IMMERSED IN TRAINING

ADVANCING POLICE PRACTICE WITH VIRTUAL REALITY

Lisanne Kleygrewe

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01

GENERAL INTRODUCTION

INTRODUCTION

Training is an essential part of the career of a police officer. Starting in the police academy, cadets are taught the basic skills and knowledge they require for their policing career. Once graduated from the police academy, police officers continue to receive training to ensure safe conduct and adequate skills for the job (Kleygrewe et al., 2022; Koedijk, 2022; Koedijk et al., 2020). More so than other occupations, police officers encounter situations that are characterized by ambiguity, complexity, and stress (Waddington et al., 2012). To cope with these situations, police officers have to possess a broad range of skills. Next to physical skills such as running, weapon handling, shooting and self-defense, police officers need to possess psychological skills such as information processing, problem-solving, de-escalation, and decision-making (Birzer & Tannehill, 2001; Blumberg et al., 2019). To train physical and psychological skills in an integrated fashion simultaneously, police agencies utilize scenario-based training as a method that replicates on-duty incidents (Di Nota & Huhta, 2019; Andersen et al., 2016). Police instructors design realistic environments using appropriate equipment, props, role-players, and sounds that create a simulation of an on-duty situation. Scenario-based training allows police officers to practice their skills while also experiencing the influence of stress on their performance (Di Nota & Huhta, 2019).

With a rise in the availability of training technologies, police agencies have now begun to utilize Virtual Reality (VR) as a means to conduct scenario-based training (Saunders et al., 2019). VR entails a binocular head-mounted display which presents the user with a simulated virtual scene (Scarfe & Glennerster, 2019). In addition to the head-mounted display, many VR systems provide full-body motion tracking to permit realistic full-body movements in the virtual environment (e.g., RE-liON VR blacksuit, REFENSE VR system). Enabling free, full-body motion, VR offers a training tool which allows police agencies to design and train a wide range of simulated scenarios that officers may encounter in the field. Compared to real-life scenario-based training, VR offers the flexibility of creating and designing training environments and scenarios independent of a physical training location, props, and protective training equipment. In virtual scenarios, police officers can safely train high-risk situations (e.g., fire, explosions, mass disturbances; see Murtinger et al., 2021) without having to handle live weapons or other equipment that could increase the risk of accidents or injury. Compared to real-life scenarios, VR allows for the inclusion of vulnerable populations in training (e.g., the elderly, children, people with disabilities; Kent & Hughes, 2022). Taken together, the integration and adjustment of various elements in VR — such as lighting and weather conditions, and responses of non-player characters — create dynamic training situations and virtually endless opportunities for scenario creation.

With the benefits that VR offers to create immersive, safe, and adaptable training environments, VR offers opportunities to adjust the (instructional) training design. The training scenarios can be designed specifically in accordance with the objectives of the training, the need of the trainees, and the available training time (Zechner et al., 2023). Entirely different or the same scenarios can be repeated, increasing amount of repetitions within a training and active time in scenarios (Giessing, 2021). The complexity of the scenarios can be adjusted prior to and during the training with in-action monitoring and on-the-fly steering of the scenario (Nguyen et al., 2021). Once the training or single scenario is finished, VR systems offer the opportunity of an after-action review — a training performance review enhanced by VR (Raemer et al., 2011; Giessing, 2021). As the VR system recorded the scenario(s), the training scenario(s) can be reviewed from a variety of perspectives (e.g., bird's eye view, police officer view, or suspect view) and enhanced by relevant performance indictors (e.g., shots fired, and targets hit). Thus, VR technology can support the training of police officer from the beginning of a session (e.g., scenario design), through the training execution (e.g., on-the-fly scenario adjustments), to the end of a session (e.g., VR enhanced performance feedback).

In the context of police practice, VR is used across many areas in training: VR is currently being used for use-of-force training (Garcia, 2019; McAllister et al., 2022), tactical training (e.g., disaster preparedness and response, Murtinger et al., 2021; Mossel et al., 2015), de-escalation training (Kent, 2022; Kleygrewe, Hutter, & Oudejans, 2023), cultural sensitivity training (Kishore et al., 2022; Doan et al., 2021), medical emergency training (Schrom-Feiertag et al., 2022), mental health awareness training (i.e., recognizing and responding to individuals with mental health conditions, Kent & Hughes, 2022), and personal professional development training (e.g., stress regulation, Brammer et al., 2021; Michela et al., 2022). The application of VR training in police has been shown to be particularly effective in improving cognitive-perceptual skills (Harris et al., 2021) and retaining and applying police-specific knowledge (Saunders et al., 2019). Specifically, research has demonstrated that the learning transfer from VR to a complex real-life situation is similar to the learning transfer from scenario-based training to the same complex, real-life situation (Bertram et al., 2015). These findings indicate that VR training is an effective training tool to prepare police officers for on-duty incidents.

Research and practice have established that VR provides an immersive, flexible, and safe training tool that appears to provide benefits to current real-life training practices (Nguyen et al., 2021; Murtinger et al., 2021; Saunders et al., 2019; Zechner et al., 2023; Kleygrewe, Hutter, Koedijk, et al., 2023). The flexibility and safety of VR as a training tool makes it particularly suitable for training specific objectives such as the preparation of police officers for complex situations in stressful and high-risk settings. Due to these benefits, more and more police agencies invest in VR as a training tool. However, there are currently no common training standards or other points of reference for successful and effective implementation and application of VR training for police. The implementation of VR training refers to the improvement of current training practices through the integration of VR into existing training frameworks. The application of VR training refers to the delivery and use of VR as a training tool to enhance training and learning of police officers. For VR training to be useful for police practice, evidence-based standards guiding the implementation and application should be developed. The implementation and application of a training technology such as VR relies on identifying the necessity for such a technology and whether the technology contributes to the effectiveness (and possibly the efficiency) of training. Therefore, this thesis sets out to answer two questions:

- How can VR training improve and supplement current police training practices?
- How can VR training be applied to enhance the training and learning experience of police officers?

This thesis focuses specifically on the use of VR for the simulation of stressful and high-risk settings. Within these settings, this thesis explores the training of perceptual-motor skills of police officers such as decision-making and acting. VR provides a training tool that combines a broad range of environments with the opportunity for police officers to safely and repeatedly perform a variety of skills which is seldomly possible in real-life training. By investigating the implementation (i.e., the improvement of current training practices with the supplement of VR) and the application (i.e., the use of VR to enhance training and learning) of VR training in police, this thesis aims to provide evidence-based guidance on how VR can advance current training practices that prepare police officers for stressful and high-risk on-duty incidents.

Implementation of VR

The implementation of VR in police training depends on the organizational context, the available resources (e.g., training time, personnel, training budget) and the benefit of VR over current training practices. Implementation, then, refers to the integration of VR as a training technology into existing training curricula and structures of the police agency. As police training (particularly the content, frequency, and duration of training) differ between police agencies (Marenin, 2004), the way in which VR can be integrated may also differ. Hence, an overview of current training practices may provide insights into training areas in which police agencies share common obstacles that developments in VR may be able to resolve.

In current real-life training, scenario-based training is considered the gold standard for integrated (motor) skill learning (Di Nota & Huhta, 2019). During scenario-based training, police officers reenact and apply skills (such as handcuffing) in on-duty like situations. The exposure to dynamic and immersive duty-like situations allows trainees to explore behavioral strategies under the influence of stress (Di Nota & Huhta, 2019). Hence, main advantages of real-life scenario-based training is the dynamic interaction with the opposition (a suspect, bystander, etc.) and the use of skills and replica tools (e.g., pepper spray) as police officers would do during real-life incidents. In order for VR to benefit current training practices, VR needs to provide advantages in training experience, learning outcomes, or resource savings (e.g., enhanced training efficiency, etc.). Compared to current real-life training, many of the advantages of VR training outweigh the drawbacks of real-life training. For instance, while real-life scenario-based training is bound to a physical location and requires a labor-intensive set-up of props, VR training provides a virtual environment that simulates a variety of scenarios independent of location. Similarly, during real-life scenario-based training, scenarios are seldomly repeatable because the restaging of scenarios is oftentimes time-consuming. Therefore, VR might be able to provide advantages that further enhance already existing training practices. Currently, no comparison of training experiences (such as the physical or psychological responses to the training itself) of VR and real-life training exists in the literature. Additionally, literature does not yet address how features of VR can be used as a tool to enhance learning in police training. In order to make informed decisions on where and how to integrate VR into current practice, evidence regarding the effectiveness of the methods for particular training objectives and its ability to enhance learning would prove valuable.

