accents, minimal sensory stimuli, and limited interactions (walking, sliding doors, picking up spheres). Reactions and interaction with the other person (Brian) within the scenario were also limited in the sense that it was mainly passive, as aforementioned, making it impossible to interrupt or take a different course of action while having to listen to the other person. Because contextual consistency and sensory richness are decisive for perceived realism (Standen et al., 2021), a lack of additional characteristics may have contributed to participants perceiving the written scenario as equally credible as the VR presentation.

This finding also has implications for the interpretation of concern as a dependent variable. Although concern increased in both conditions, there was no difference in the degree of increase between the different conditions. This can be partly explained by the lack of a difference in perceived realism, suggesting that the moral and threatening nature of the scenario was powerful enough in itself to elicit affective responses—regardless of the form in which it was presented. An additional methodological limitation lies in the measurement of engagement using realism and presence. In this study, presence was measured exclusively in the VR condition, making it impossible to directly compare this construct between conditions. Since engagement (presence) is a known mediator between immersion, realism and affective impact, this constitutes an important limitation when interpreting the role of modality.

As was evident from the open responses of participants, the experience in the VR condition was regularly described as *"realistic"* and *"as if I were there myself"*, while participants in the text condition were more likely to include in their statements, remarks such as: *"it was difficult to picture it"* or *"I imagine it would be like that"*. These differences point to a distinction in the type of realism that was addressed in the two conditions, a distinction that corresponds to the conceptual difference between perceptual and cognitive realism (Nash, 2017). Perceptual realism refers to the extent to which visual, auditory, and spatial characteristics are perceived as credible, while cognitive realism relates to the logical structure and recognisability of a scenario within the participant's existing worldview.

In the VR condition, sensory stimuli may have activated perceptual realism, while participants in the written condition relied more on cognitive simulation and their own interpretation. When participants have limited prior knowledge or mental representations of a domain—as in the case of space crime—the internal coherence and plausibility of the scenario is an important source of realism. This is consistent with research showing that scenarios are considered more realistic when they are narratively consistent with existing beliefs, regardless of modality (Brugman, 2024). At the same time, the qualitative findings help to better interpret the quantitative results, which found no significant difference in perceived realism between the conditions. It is possible that the cognitive realism of the written scenario partially compensated for the lack of perceptual richness, resulting in similar realism scores. In the current study, perceived realism in VR appears to have played a more direct role in the assessment of behaviour and its severity, whereas in the text condition, the interpretation of realism may have been influenced more by cognitive simulation and narrative logic (Nash, 2017). This complementarity underlines the importance of additional qualitative analyses when interpreting the effects of realism on attitude and concern.

The importance of narrative coherence offers an additional explanation for the lack of significant main effects of realism. The studies by Weber et al. (2021) and Pizzolante et al. (2024) showed that even high-tech VR experiences are rated as less realistic when the narrative is inconsistent or when users have little prior knowledge of the domain. This interpretation is supported by some open-ended responses in which participants described Space Crime as unfamiliar to them or as a domain not thought of before, as quoted in: '*It was something I had never thought of before... I see it is important to research and investigate."* Another reflected: *"I never thought space could be dangerous... it might even be more dangerous because you can't flee."* A third participant stated: *"I didn't think sexual harassment could happen during space missions... I consider this much more serious than the same situation on Earth*.' This suggests that realism does not come exclusively from immersion but depends partly on semantic and conceptual alignment between user and scenario.

Although a significant interaction effect was found between realism and condition on attitude, suggesting that realism was a stronger predictor of attitude in the VR condition than in the written condition, perceived realism did not lead to a significant change in attitude or concern over time, either as a main effect or as a moderator. This suggests that realism in this context does not automatically translate into affective or behavioural impact. Instead, realism appears to reinforce attitudinal responses only under certain conditions—for example, when the scenario is consistent with the participant's worldview or when the narrative offers sufficient points of recognition to connect cognitively. It should be noted that the current study was conducted once with a relatively passive scenario design, and that presence was only measured in the VR condition. The absence of a comparable measure of engagement in the written condition complicates a full interpretation of the role of immersion. In addition, the average realism per condition showed a widespread, which may indicate individual differences in interpretation, prior knowledge and narrative absorption. The finding that the effect of condition on attitude disappeared when realism was included as a moderator (see results of hypothesis 3) emphasises that realism plays a crucial but complex role in VR research on morally charged themes.

Future research could investigate how manipulating narrative structure, the presence of contextual anchors or strengthening domain knowledge influences the impact of realism on attitude and concern. The composition of the sample also deserves attention: when participants have limited prior knowledge of a topic, such as space crime in this case, even well-designed VR environments may struggle to generate the desired psychological effect.

Limitations

Although this study offers valuable insights into the perception of space crime based on written and virtual scenarios, there are some methodological and substantive limitations that should be taken into account. First, the hypothesis that the VR condition would lead to stronger changes in attitude and concern was only partially confirmed. Although this is in line with the aim of the study—namely to explore the unique impact of immersive media—the distinction between the modalities makes it difficult to attribute the effects solely to immersion. The VR condition included visual elements and an immersive, spatial experience, while the written condition was entirely textual. As a result, the observed differences (or lack thereof) cannot be viewed separately from the different forms of representation. A future experiment could investigate the extent to which these modality effects can be isolated by, for example, adding a third condition, such as a video presentation, or by better aligning the two scenarios in terms of content, length and timing.

Furthermore, it is possible that attitude is less sensitive to short-term change than concern. Attitudes are often more deeply rooted in moral and ideological beliefs. A longer follow-up measurement or repeated exposure could possibly have demonstrated a clearer change in attitude. Attitude was also measured with only seven items; expanding this scale could increase reliability.

The expectation that participants in the VR condition would report greater engagement and realism than in the written condition was not confirmed. A first psychometric limitation is that engagement was not systematically measured in both conditions. The variable “presence” was only included for participants in the VR condition, which meant that a direct comparison between modalities was not possible. Adding a conceptually equivalent measure of engagement in the written condition would have strengthened the internal validity of this comparison.

The manipulation of perceived realism also proved to be of limited effectiveness. The results showed that the average level of realism did not differ significantly between conditions. Although a significant interaction was found between realism and condition on attitude, this effect disappeared as soon as realism was no longer included as a moderator in the model. This indicates an unstable or context-dependent effect of realism, whereby the construct may not have been powerful enough to structurally influence attitude change. A possible explanation for this lies in a floor or ceiling effect within the measurement of realism: the scores on this scale showed relatively little variation, which may indicate a limited sensitivity of the measure.

In addition, the open responses suggested that the unknown and abstract nature of the scenario—think space crime, legal ambiguity and future technology—made it difficult for participants to adequately assess the realism of the situation. This can be interpreted as a domain-specific cognitive problem, whereby the lack of mental reference frames makes it difficult to reliably assess realism. Future research could overcome this by choosing more recognisable scenarios, such as climate disasters or pandemics, with which participants are likely to have more experience and prior knowledge.

Finally, the hypothesis that perceived realism acts as a moderator in the effect of condition on attitude and concern was not confirmed. Although subtle trends were visible in visualisations, the sample was too small to detect such interactions with sufficient statistical power. An alternative approach would be to model realism as a continuous variable and include control variables such as domain knowledge, empathy or previous VR experience. A larger and more balanced sample, for example in terms of gender, age or technological affinity, would significantly increase the likelihood of detecting moderation effects.

Conclusion

This study investigated the extent to which an immersive virtual reality scenario, compared to a written version, influenced attitudes, concerns, and perceived realism regarding space crime. The results show that VR can contribute to stronger moral attitudes: participants in the VR condition reported higher attitude scores than in the written condition, suggesting that visual immersion can enhance the moral evaluation of unfamiliar situations. At the same time, concern about space crime increased in both conditions, implying that the content of the scenario—a morally charged and legally ambiguous incident— was sufficient in itself to activate affective engagement, regardless of modality. Perceived realism was rated as low on average and did not differ significantly between conditions, pointing to the importance of narrative coherence and domain knowledge in the credibility assessment of new virtual scenarios. Although an interaction effect was found between realism and condition on attitude—suggesting significant attitude change in participants after experiencing the VR condition—this effect disappeared when realism was no longer included as a moderator. Additionally, perceived realism did not play a moderating role for concern, highlighting the complexity of psychological influence via immersive media.

In summary, this study shows that VR is capable of eliciting moral engagement in abstract and unfamiliar domains, provided it is carefully designed and grounded in content. This highlights the potential of VR as a tool for ethical reflection and education in contexts where traditional knowledge or experience is lacking. In particular, this sheds new light on how we can investigate and discuss moral and legal issues surrounding space crime, as a prelude to a future in which human behaviour increasingly takes place beyond Earth.