Application of VR

The application of VR in police training depends on the training objective and the capabilities of VR to support the objective. Application of VR, then, refers to the delivery and use of the training technology in practice. As VR is already being used to effectively fulfill various objectives in police training (see section 'Defining VR in the context of police'), research should investigate how the application of VR can be improved further; for instance, by examining how the drawbacks of VR can be mitigated and how the advantages of VR can be utilized to maximize the effectiveness of VR as a training tool.

Current drawbacks in VR police training relate predominantly to the limited multi-sensory fidelity (Giessing, 2021). In real-life situations and training, police officers rely on vision, hearing, touch, smell, and taste. In VR, vision and hearing are the predominant senses trainees use to engage with the virtual environment. The reduced experience of senses in VR limits the exploration of an environment through the sense of smell and taste and limits the physical interaction with, and physical feedback of, virtual objects (Uhl et al., 2022). Particularly in threatening situations, the multi-sensory experiences of police officers are relevant for performance in stressful contexts. For instance, in training situations where an opponent is able to physically threaten the police officer (e.g., shooting at the officers with colored-soap cartridges), police officers experience representative responses akin to on-duty experiences (e.g., higher levels of anxiety, higher heart rates, faster reaction times). Training situations in which no physical threat and therefore no physical feedback in response to the officers' actions was present, the officers' responses were not representative of on-duty experiences (Nieuwenhuys & Oudejans, 2010). Thus, in order for VR police training to be more representative, research and technology may explore how to advance the multisensory fidelity of current VR systems (Brunswik, 1956; Davids et al., 2013; Uhl et al., 2022).

VR training has the clear advantage that it provides objective feedback of the training performance. Effective feedback has been shown to improve learning (Hattie & Timperley, 2007). With the after-action review tool, police instructors have the opportunity to provide objective and specific feedback tailored to the trainee. While research in reality-based (psychomotor task) training settings has explored how type and modality of feedback influence learning (Zhu et al., 2020), guidance on how to use simulation-based feedback tools has not yet been explored. Thus, the application of VR training may benefit from guidelines on how to use VR tools such as the AAR to increase the training and learning experiences of police officers.

Taken together, mitigating the drawbacks of VR (e.g., multi-sensory fidelity) and maximizing the advantages (e.g., application of AAR) may provide technological advances and instructional guidance on the use of VR in police practice.

Defining Virtual Reality

In the context of this thesis, VR refers to systems that provides an immersive three-dimensional (3D) virtual environment in which users can move about freely. Within this thesis, two different VR training systems from different VR providers were utilized — a portable, partly radio, partly body-worn motion tracking system using sensor fusion provided by RE-liON (www.re-lion.com; see Figure 1.1) and a full-body (outside-in) optical tracking system provided by REFENSE (www.refense.com).

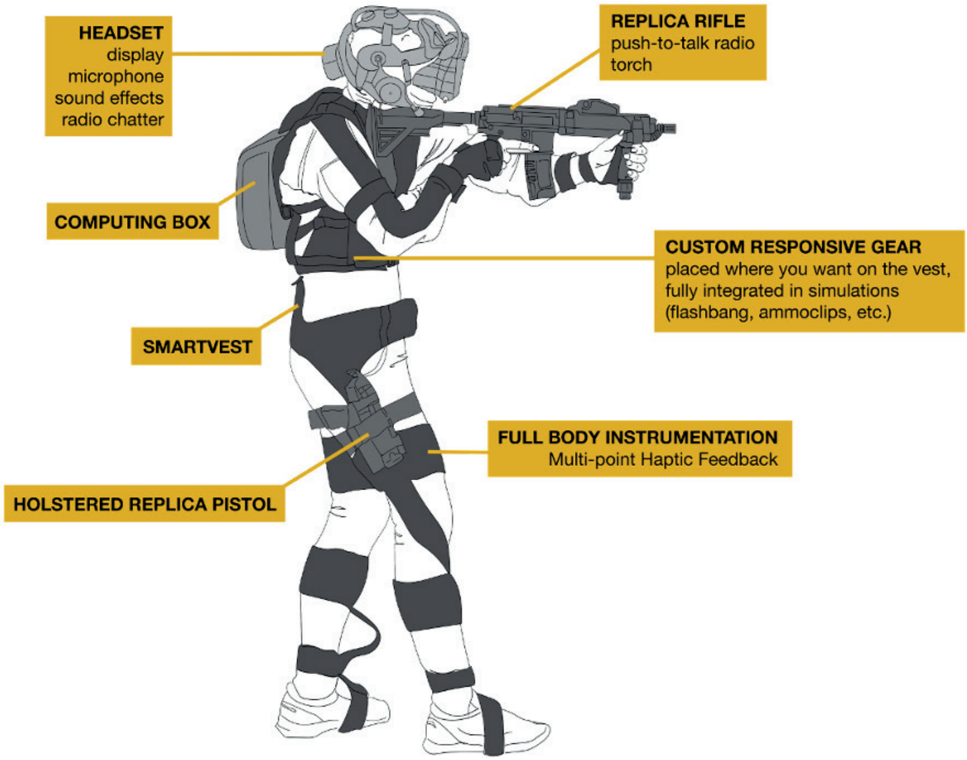

Figure 1.1. Example of a full-body VR system using a smartvest (RE-liON).

The two systems used for the VR studies in this thesis share common features which align with this thesis' definition of VR:

- The VR system consists of a head-mounted display which infers three-dimensional properties of a simulated environment through a projection of a two-dimensional perspective of a virtual scene onto each eye (Scarfe & Glennerster, 2019);
- The VR system enables free, full-body movements in the simulated environment through sensors on the feet and hands (e.g., REFENSE system) or smartvests with sensors on the entire body (e.g., RE-liON system, see Figure 1.1);
- The VR system enables police officers to move in a physical space (in this thesis, a space of up to 30 x 30 meters onto which the virtual training environment is plotted);
- The VR system provides replica service weapons that can be functionally utilized in the virtual environment;

- The VR system enables simultaneous, multi-person use (see Figure 1.2);
- The VR system allows for the use of role-players during virtual scenarios — actors, instructors, or trainees who play the role of a suspect, perpetrator, or bystander;
- The VR environment enables the use and steering of multiple non-player characters (NPCs) that represent suspects, perpetrators, and/or bystanders in the virtual environment.

Figure 1.2 VR police training system (from RE-liON)[1]

[1] This picture was taken during the COVID-19 pandemic in which trainees were required to wear facemasks. The facemasks are not part of the regular VR training equipment.

EPISTEMOLOGY OF THE AUTHOR AND THIS THESIS

My personal epistemology is based on the belief that complex practical problems are most effectively investigated in the natural settings in which they occur. Investigating practical problems in their applied settings provides an enhanced understanding of complex issues by embracing confounding and latent variables inherent to applied work, as well as by collaborating with practitioners who are experts in the field. Collaboration, particularly of interdisciplinary nature, provides a broader view on the practical problem and a better understanding of possible solutions. To approach practical problems and provide practically relevant insights, the research design and resulting conclusions should be evidence-based (i.e., founded on the best available evidence for used methods and interpretation) and context-dependent (i.e., taking into account the specific context in which the research is being applied). This applied research approach, however, should not negate the importance of theoretical foundation in investigating and examining practical settings. Particularly in the context of VR for police, a strong connection between theory and practice permits the development and improvement of a training technology in the practical setting in which the technology has to function. For instance, by utilizing educational learning theories to guide the training design of a VR session, the outcome of the training may further inform how the training design and training technology can be improved.

Translating my personal epistemology into the framework of this thesis, I aim to highlight the importance of an interdisciplinary, evidence-based, and context-dependent empirical approach to applied research. Doing so, I tested the two previously introduced VR systems (see section "Defining Virtual Reality") as part of official training days at the police agencies, collaborating with VR technology partners and police end-users. Moreover, I aim to emphasize the interplay between theoretical foundations and practical application, particularly, in the investigation and application of educational training technologies such as VR. Thus, to improve the technology itself and examine the effectiveness for the delivery of the training technology, I claim that theory and practice should go hand in hand and inform one another. While this thesis did not set out to validate a theoretical model, the basis of each chapter is supported by a theoretical foundation related to learning and instructional design, primarily focusing on the integrated model of perceptual-motor performance and anxiety (Nieuwenhuys & Oudejans, 2012, 2017), representative learning design (Davids et al., 2013), and cognitive load theory (Van Merrienboer & Sweller, 2005; Mugford et al., 2013). These models and theories set the groundwork on which the design and interpretation of the applied research conducted within the context of this thesis is based and are therefore elaborated on below.

Integrated Model of Perceptual-Motor Performance and Anxiety

The integrated model of perceptual-motor performance and anxiety (Nieuwenhuys & Oudejans, 2012, 2017) describes the influence of anxiety on perceptual-motor performance. The model suggests that personal and environmental characteristics influence the experience of anxiety in pressure situations. Experiencing high levels of anxiety may lead to stimulus-driven control (e.g., attending to threat-related rather than task-relevant information). The experience of anxiety can be mitigated by the investment of extra mental effort which in turn may lead to goal-directed control (e.g., attending to task-relevant rather than threat-related information). The outcome of the balance between stimulus-driven or goal-directed control influences how a person perceives, selects, and acts under pressure. The investment of additional mental effort, if invested appropriately, may correct the balance.

Police officers perform in stressful contexts that lead to an increase in anxiety. Studies in real-life training have shown that training with anxiety improves performance in high pressure situations (Nieuwenhuys et al., 2009; Nieuwenhuys et al., 2012; Nieuwenhuys & Oudejans, 2010, 2011). For VR training to be beneficial, the virtual environment and training scenarios should be able to elicit stress responses in trainees. Therefore, the VR experiments in this thesis (particularly, Chapters 3 and 4) assess the physiological responses (e.g., heart rate), stress mitigation strategies (e.g., investment of mental effort), and subjective levels of perceived stress of police officers.

Representative Learning Design

Representative learning design provides an instructional framework for designing effective learning environments (Pinder et al., 2011). The framework describes the importance of dynamical interactions between the learner and their environment (i.e., ecological dynamics, Davids et al., 2013). Individuals experience a variety of (task) constraints in their performance environment that provide new information to update and inform their subsequent actions. The constant interplay between perception (e.g., detecting visual and auditory information in the environment) and action (e.g., moving towards an intended goal) provides adaptive and functional solutions to effectively engage with the environment. When designing training environments, the constraints that learners experience in their performance environment should be included in the training environment to allow learners to explore adaptive and functional solutions relevant to the performance context in training.

To implement a representative learning design in VR, we first ensured that we utilize VR systems that provide functional, full-body movements (e.g., the possibility to walk normally in VR; use of on-duty weapons in VR) and aimed to create training scenarios that realistically capture the experiences and constraints that trainees may encounter on duty (Chapters 3-5). To this end, we sampled training scenarios from the specific performance environment (Pinder et al., 2011). Because VR provides a virtual simulation of an environment, in a next step, we ensured to specifically assess sense of presence (i.e., the feeling of truly being there in the virtual environment; Slater & Wilbur, 1997) and the experience of ecological validity of the virtual environment (Lessiter et al., 2001; not to confuse with ecological validity as defined by Brunswik, see Araujo et al., 2007). We did so to ensure that trainees experienced that the virtual training environment provided equally representative opportunities for perception and action as their performance environment (e.g., realistic context, realistic problems, and realistic solutions; Hutter et al., in press).

Cognitive Load Theory

Cognitive load theory (CLT; Van Merrienboer & Sweller, 2005; Sweller, 2011) describes how the working memory impacts learning. The theory states that human working memory has a limited capacity and that cognitive load (i.e., the amount of mental effort required to process information) affects learning. According to CLT, a training session should be designed in such a way that it manages intrinsic load effectively (e.g., by differentiating to the level of trainees), reduces extraneous load (e.g., by omitting all unnecessary complexities from task design and instruction), and maximizes germane load (e.g., by providing task design and instructions that refer directly to learning).

VR police training is oftentimes a new experience for police officers and therefore may require a different instructional design than the scenario-based training they are used to. To explore the cognitive load that trainees experience in VR, we measure mental effort (via a visual analogue scale) in VR (Chapters 3 and 4) and explore which specific factors lead to the investment of mental effort in VR training (Chapter 2).

STUDY AIMS AND STRUCTURE OF THE THESIS

The studies in this thesis aim to investigate a range of benefits and challenges of VR as a training tool for police training. The chapters of this thesis are structured in the following way:

In Chapter 2, we present an overview of the organization and delivery of training across European law enforcement agencies. The qualitative study provides insights into the strengths and challenges of current European police training practices.

In Chapter 3, we examine physical and psychological training responses of experienced police officers to VR training and scenario-based real-life training. We provide factors, such as participant characteristics and VR experiences (e.g., the experience of negative effects), that influence the psychological training responses to VR training.

In Chapter 4, we evaluate the effectiveness of adding a pain stimulus to VR training and a 2D training simulator to increase their representativeness. We explore the influence of the pain stimulus on physical and psychological training responses, as well as sense of presence in VR (i.e., the feeling of truly "being there" in the virtual environment).

In Chapter 5, we assess the use of VR's after-action review features to enhance the learning efficacy of police officers. We explore whether reviewing the training performance from various perspectives (e.g., bird's eye view, police officer view, suspect view) and with addition of VR features (e.g., showing the line of fire of the service weapon) enhance the learning efficacy of police officers.

Collectively, the chapters aim to provide insights into the implementation and application of VR training into police practice. In line with the cover of this thesis, the chapters are structured in such a way that they show the journey from real-life practices to training with VR technology — first highlighting the strengths and challenges of current (real-life) training practices, then comparing real-life training and VR training, until finally demonstrating how VR training can be utilized to enhance representativeness and learning for police. This thesis addresses police training on a European scale. The studies have been conducted with seven European law enforcement agencies, with particularly close collaborations with the Dutch National Police and the Stadtpolizei Zürich (City Police Zurich, Switzerland).

The epilogue summarizes the findings and implications of each chapter. It describes how VR training can be implemented to improve and supplement current training practices and provides an overview for the practical application of VR training in police practice. Lastly, the epilogue describes how theory and practice connect to advance the developments of VR as a training technology for police.

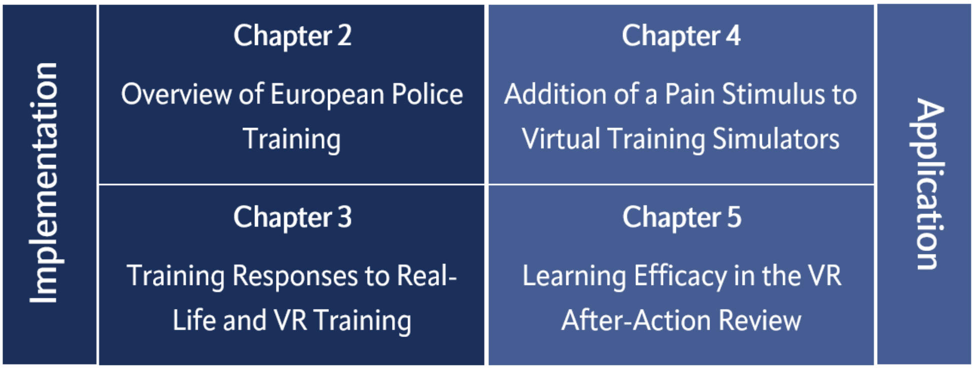

Figure 1.3. Overview of Thesis Chapters


POLI

02

POLICE TRAINING IN PRACTICE: ORGANIZATION AND DELIVERY ACCORDING TO EUROPEAN LAW ENFORCEMENT AGENCIES

Kleygrewe, L., Oudejans, R. R. D., Koedijk, M., & Hutter, R. I. (2022). Police Training in Practice: Organization and Delivery According to European Law Enforcement Agencies

Frontiers in Psychology

ABSTRACT

Police training plays a crucial role in the development of police officers. Because the training of police officers combines various educational components and is governed by organizational guidelines, police training is a complex, multifaceted topic. The current study investigates training at six European law enforcement agencies and aims to identify strengths and challenges of current training organization and practice. We interviewed a total of 16 police instructors and seven police coordinators with conceptual training tasks. A thematic analysis (Braun & Clarke, 2006; Terry et al., 2017) was conducted and results organized in the two main themes evident across all six law enforcement agencies: organization of training and delivery of training. Results show that governmental structures and police executive boards are seen as the primary authorities that define the training framework in which police instructors operate. These administrative structures regulate distant and immediate resources, such as available training time, training facilities, equipment, and personnel. Within the confines of available resources and predetermined training frameworks, results indicate that police instructors thoroughly enjoy teaching, creating supportive and motivating learning environments, and applying their personal learning perspectives to training. Nonetheless, police instructors are critical of the level of training they are able to achieve with the available resources.