References

Baker, M. (2020, August 27). NASA Astronaut Anne McClain Accused by Spouse of Crime in Space. *The New York Times*. https://www.nytimes.com/2019/08/23/us/astronaut-space-investigation.html

Briggs, J.C. (1999). The promise of VR. The Futurist, 13-18.

Brugman, B. C. (2024). How the effects of emphasizing ethics are examined: a systematic review of moral framing experiments. *Annals of the International Communication Association*, *48*(4), 436–455. https://doi.org/10.1080/23808985.2024.2393845

Capstick, S. B., Pidgeon, N. F., Corner, A. J., Spence, E. M., & Pearson, P. N. (2016). Public understanding in Great Britain of ocean acidification. *Nature Climate Change*, *6*(8), 763–767. https://doi.org/10.1038/nclimate3005

Carbajales-Dale, M., & Murphy, T. W. (2022). The environmental and moral implications of human space travel. *The Science of the Total Environment*, *856*, 159222. https://doi.org/10.1016/j.scitotenv.2022.159222

Casper, M. J., & Moore, L. J. (1995). Inscribing bodies, inscribing the future: gender, sex, and reproduction in outer space. *Sociological Perspectives*, *38*(2), 311–333. https://doi.org/10.2307/1389295

Cornet, L., Besten, A. L. D., & Van Gelder, J. (2019). VIRTUAL REALITY EN AUGMENTED REALITY IN JUSTITIËLE CONTEXT. *ResearchGate*. https://www.researchgate.net/publication/331628996_VIRTUAL_REALITY_EN_AUGMENTED_REALITY_IN_JUSTITIELE_CONTEXT

Cummings, J. J., & Bailenson, J. N. (2015). How immersive is Enough? A Meta-Analysis of the Effect of Immersive Technology on User presence. *Media Psychology*, *19*(2), 272–309. https://doi.org/10.1080/15213269.2015.1015740

Entradas, M., & Miller, S. (2010). Investigating public space exploration support in the UK. *Acta Astronautica*, *67*(7–8), 947–953. https://doi.org/10.1016/j.actaastro.2010.06.015

Eski, Y. (2023). *Space, the Final Frontier to Exploit and Annihilate: Space Exploration, Inhabitation and Settlement* (pp. 71–98). https://doi.org/10.1007/978-3-031-36092-3_6

Eski, Y., & Lampkin, J. (2024). Crime, criminal justice and ethics in outer space. In *Routledge eBooks*. https://doi.org/10.4324/9781003437178

Feldman, M., & Taylor, H. (2025). *Space piracy: Preparing for a Criminal Crisis in Orbit*. Wiley.

Forganni, A., Borowitz, M., Hoerber, T., & De Sousa, B. R. (2024). *Routledge Handbook of Space Policy*. Routledge.

Fox, J., Arena, D., & Bailenson, J. N. (2009). Virtual reality. *Journal of Media Psychology Theories Methods and Applications*, *21*(3), 95–113. https://doi.org/10.1027/1864-1105.21.3.95

Green, M. C., & Brock, T. C. (2000). The role of transportation in the persuasiveness of public narratives. *Journal of Personality and Social Psychology*, *79*(5), 701–721. https://doi.org/10.1037/0022-3514.79.5.701

Hermida, J. (2005). Crimes in Space: A legal and criminological approach to criminal acts in outer space. In *International Institute of Space Law*. American Institute of Aeronautics and Astronautics, Inc. https://www.elevenjournals.com/tijdschrift/iisl/2005/2%20Legal%20Aspects%20of%20Expanding%20Human%20Presence%20Beyond%20Low%20Earth%20Orbit/IISL_2005_048_002_008.pdf

Holmes, O. (2025). Crisis in Antarctica: can science teams ever prepare for isolated assignments? *The Guardian*.

https://www.theguardian.com/world/2025/mar/21/antarctica-alleged-assault-science-teams-isolated-assignments

Jang, J. Y., & Kim, D. Y. (2024). How immersive retailing affects consumers' urge to buy: Impacts of Self-Imagery, positive emotion, and Self-Relevance. *International Journal of Human-Computer Interaction*, 1–15. https://doi.org/10.1080/10447318.2024.2356394