Keywords: police training, didactics, curriculum evaluation, police instructors, assessment

INTRODUCTION

Police training plays a crucial role in the development of police officers. Compared to other occupations, police officers spend the entire beginning of their policing career training and preparing for the job (Wilson et al., 2010). Police cadets may spend up to three years in basic training before they are considered police officers and encounter any job-specific situations independently. This comparatively long period of initial training makes sense when considering that police officers respond to diverse and complex on-duty demands on a daily basis (Anderson et al., 2002; Gershon et al., 2009; Paton, 2009). Police officers are tasked with enforcing laws, protecting civilian life and property, responding to (emergency) calls, and apprehending and arresting criminals, to name only a few. Consequently, it is likely for police officers to encounter complex, high-risk situations (Marenin, 2004; Waddington et al., 2012). Dealing with these high-risk situations adequately requires expansive knowledge and skills, which police officers ought to acquire in training. Police academies and law enforcement agencies are responsible for equipping officers with the relevant skills to successfully resolve any on-duty demands placed upon them (Chappell, 2008).

The common objective of police training has hardly changed over time – to help police officers perform their job (Ness, 1991; Koedijk et al., 2019). However, what police training consists of has changed significantly over the years. Traditional policing required police officers to possess self-defense, arresting, shooting, and driving skills, which was reflected in training that focused primarily on teaching these physical activities (Chappell, 2008). Current policing places a focus on additional skills such as communication, problem-solving, and decision-making (Birzer & Tannehill, 2001; Blumberg et al., 2019). To facilitate these skills in the context of policing, police academies and law enforcement agencies needed to adjust the structure, content, and delivery of their formal training (Marenin, 2004). Traditionally, police instructors taught their students knowledge and skills using a uniform, linear training approach (Birzer & Tannehill, 2001; McCoy, 2006). For instance, teaching cadets self-defense skills would require instructors to explain the exact techniques and to illustrate a fixed set of movements for cadets to observe and apply in a static, low-pressure setting. Considering that police officers encounter complex and dynamic incidents, where decision-making, situational awareness, and communication skills might be decisive for the outcome, the traditional, uniform approach to training seems to have little to do with the realities of police work (Renden, Nieuwenhuys, et al., 2015).

Recent literature in the field of police training investigated how to better facilitate skills and improve specific components of police training. For instance, Di Nota and Huhta (2019) have illustrated how realistic and immersive scenario-based training can improve police officers' skills such as situational awareness and decision-making. Similarly, integrating elements of anxiety and stress into training — akin to what police officers would experience in high-risk on-duty situations — has shown to improve use of force performance under stressful conditions and paved the path for police training to become more realistic (Oudejans, 2008; Nieuwenhuys & Oudejans, 2011; Andersen et al., 2016). Furthermore, police instructors are called to create learner-centered training environments that foster the "exploration and learning of functional solutions" to reduce the gap between police training and police work on duty (Koerner & Staller, 2021, p. 10; White & Escobar, 2008). This means moving away from traditional classroom-based, trainer-centered teaching to enhance performance, skill transfer, and retention.

While research has contributed immensely to the quality of police training, current literature is yet to provide a comprehensive overview of police training across law enforcement agencies. Two reasons, in particular, might explain the lack of a cross-cultural overview of police training. First, almost every law enforcement agency organizes the frequency, duration, and content of their training differently (Marenin, 2004). This is due to many factors. The availability of resources and budget for training may determine how much and how often training can be conducted (White & Escobar, 2008), while the content of training will vary as it is tailored to particular needs of the region of operation. For instance, urban and rural environments pose different sets of challenges to police work which should be reflected in the training of police officers (Crank, 1990; Huey & Ricciardelli, 2015). Second, societal or situational influences (e.g., occurence of a terror attack, see Henry, 2002), changing policies (e.g., implementation of COVID-19 measures, see Laufs & Waseem, 2020; Frenkel et al., 2021), and technological advances (e.g., the integration of the body cam, see Koen et al., 2018; development of VR training, see Giessing, 2021) may call for specific adjustments in structure and content of police training. The concurrence of organizational, situational, and technological influences is what makes training practices unique to each law enforcement agency. As a consequence, the landscape of police training across law enforcement agencies is extremely diverse.

Although the diversity of training practices across European law enforcement agencies may explain why thus far no cross-cultural overviews of police training are collated, this does not mean that such an overview would be of no use. An overview featuring the commonalities and differences of European training practices highlights the diverse contexts in which law enforcement agencies educate and train police officers. This will, due to the variety in training practices, encompass a broad range of solutions law enforcement agencies have found for a broad range of issues with training. This may allow law enforcement agencies to learn from good practices in the training of other agencies and may help them to identify their own strengths and challenges in training more clearly. At the very least, law enforcement agencies may learn that they are not alone in particular aspects of training they struggle with and can be invited to join forces with other agencies to try and find improvements or solutions. These functions of a cross-organizational overview of training practices will be particularly salient if gained from the perspective of the actual law enforcement agencies and their personnel who conceptualize and deliver the training. In addition, the law enforcement agencies' perspectives will benefit researchers on police training as it allows them to focus on current and practically relevant training areas that may necessitate further (scientific) attention. Evidence-based practice and practice-based evidence go hand in hand (or at least they should). As such, an overview of the intricacies of police training as experienced by law enforcement personnel such as training instructors is important and informative for police practitioners and researchers alike.

Manning (2009) eloquently argued that "police practices are well understood within the police world, and the reporting, designed for external audiences, is a shadowy figure" (p. 462). To shed light on the world of police training, we aim to gain insights into the commonalities and differences of European training practices and identify their strengths and challenges according to those who conceptualize, organize, and provide the training. Gaining insight into the strengths and challenges of police training as experienced by European law enforcement agencies will provide police practitioners and researchers an opportunity for optimizing the current state of police training.

MATERIALS AND METHODS

Research Design

We utilized a qualitative research design to investigate the current state of police training at six European law enforcement agencies. We conducted individual interviews with police coordinators and instructors with the aim to identify strengths and challenges in police training.

Prior to conducting the interviews, we requested and received training-related material such as training and assessment manuals, lesson plans, training protocols, and training policies. We have studied these in detail to familiarize ourselves with the content and context in which police training takes place at each of the six law enforcement agencies. Reviewing the training-related material provided input for the interview guides and provided the interviewer with information on the language use and job-specific terminology expected from participants.

Participants

In total, 21 semi-structured interviews were conducted on training sites at six European law enforcement agencies. The agencies were located in the Netherlands, Germany, Sweden, Romania, and Belgium. We interviewed a total of 23 participants (two female). 16 participants were police instructors with an average age of 39.75 years (SD = 6.59) and an average police work experience of 15.56 years (SD = 8.34). Seven were training coordinators (department heads, unit leaders, or instructors with conceptual tasks or other coordinative roles in police training) with an average age of 47.43 years (SD = 5.29) and an average police work experience of 26.86 years (SD = 7.32). The participants had knowledge of, and expertise in, the training of police cadets, the continued professional development of police officers, special forces officers, and police instructors. The profile of the participants of each law enforcement agency is further described in Table 2.1. To comply with confidentiality agreements with the law enforcement agencies, the participants and their respective organizations are anonymized. Ethical approval was obtained from the Social and Societal Ethics Committee of the Katholieke Universiteit Leuven as part of the SHOTPROS project (work package 9: ethics) which is funded by the European Union's Horizon 2020 Research and Innovation Programme (Grant number: 833672).

Table 2.1. Profiles of the participants per law enforcement agency.

Organization	Participants
LEA 1	Instructor with conceptual training tasks (TC1). Instructors of continued professional development topics (I1, I2).
LEA 2	Instructor of shooting, close combat, and tactical training, with conceptual training tasks (TC2). Instructor of firearms instruction (I3). Instructor of tactical procedures of extreme violence and firearms instruction (I4). Instructor of firearms and equipment and fitness training (I5).
LEA 3	Weapon unit leader with coordinative training tasks (TC3). Instructor of firearms and equipment (I6).
LEA 4	Instructor coordinator with conceptual training tasks (TC4). Instructor and patrol officer (I7). Instructor of security detail personnel with organizational tasks (I8). Instructor of tactics, firearms instruction, first aid, and communication and border patrol officer (I9). Instructor of self-defense and tactical procedures and patrol officer (I10).
LEA 5	Head of instructor qualification unit for operational training (TC5). Instructor with conceptual tasks (TC6). Instructors of qualification and development of police instructors (I11, I12, I13, and I14).
LEA 6	Instructor with coordinative training tasks (TC7). Instructor of firearms and self-defense and military instructor (I15). Instructor of communications and military instructor (I16).

Note: "TC" refers to training coordinators; "I" refers to instructors. Coordinative training tasks refer to tasks in which training aspects are coordinated (e.g., scheduling, availability of instructors, personnel, location, etc.). Conceptual training tasks refer to tasks in which trainings are conceptualized (e.g., development of a training module, training plan, or training lesson, etc.).

Interview Guides

Based on the initial review of the training documents from law enforcement agencies, we developed two separate interview guides: one for interviews with police training coordinators with conceptual training tasks and one for interviews with police instructors. The interview guide for training coordinators consisted of discussion topics regarding the frequency, duration, and components of training, assessment and evaluation of officers, training for stressful situations and decision-making, an evaluation of the current training curriculum, and effective and innovative training practices. The interview guide for police instructors consisted of opinion inquiries regarding the overall experience as an instructor, their favorite parts of training, training methods they commonly implement in their training, and their views on what constitutes effective training. The interview guides can be requested from the first author.

Procedure

To capture diverse perspectives of European police training, the first author visited the locations of six European law enforcement agencies in five different countries. To recruit participants for the interviews, we utilized purposive sampling where contact persons at each law enforcement agency referred us to key informants who further helped us recruit potential participants for the current study (Smith et al., 2009). All interviews were conducted by the first author, whose native language is German and who is fully proficient in English. To participate in the study, participants had to be (a) proficient in English or German, (b) provide operational police training as an instructor, or have a role in the conceptualization and organization of operational police training. Prior to visiting the location of the law enforcement agencies, our contact person ensured that at least one participant was in a position to be interviewed as training coordinator. Additional interviews with instructors were conducted based on the availability of instructors on location. We conducted all interviews face-to-face at the locations of the law enforcement agencies. Prior to conducting the interviews, we informed participants about the content and purpose of the study and asked for permission to audio-record the interview. All participants signed informed consent agreements prior to being interviewed. Due to time constraints of participants at one law enforcement agency, one of the interviews was conducted in a focus group setting with three participants (one training coordinator, two instructors) at the same time. For this interview, the interview guide for training coordinators was used.

Analysis

We conducted an inductive thematic analysis following the steps described by Braun and Clarke (2006): familiarizing with the data, generating codes, constructing themes, reviewing potential themes, defining and naming themes, and producing the report. After transcription, translation of German interviews into English, and familiarization with the data, the transcripts were imported to ATLAS.ti 9 for analysis. The analysis started with open coding; we generated initial codes across the entire dataset. Initial descriptive codes were developed for any data segments that were meaningful to the researchers. In subsequent rounds of coding, we used our research questions to further specify the code labels. That is, we focused on data segments and code labels that referred to commonalities and differences of European training practices as well as signified strengths and challenges in these practices. Using thematic maps, provisional themes were explored in an iterative process to investigate the themes' relationship between each other and to the research questions. Provisional themes that captured the dataset meaningfully and informed answers to the research questions were further employed as final themes. Next, we clearly named and defined the conceptualized themes and sub themes. To ensure that the final sub themes and their labels captured relevant aspects of the main themes, we wrote theme definitions summarizing the central idea (Terry et al., 2017). For validation purposes, a second researcher reviewed the transcripts and codes to ensure that results adequately reflected the original data.

RESULTS

The thematic analysis (Braun & Clarke, 2006; Terry et al., 2017) resulted in two main themes that were evident across all six law enforcement agencies: the organization of training and the delivery of training. In the following, the two main themes and their sub themes are presented separately. The main theme of organization of training relates to more formal, institutional information from the interviews regarding the structure and organization of training. The main theme of delivery of training reflects particular experiences and opinions of police coordinators and instructors about conducting and delivering the training. Table 2.2 provides an overview of the main themes, their sub themes, and the corresponding codes.

Table 2.2. Overview of main themes, sub themes, and their corresponding codes.

Main Themes	Sub Themes	Codes/Topics	N of Total Quotations	N of Participants	N of Agencies
Organization of Training	Training Curricula	Police Academy Training	24	10	6
		Training Frequency	34	11	6
		Hierarchical Organization Structure	21	11	5
		Curriculum Development	20	13	6
		Curriculum Evaluation	13	7	6
	Resource Availability	Equipment Availability	12	8	6
		Instructor/Personnel Availability	9	7	5
		Training Facilities	20	11	5
		Training Time	19	11	6
		Need to Have Officers on Street	6	4	3
	Training Components	Practical Skill Components	14	9	6
		Stress Components	19	11	6
		Decision-Making Components	7	5	4
		Combined Training Components	19	10	6
		Dissatisfaction with Components	8	6	3
	Assessment	Assessment Method	15	6	6
		Assessment Frequency	8	5	4
		Assessment Consequence	15	8	6
Delivery of Training	Role of the Instructor	Perceived Responsibility	10	5	3
		Task Description	22	19	6
		Training Preferences	22	14	5
		Enjoyment	22	13	5
	Didactical Approaches and Concepts	Linear Pedagogy	11	9	4
		Exploratory Learning	9	7	4
		Feedback	17	10	5
		Repetition	13	7	5
	Training Environment	Importance of Training Environment	10	8	4
		Tailored Training Environment	11	5	4
		Realism in Training Environments	10	8	5

Note: For each code, the table provides the number of total quotations, the number of participants (training coordinators and instructors) that the quotations came from, and the number of law enforcement agencies that these participants belonged to.

Organization of Police Training

Training Curricula

To understand the organization of formal training practices within policing, a specific look at the training curriculum of a law enforcement agency is key. A total of 33 quotations from the interviews were related to training curricula. The training curriculum outlines the components of training, as well as the frequency and duration that is spent on each of the training components. According to the interviewed law enforcement agencies, the education of a police officers is organized into two distinct phases: the basic formation of cadets at the police academy and the continued professional development of officers. At the law enforcement agencies that have been interviewed, the basic formation of cadets ranges from one to three and a half years depending on the requirements of the agency and consists of obtaining theoretical knowledge, practical knowledge, and internship-type on-duty experiences. Once graduated from the police academy, police officers continue to receive training on a yearly basis. During this continued professional development, the frequency and duration of the training is dependent on the law enforcement agencies requirements. For five of the interviewed agencies, the duration of training that patrol officers receive ranges from 16 to 48 h per year, organized into three to six training days per year. One law enforcement agency organizes their training on a weekly basis, where 2 h of training are carried out each week. A minimum of 6 h per month needs to be spent on practical training activities.