Karagiannopoulos, V., & Winstone, J. (2019). Constructive and enabling ethics in criminological research. In *Springer eBooks* (pp. 1–16). https://doi.org/10.1007/978-3-319-76040-7_67-1

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator Sickness questionnaire: an enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology*, *3*(3), 203–220. https://doi.org/10.1207/s15327108ijap0303_3

Kuhail, M. A., Abdulkerim, A. Z., Thornquist, E., & Haile, S. Y. (2025). A review on the use of immersive technology in space research. *Telematics and Informatics Reports*, 100191. https://doi.org/10.1016/j.teler.2025.100191

Lampkin, J., & White, R. (2023). Space criminology. In *Springer eBooks*. https://doi.org/10.1007/978-3-031-39912-1

Masson-Zwaan, T., & Freeland, S. (2010). Between heaven and earth: The legal challenges of human space travel. *Acta Astronautica*, *66*(11–12), 1597–1607. https://doi.org/10.1016/j.actaastro.2009.12.015

McDougall, W. A. (1985). Sputnik, the space race, and the Cold War. *Bulletin of the Atomic Scientists*, *41*(5), 20–25. https://doi.org/10.1080/00963402.1985.11455962

Mehta, T. (2023). *BEYOND BORDERS: APPLICABILITY AND CONTOURS OF CRIMINAL LAW IN SPACE*. https://journals.nujs.edu/index.php/lac/article/view/60

Michel, C., Cochran, J. K., & Heide, K. M. (2015). Public knowledge about white-collar crime: an exploratory study. *Crime Law and Social Change*, *65*(1–2), 67–91. https://doi.org/10.1007/s10611-015-9598-y

Nash, K. (2017). Virtual reality witness: exploring the ethics of mediated presence. *Studies in Documentary Film*, *12*(2), 119–131. https://doi.org/10.1080/17503280.2017.1340796

Nelis, S., Holmes, E. A., Griffith, J. W., & Raes, F. (2014). Mental imagery during daily life: Psychometric evaluation of the Spontaneous Use of Imagery Scale (SUIS). *Psychologica Belgica*, *54*(1), 19–32. https://doi.org/10.5334/pb.ag

Pizzolante, M., Bartolotta, S., Sarcinella, E. D., Chirico, A., & Gaggioli, A. (2024). Virtual vs. real: exploring perceptual, cognitive and affective dimensions in design product experiences. *BMC Psychology*, *12*(1). https://doi.org/10.1186/s40359-023-01497-5

Salman, A. A., Kopp, B. J., Thomas, J. E., Ring, D., & Fatehi, A. (2020). What are the priming and ceiling effects of one experience measure on another? *Journal of Patient Experience*, *7*(6), 1755–1759. https://doi.org/10.1177/2374373520951670

Savage, R. (2025). Antarctic researcher accuses colleague of death threat and assault. *The Guardian*. https://www.theguardian.com/world/2025/mar/17/antarctic-researcher-accuses-colleague-of-death-threat-and-assault-south-africa

Scully, J. L. (2014). On Unfamiliar Moral Territory: about variant embodiment, enhancement and normativity. In *Palgrave Macmillan UK eBooks* (pp. 23–37). https://doi.org/10.1057/9781137405531_2

Skarbez, R., Brooks, F. P., Jr, & Whitton, M. C. (2017). A survey of presence and related concepts. *ACM Computing Surveys*, *50*(6), 1–39. https://doi.org/10.1145/3134301

Slater, M., Antley, A., Davison, A., Swapp, D., Guger, C., Barker, C., Pistrang, N., & Sanchez-Vives, M. V. (2006). A virtual reprise of the Stanley Milgram Obedience Experiments. *PLoS ONE*, *1*(1), e39. https://doi.org/10.1371/journal.pone.0000039

Slater, M., Rovira, A., Southern, R., Swapp, D., Zhang, J. J., Campbell, C., & Levine, M. (2013). Bystander responses to a violent incident in an immersive virtual environment. *PLoS ONE*, *8*(1), e52766. https://doi.org/10.1371/journal.pone.0052766

Slater, M., & Sanchez-Vives, M. V. (2016). Enhancing Our Lives with Immersive Virtual Reality. *Frontiers in Robotics and AI*, *3*. https://doi.org/10.3389/frobt.2016.00074