Although duration and frequency of the training differ across law enforcement agencies, similarities exist as well. All interviewed law enforcement agencies have a higher entity such as a (national) police board or (governmental) interior ministry that determines or approves training curricula. For instance, on a yearly basis the governing entity for police education provides a training focus that determines the contents that this particular law enforcement agency has to provide in their training for a particular year:

> *"Every year we get [guidelines] from the national leader for practicing policy. And that's tactics, firearms, and self-defense. And every year we get the information on what the year's focus is going to be, for instance, terrorism, deadly violence or to increase the knowledge about psychological differences. So, we'll get a document describing what kind of focus we should have during our practice for the year." (TC4)*

When we asked training coordinators to reflect on their training curricula, the development thereof, and the delivery of amount and content of training to trainees, the responses across all six interviewed law enforcement agencies were remarkably similar. Training coordinators stated that the training curricula set the framework in which training delivery can take place. This framework consists of two factors; first, the frequency, duration, and components of the training curricula that are largely determined by the responsible external entities; secondly, the availability of resources to conduct the training prescribed in the training curricula. Training coordinators claim that what makes their training sufficient is not the development or state of the curriculum itself but what the instructors are able to achieve within the framework of the curriculum and with the resources available to them (see also training delivery):

> *"I think with the time that we have here to train, we're doing a good job, I think because everything depends. Everything is in the legislation about how many hours you can train a certain aspect of the formation and with the time that we have. If we had 2 years, it would be better, if we had a thousand rounds, it would be better." (TC2)*
>
> *"I think we're doing well for what we can do at the moment. It can always be better; of that I am convinced. But we do not have the means to do it the way we want to." (TC5)*

Resource Availability

With a total of 66 quotations, the availability of resources for training was a large topic for training coordinators and instructors: particularly the (limited) availability of instructors and personnel, training equipment, training facilities, training locations, and training time. For training coordinators and instructors, the shortcoming of these resources directly affects the quality of training, as well as the amount of knowledge and skills instructors are able to teach to cadets and police officers:

> *"We have a short number of trainers, so that's also something that is there. The quality of our training is under pressure." (TC1)*
>
> *"Due to the high number of students, it is not even possible to give every student a role-play on the respective topic. Unfortunately, that is just not doable, so [trainees] have to learn a lot by looking and watching. In terms of resources, this is unfortunately not possible any other way." (TC3)*
>
> *"If you come [to the training center] four times a year, then two of those times are tests, like the shooting test, the legal theory test. Then there's not much time to learn something." (I2)*

Training coordinators and instructors made clear wishes and suggestions on resources they require to improve the quality of their training:

> *"My wish is to have a group of trainers only doing training because now I borrow the trainers from regular daily [work], you know, patrolling." (TC4)*
>
> *"The [instructors] need more logistics. We have no training infrastructures. We have no buildings, and we have no weapons." (TC7)*

Training Components

To ensure that police officers continue to be well prepared for any on-duty incidents, law enforcement agencies provide training content that ensures that officers have the knowledge and skill to resolve situations they encounter on duty. The common training components discussed by all six law enforcement agencies include weapon handling, shooting, self-defense, arresting skills, tactical procedures (such as tactical movements during a building search), and communication. However, the way these components are trained differs across agencies. For instance, one law enforcement agency structures their formal yearly training content into five modules (one module for each training day), where three modules focus on the training of practical skills like weapon handling and shooting, equipment handling (e.g., multipurpose baton, taser), and tactical procedures and movements. The other two modules consist of scenario-based training relating to the yearly training focus. In contrast, within the mandatory structure of spending a minimum of 6 h per month on practical skills (e.g., handcuffing, self-defense, use of force), another agency lets the unit leader of each police unit dictate the training components based on the needs of his or her officers.

According to training coordinators and instructors, using scenario-based training is seen as the most holistic and effective form of training. Scenario-based training is implemented in the delivery of training in each of the interviewed law enforcement agencies. Instructors make use of scenario training to combine training components:

> *"The scenarios and role-play, everything of police training goes into it. So, you have two guns, you have knives, you have persons, cars and they have to act like they are on the street. And so that's everything. When you are on the shooting range, you only shoot. When you are in the dojo, you only fight. But in the role plays, you do everything and it's more complete." (I4)*

The integration of stress inoculation training and decision-making is for most training coordinators and instructors an important part of these role-plays. Instructors use scenario trainings and role-plays to increase stress resilience of trainees and prepare them for stressful encounters on duty:

> *"The trainees are prepared for [stressful situation] through specific scenario trainings in which [instructors] play with the stress. [Instructors] see how the trainees feel and control the stress. For those who can take it better, you go a little higher. The instructors can do that. You can actively increase [the stress] a bit or flatten it a bit, if you notice*

> *that they are not getting further. Through this targeted scenario training, [trainees] will become familiar with these stress levels." (TC3)*

While performing under stress and making appropriate decisions in high-risk situations are integrated into the role-plays that instructors conduct, training coordinators stated that there is no set training component in the curricula which separately or specifically aims at preparing trainees for stressful situations on the job or teaches them appropriate decision-making and acting skills for on-duty encounters. To this end, most law enforcement agencies look to improve the current state of practice:

> *"As I said, I think we're at the beginning with decision-based training, we're just getting started. So far, it has always been the case that we have provided a strict line and the solution to it was already predetermined. We are currently parting with [this approach] precisely because there is not always just one solution, there must be several solutions and several paths to reach these solutions." (TC5)*

Assessment

To ensure that cadets and police officers maintain a sufficient standard of skill from the training components facilitated during the basic formation and the continued professional development, law enforcement agencies have various assessment measures in place. Across the law enforcement agencies that have been interviewed, these assessments entail written or theoretical tests of laws and regulations, shooting assessments on the shooting range, assessments of arresting and self-defense skills, the handling of certain gear such as the baton, physical fitness tests, and for some law enforcement agencies a combination of these.

Particularly during the continued professional development, not all European law enforcement agencies rely on formal assessment methods. One law enforcement agency mentioned that instead of having formal tests, police officers have evaluations with their unit leader on a yearly basis. The unit leader evaluates the officers' on-duty performance and suggests areas in which additional training is needed. Based on this evaluation, the officer in question will be assigned to training courses that address his or her specific insufficiencies.

For law enforcement agencies that require formal assessment during the continued professional development, officers have to complete testing on a yearly basis. A particular assessment focus is placed on the weapon handling and shooting testing that takes place on a shooting range, which for one of the interviewed law enforcement agencies falls outside the range of yearly testing and instead takes place every 6 months. In case a police officer fails the shooting assessment, the officer has to hand in his or her service weapon and successfully repeat the shooting assessment before the weapon is returned and the officer is allowed to patrol the streets again.

However, due to resource limitation, such as the need for officers to patrol the streets, other areas of assessment do not have the same consequences as protocol dictates:

> *"What happens if you fail the exam? In those areas, it is checked whether there's a need for additional training. Often that is the case, and that would also be possible [to take on] for the instructors. But the authorities don't send people because they have to be on the streets. Then that's it, the person has deficits, but oh, maybe next year [it will be better]." (TC6)*

On the other hand, failing certain types of assessments may not have pre-dictated consequences at all:

> *"The physical test is the only thing that hasn't got consequences. You should get a positive [results], but if you don't, no problem, you can still be on the street." (TC1)*

Delivery of Police Training

Role of the Instructor

According to the interviewed training coordinators and instructors, police instructors have an essential role in the conceptualization and delivery of a training session. To ensure that trainees learn effectively and efficiently, instructors have a wide range of demanding tasks to fulfill. Across the six interviewed law enforcement agencies, there are differences in tasks that instructors take on. For instance, two law enforcement agencies train their instructors to teach all components of training, whereas the other four law enforcement agencies have instructors that specialize and provide training solely in particular components such as shooting, self-defense, or tactical procedures. Similarly, some instructors specialize in the training of particular trainee groups like police recruits, regular police officers, or specialized teams such as special forces or undercover teams.

Independent of any specialization, all interviewed instructors feel a strong sense of responsibility associated with their role as a teacher. Instructors primarily felt that their responsibility in providing the training is to set up each training session with the aim to advance the knowledge and skill of the trainees and to create a safe environment in which trainees can learn:

> *"The role of teachers is to make the trainings. You're responsible for the safety in the training but also for making the good steps [in teaching]. […]. You have to think about what is the purpose of my training? And what do we want to reach at the end?" (I1)*

Next to feeling a strong sense of responsibility associated with their role as instructors, the instructors we interviewed seem to thoroughly enjoy providing training to trainees, resulting in 22 quotations related to enjoyment of their profession. The source of enjoyment that instructors share differs. For instance, three instructors explicitly stated that the training session itself is what they enjoy the most; particularly, having a training environment in which the interaction with the trainees is productive yet fun:

> *"I think that it's the most important for me as a teacher to have fun in my lessons, but also to [teach] them something and have a good interaction together." (I1)*

Similarly, some instructors enjoy taking part in the learning process and witnessing the progress of their trainees the most. For yet others, the methodology of setting up a training is inherently enjoyable. For example, four instructors mentioned that the way they conceptualize the training is what brings them enjoyment in their profession as an instructor:

> *"I like the way you build up a training. So that it's useful and that it is as relevant as possible. That's what I like. To play with that in your head before the training to get it so that it is all. So that it is a good training where people really learn. That's what I enjoy most about giving training." (I2)*

Although the source of enjoyment for their profession differs amongst instructors, the sense of responsibility to teach trainees relevant knowledge and skills prevails across all interviewed instructors and is reflected at the core of what instructors enjoy about their role as police instructors.

Didactical Approaches and Concepts

Because the delivery of training across and even within law enforcement agencies is as diverse as the frequency and duration specified in the training curricula across Europe, in the following, we provide an overview of the didactical approaches and concepts that European police instructors currently rely on in their training.

Linear Pedagogy

When setting up a training program or a single training session, the interviewed law enforcement agencies[2] rely on a linear approach, building up a training in sequential stages from simple to complex. One instructor illustrated this approach using arresting techniques as an example:

> *"So far, we've set up a lot of trainings from simple to complex. That means if you now want to learn an arrest technique that is a bit more complex, you have to start with the basics first, and then you build it up piece by piece. This means that the movements are sequenced. And at the end you do a learning objective check on this skill. You build up a bit of stress and see what stuck. The reality outside is that the possible suspect [you would use the arresting technique on] may move a little. That means, I won't always be able to call on this great one technique that I have now trained for 2 h. I will have other stressors around it and maybe I will make other decisions as well." (I14)*

While this approach can be considered common practice amongst the interviewed law enforcement agencies, some instructors and training coordinators see the difficulty in this approach. As is demonstrated in the quote above, teaching skills in a linear fashion to achieve the perfect technique is seldom realistic or applicable during on-duty incidents. To this end, one law enforcement agency explicitly mentioned that they aim to part with this approach which allows for more flexibility and realism in their training programs and sessions.

Exploratory Learning

Although the linear approach of teaching appears to be common practice amongst the interviewed law enforcement agencies, a few instructors approach their training sessions by placing exploration of movements rather than perfect technique at the center. Seven of the interviewed instructors (from four different law enforcement agencies) prefer to set up their training sessions in a way that lets their trainees explore different movements and solutions to problems themselves. One instructor describes his approach to exploration in training as follows:

> *"I like to do it [this way]: I give a case and I'm not going to show you how to do it, you just do it. And then they do it. And it works out okay. But then I put in some input and*

[2] Four law enforcement agencies explicitly described a linear approach in training, while the remaining two agencies did not explicitly discuss a linear approach to a training program or session during the interviews. Based on the reviewed training-related material from the law enforcement agencies themselves, these two agencies also use a linear approach in their training practices.

say maybe like this and then they'll try again and again. Not like provide [information on] this is the way that you're always going to open a door, and this is the way you will always work an attack. If you do that, they are just going to copy me. And they might have good ideas too. So, I like to give them a chance to try. And if I see that it's not good, I try to give them hints and then they find it out by themselves." (I10)

Feedback

With 17 quotations relating to feedback, instructors described that providing effective feedback is one of the most important tasks of the instructor during a training session. Giving feedback allows instructors to review their trainees' performance, provide suggestions for improvement, and gather input from the trainees, while also ensuring that what is being learned by the trainees aligns with the purpose of the training session. Although most interviewed instructors mentioned that they utilize training time for giving feedback, the way they provide it differs from agency to agency. Some law enforcement agencies use unstructured feedback in which the role of the instructor is to debate the trainees performance and look for better solutions together, while other agencies prefer a more structured approach. For instance, one law enforcement agency has specific content that the instructors cover during a scenario-based training session:

"We have a specific way of giving feedback and we are working on four points: And that's safety, communication, movement, and treating the problem. And I think if you talk about those four aspects, you cover 90 percent of what you need to cover in a really small timeframe." (TC2)

Although the content of the feedback might be the same for instructors of the same law enforcement agency, the delivery of feedback oftentimes differs from instructor to instructor even within an agency. For instance, when using verbal feedback, four of the interviewed instructors explicitly mentioned that they prefer to have their trainees reflect on their performance themselves before the instructor provides input and recommendations. Four other instructors also noted the use of physical feedback as immensely important for their trainees to learn. For those instructors, physical feedback refers to feedback that trainees get from the training environment. To highlight this, one instructor (I2) provided the example of receiving a pain stimulus such as getting hit with non-lethal training ammunition when a trainee is not taking cover properly during a training scenario.

While the content, delivery, and type of feedback are important for instructors to consider, instructors have also mentioned that the timing of feedback is relevant in a training session.

For instance, one instructor explained that he switches between providing feedback during a training scenario and providing feedback after the scenario is over:

> "Sometimes in some trainings, you will stop and say, OK, look how you're standing, guys. Is that OK? Or what's a better way to stand? And then you go, OK, you stand there and go further. So, you're teaching in the moment. That's a way of teaching and sometimes you need that [...]. And sometimes it's better to let it go and then afterward say, OK, look what you did. What more do you see? Is there someplace better you can stand? And then they [can] think about it." (I1)

Repetition

To ensure that trainees gain experiences in training and learn from situations in a safe, practical setting, instructors let trainees repeat a variety of training scenarios within a training session. For many of the interviewed training instructors (7), implementing repetition in the set-up of a training session is a staple part of their preparation. However, the opinions of instructors regarding the approach to repetition differ. For instance, one approach involves allowing trainees to repeat the same scenario to let them learn from their mistakes, while the other approach entails creating repetitions of slightly differing scenarios to provide new situations for trainees to solve. The former approach relates to a form of drill practice where trainees repeat the same task in the same setting until they are fully capable of solving the scenario. The approach of repeating the same scenario teaches trainees to apply a particular skill in a particular context. The latter approach—varying the environment and situation context of the scenario from one repetition to the next — allows trainees to explore solutions and make decisions regarding the use of the skill taught in the lesson.

In conclusion, because the delivery of training is not as heavily regulated as the components and skills that need to be trained, a lot of variation in the didactical and methodological approaches to training exists across and within the interviewed law enforcement agencies. Due to the limited regulation of training delivery, instructors have more freedom to use their expertise and experience to design and deliver a training session. Although common practices such as linear approaches to training exist in the training programs of law enforcement agencies, instructors are still able to use their expertise to set-up and deliver a training that aligns most with their perspective on how learning takes place effectively.

Training Environment

In preparation for a training session, the interviewed instructors described the importance of creating an effective training environment to enrich the quality of learning and motivation of trainees. To this end, instructors have differing opinions on what makes a training environment effective. For example, two instructors stated that an environment that allows trainees to make mistakes without judgment from peers or instructors is the most vital part. For another instructor, creating a positive environment in which trainees can have fun and are seen for their individual qualities is what makes the training environment effective for learning to take place:

> *"I make very clear announcements. Definitely. But I also allow the individuality. I allow fun and joy because only in a positive learning atmosphere can you get the most out of people." (I12)*

In addition, five instructors (from four different law enforcement agencies) mentioned that tailoring the training environment to the needs of the trainees is what allows for an environment to support a high quality of learning. To this end, one instructor described that the level of experience that the trainee groups have (e.g., recruits versus special forces) determines the way he sets up his training environment. The instructor explained that in a training session, he largely uses a variety of communication styles to adjust the environment to the level of the trainee groups. For instance, when training with special forces officers, his communication is more task-oriented and deviates little from the training objective. When training with recruits, he allows them the space to ask questions and reflect on problems and solutions.