Slovic, P., & Peters, E. (2006). Risk perception and affect. *Current Directions in Psychological Science*, *15*(6), 322–325. https://doi.org/10.1111/j.1467-8721.2006.00461.x

Standen, B., Anderson, J., Sumich, A., & Heym, N. (2021). Effects of system- and media-driven immersive capabilities on presence and affective experience. *Virtual Reality*, *27*(1), 371–384. https://doi.org/10.1007/s10055-021-00579-2

TCullen, F., & Wilcox, P. (2010). Wilson, James Q., and Richard J. Herrnstein: Crime and human nature. *Encyclopedia of Criminological Theory*. https://doi.org/10.4135/9781412959193.n280

UNITED NATIONS. (2002). *UNITED NATIONS TREATIES AND PRINCIPLES ON OUTER SPACE*. https://www.unoosa.org/pdf/publications/STSPACE11E.pdf

Van Gelder, J., De Vries, R. E., Demetriou, A., Van Sintemaartensdijk, I., & Donker, T. (2019). The Virtual Reality Scenario Method: Moving from Imagination to Immersion in Criminal Decision-making Research. *Journal of Research in Crime and Delinquency*, *56*(3), 451–480. https://doi.org/10.1177/0022427818819696

Van Gelder, J., Martin, C., Van Prooijen, J., De Vries, R., Marsman, M., Averdijk, M., Reynald, D., & Donker, T. (2018). Seeing is Believing? Comparing Negative Affect, Realism and Presence in Visual Versus Written Guardianship Scenarios. *Deviant Behavior*, *39*(4), 461–474. https://doi.org/10.1080/01639625.2017.1407106

Van Gelder, J., Otte, M., & Luciano, E. C. (2014). Using virtual reality in criminological research. *Crime Science*, *3*(1). https://doi.org/10.1186/s40163-014-0010-5

Van Laer, T., De Ruyter, K., Visconti, L. M., & Wetzels, M. (2013). The Extended Transportation-Imagery Model: A Meta-Analysis of the antecedents and consequences of consumers' narrative transportation. *Journal of Consumer Research*, *40*(5), 797–817. https://doi.org/10.1086/673383

Van Sintemaartensdijk, I. (2022). *Burglary in Virtual Reality*. [PhD-Thesis - Research and graduation internal, Vrije Universiteit Amsterdam]

Van Sintemaartensdijk, I., Van Gelder, J., Van Prooijen, J., Nee, C., Otte, M., & Van Lange, P. (2020). Mere presence of informal guardians deters burglars: a virtual reality study. *Journal of Experimental Criminology*, *17*(4), 657–676. https://doi.org/10.1007/s11292-020-09430-1

Vela, M. B., Erondu, A. I., Smith, N. A., Peek, M. E., Woodruff, J. N., & Chin, M. H. (2022). Eliminating explicit and implicit biases in health care: evidence and research needs. *Annual Review of Public Health*, *43*(1), 477–501. https://doi.org/10.1146/annurev-publhealth-052620-103528

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

Wu, Y., Peng, K., Yao, Y., & Guo, Y. (2024). Sustainable space travel: What can we do in education from economic and environmental perspectives? *Sustainability*, *16*(2), 684. https://doi.org/10.3390/su16020684

Appendices

Appendix A

Written scenario script

Vignette Scenario (including background story)

You are a researcher at NASA and recently started a new project on artificial gravity. After years of training, you are finally going on your first mission to space: You fly to the space station IRIS (the International Research & Innovation in Space) to conduct experiments for your research.

To help you envision your role as a researcher in space, here is some more information about your research and space missions in general.

If humans want to go on space missions for a long period of time, possibly like going to Mars, there is a necessity to create artificial gravity. Our bodies are used to an environment with gravity. We, for example, have a cardiovascular system pumping our blood against the gravitational force from our heart to our feet, up and down our bodies. To maintain good health of astronauts, it is widely believed that we need to create artificial gravity since we do not know what developments a human body takes when being subjected to microgravity for too long. Different ways to create artificial gravity exist, the most prominent one being spinning rooms or entire spaceships at high speed. This is what your research focuses on.

Before going to space, there are important rules that you must know:

1. You need to exercise for at least two hours a day to prevent loss of muscle mass and bone density.
2. On space missions, sex is prohibited.
3. On space missions, there is zero tolerance for alcohol or any other drug/substance use.

Coming back to the scene you will find yourself in, you will spend a week on the IRIS. With you on the space station are flight engineer John and the commander of the IRIS, Brian. Brian is your superior and in space for almost a year now. You are now on your third day on the space station. You wake up excited to run your next experiment. You glimpse through the room and notice Brian is not in his bed anymore. You do not make much of that and get ready. Missioning in space was one of your biggest dreams, so even getting ready is exciting. Due to your limited time in space, it is essential to stick to your schedule and continue working as soon as possible. You need walk out of the bedroom to go fulfil your tasks and pass a corridor to go to the other side of the spaceship in order to find the lab. When you open the door to leave the bedroom, Brian is standing in the doorway.

The following scene unfolds:

Brian: “Morning! Good to see you, I was already waiting for you. Did you sleep well? Wow, you smell nice!”

Before you get the chance to reply he continues: “Yeah so, ! I still wanted to talk to you about something… I’ve noticed that since you have been here, something is different. I just would really like to get closer to you and honestly I don’t think I can resist much longer. I have been here for too long already, and well, let’s say, you now, people get lonely up here. It’s been a while since I touched someone, or that someone touched me. You know? So… uhm. what do you think about it? Do you want to have some fun fun? Haha! I am sure you have a minute for me, don’t you?”

Brian seems to be initiating physical contact. He steps closer, so you take a step back.

Brian: “Don’t be stupid, I know you also wat this. You know what , without me, you never would have been here. Quid pro quo, you know? I give you something, you give me something. There must also be something in it for me. Why are you pushing me away? You don’t really believe I actually took you on board for your skills right? You know you are here for your looks. Okay fuck this, I don’t even need you. I could have done the project all by myself. Who do you think supports your research on artificial gravity if not me”

Brian raises his voice again: “Come here. Where do you wanna go? You know you can’t escape me. If you don’t obey, if you don’t listen to me, I will terminate your research. Hope you come to your senses soon or the mission will not end in your favour.”

Brian moves away rom the door. You walk past him to go work on our task and walk along the corridor. There you enter the lab space. Therefore, you decide to just go back to work on your task. Here you find the three spheres you have to inspect in the colours purple, blue and pink. You pick them up, and they appear to look normal and have no discoloration. You check the board to report the number, which is 976.

Appendix B

VR scenario script

Script Harassment Scene - VR scenario

Cover story to be explained to participants prior to harassment

You are a researcher at NASA and recently started a new project on artificial gravity. After years of training, you are finally going on your first mission to space: You fly to the space station IRIS (the International Research & Innovation in Space) to conduct experiments for your research.

To help you envision your role as a researcher in space, here is some more information about your research and space missions in general.

If humans want to go on space missions for a long period of time, possibly like going to Mars, there is a necessity to create artificial gravity. Our bodies are used to an environment with gravity. We, for example, have a cardiovascular system pumping our blood against the gravitational force from our heart to our feet, up and down our bodies. To maintain good health of astronauts, it is widely believed that we need to create artificial gravity since we do not know what developments a human body takes when being subjected to microgravity for too long. Different ways to create artificial gravity exist, the most prominent one being spinning rooms or entire spaceships at high speed. This is what your research focuses on.

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This is the scene the scene you will find yourself in in VR.

Your task in this scene (once Brian has stopped talking to you and has moved away from the door) is to go and walk into the corridor all the way to the next room to the lab space. There you will find a place with three spheres, which you have to inspect to see if each sphere consists of only one colour. After that you have to look at the board with the numbers close to it to see what the numbers are for today.

Please let the experiment leader know you are ready to view the VR scenario.

Appendix C

Self-developed Questionnaires

Space crime knowledge – open questions

If your view on space crime has changed as a result of this study, could you explain why?

Do you think special laws/legislation is needed to tackle crime in space? Why or why not?

Do you have any additional thoughts or comments on this study or the topic of space crime?

Manipulation check (VR)

What did the other person in the scenario look like?

What did the environment you were in look like?

Do you remember the tasks that you did? What was the output?

Do you know who the person harassing you was?

How personal did the attack feel to you [scale 1-5]

Manipulation check (scenario)

What did you imagine the other person to look like?

What did you imagine the environment to look like?

Do you remember the tasks that you did? What was the output?

Do you know who the person harassing you was?

How personal did the attack feel to you [scale 1-5]