While instructors aim to provide a supportive training environment through their guidance and communication, they also consider the physical training environment as a factor in creating an effective space for trainees to learn. This includes the setting in which the training takes place such as a shooting range or other training facilities but also the equipment available to conduct a training such as FX systems (a non-lethal combat training system that allows trainees to use shooting weapons with marking cartridges). To this end, instructors expressed concern regarding the level of realism they are able to achieve with the resources available to them:

> *"For example, right now in the [training] centers that we have, we have different layouts, but they are still the same. And at one point, the person who is training is going to act like a robot. He knows the door is there. He knows he has two rooms, and I don't know how many windows." (I15)*

The familiarization with the fixed training facilities may lead trainees to dismiss important skills such as the careful scanning of a room that they would use in an unfamiliar, real-life setting. Similarly, when using FX systems, trainees are required to wear protection gear that they would not be wearing when they are patrolling the streets. Oftentimes this additional training equipment, though allowing for the safe use of shooting weapons in training, may hinder the level of realism of a training:

> *"Whenever I have to disguise myself, because I put on protection helmets or something else, then you very often have the problem that the equipment interferes, it fogs up, I can no longer see anything. Also, I have no recognition of the hits because I am wearing thick clothes." (I14)*

Instructors agree that although advances have been made, the issue of familiarization with fixed training facilities and the limited availability of current training equipment impedes the level of realism that instructors would like to achieve when designing training environments.

DISCUSSION

The organization and delivery of training practices described by training coordinators and police instructors of European law enforcement agencies reflect the diverse landscape of police training. This diversity is expressed in the training curricula, the organizational provisions of resources for training, and the didactical approaches to training delivery. In particular, the time recruits spend in basic training at the police academy highlights the diverse context of training across law enforcement agencies. While the amount of time recruits spend in the police academy is three and a half years for one law enforcement agency, police recruits at a different agency attend only for one year before assuming their position as patrol officers. This difference in education and training may be of particular concern for the increasing need of joint investigations in cross-border police cooperation (Meško, 2017). Cross-border investigations in which police officers of different agencies work together — relying on mutuality of knowledge of operational measures and investigative procedures — may prove challenging when knowledge and expertise of the officers differ tremendously across agencies.

While differences exist in police training across European law enforcement agencies, many of the current training practices share common principles. With the shared objective of providing training to develop the necessary proficiencies and improve the performance of police officers, law enforcement agencies across Europe focus on similar training components to ensure that officers are equipped with adequate knowledge and skills for duty. The interviewed agencies placed a particular focus on training of physical skills such as shooting, arresting, self-defense, and tactical procedures. The structuring of these skills into segmented training components (e.g., a training segment of the curriculum focusing only on learning to shoot, a different segment focusing only on learning self-defense skills) is a common principle in the organization of training. This finding is consistent with training practices of other European law enforcement agencies who also train particular components such as self-defense and arrest training, firearms training, and tactical training in isolated training segments (Staller et al., 2022). Similarly, the common principle in teaching of these components holds that training should be structured in a linear fashion moving from simple to complex, learning about the skill in a lecture-based setting, practicing the skill in a controlled setting such as the shooting range or the dojo, and then applying the skill in scenario-based role-plays (Renden, Nieuwenhuys, et al., 2015). Taken together, the common principles law enforcement agencies share in the organization and delivery of training is the linear approach to learning.

The described overview of European police training practices represents the current state of training according to those who conceptualize and deliver it. Based on this current state of training, we discuss strengths and challenges of European police training with the aim to provide law enforcement agencies with examples of good practices, possible improvements, and solutions to challenges they may experience, as well as provide researchers with shortcomings in training that would benefit from further investigation.

Strengths of Current Training Practices

Five of the six interviewed law enforcement agencies structure their training content of the continued professional development of police officers on the basis of a yearly training focus determined by an administrative police board for decisions on training curricula. Having a yearly content-specific training focus provides training coordinators and police instructors with current and realistic contexts in which they can structure and deliver the training of skills and procedures. Next to providing realistic and current training contexts, a yearly training focus determined by a national or regional advisory board is assumed to reflect the specific needs of each law enforcement agency's region of operation, highlighting the necessity of training skills and procedures in the context of what has previously been an area of attention in that region. For instance, a multitude of police encounters with people with mental illnesses revealed that officers had difficulties recognizing, addressing, and interacting with people with mental illnesses (see Morabito, 2007; Livingston, 2016). A large number of these incidents may call a national or regional police board to decide to place a yearly training focus on interaction with people with mental illnesses — as has been the case for one of the interviewed law enforcement agencies. By maintaining an overview of the most pressing national or regional matters, administrative police boards can use the yearly training focus to shape their training content to be realistic, current, and relevant.

Another strength that the interviewed law enforcement agencies share is their ability to critically evaluate the efficacy of the current state of their training practices. To this end, training coordinators and instructors aim to identify shortcomings of their current practices and look to improve the state of training of their agencies. For instance, when recognizing that teaching police officers the perfect technique in a static setting did not ensure transfer to the complex and dynamic settings that officers encounter on the street (Pinder et al., 2015; Staller et al., 2022), the instructors began looking to adjust their approach to skill learning. Current changes that the interviewed law enforcement agencies aim to implement into their training include moving away from isolated technique mastery of a single skill (Abraham & Collins, 2011), implementing decision-based training (Helsen & Starkes, 1999; Johnsen et al., 2016), and changing pedagogical approaches from strictly linear to nonlinear (see Koerner & Staller, 2018, 2021), combating the common principles that are still reflected in training curricula and delivery. The ability of training instructors, coordinators, and law enforcement agencies to be self-critical and identify areas of improvements in training facilitates the development of current practices.

Current police training and its delivery benefit from the diverse expertise of police instructors. Instructors' perception of how learning takes place differs both across and within law enforcement agencies — similar to how one trainee's learning preference differs from the next (Abraham & Collins, 2011). Because of their diverse perspectives on learning, each police instructor takes a unique approach to the delivery of their training. When law enforcement agencies provide their instructors with autonomy in the delivery of training, instructors have the opportunity to use their expertise and develop an approach that fits them best, rather than adhering to a prescribed teaching style that does not align with their expertise and preference. Giving police instructors the autonomy to use their expertise to guide a training session increases the chance that instructors are fully engaged in their practice and create motivating training environments for trainees (Klusmann et al., 2008; Christenson et al., 2012). This autonomy and space for diversity may indeed also be reflected in the high levels of enjoyment and motivation of instructors found in this study.

Challenges of Current Training Practices

The overview of current training practices across European law enforcement agencies reveals numerous shared challenges that police coordinators and instructors face in the organization and delivery of police training. First, because the organization of police training — including the development and approval of training curricula — is governed by the hierarchical structure inherent to European law enforcement agencies, making modifications to the current state of training requires administrative effort (Martin et al., 2017; Shipton, 2020). For example, when instructors identify areas for improvement in their training, they have to take numerous steps to reach the level at which changes to training structures and curricula can be implemented. This process can be tedious and time-consuming, particularly if the deciding body for approval or rejection of modification to the training framework and curriculum is a governmental organization such as the internal ministry. Thus, although training coordinators and instructors may recognize room for improvement in their training practices and provide suggestions that align with developments and implementation recommendations in the scientific field (see Marenin, 2004; Koerner & Staller, 2021; Staller et al., 2022), for these suggestions to be reflected in training curricula and training delivery, numerous lengthy administrative hurdles have to be taken. Although the hierarchical structure of law enforcement agencies has the benefit of steering the content of training from an organizational position (e.g., by providing a yearly training focus), the drawback associated with this centralization is the slow and complex process for changes to take effect. While established organizational structures and processes are difficult to overcome or change — particularly in the world of policing (Chappell & Lanza-Kaduce, 2010) — law enforcement agencies may start by setting up internal "input groups" consisting of training coordinators and instructors to collect and monitor immediate challenges to the organization and delivery of training. The first function of such input group is to act as a direct link between the current state of training and the organizational entity in charge of training related decision-making. The second function of the input group is to differentiate challenges that require administrative structures and the attention of the organizational entity (e.g., changes to the training curriculum) and challenges to which solutions can be found and implemented on an immediate level [e.g., taking a learner-centered teaching approach in training sessions (Koerner & Staller, 2021)].

Another challenge that police instructors face points at the level of training delivery. When delivering a training, police instructors recognize the importance of providing realistic training to their trainees (Renden, Nieuwenhuys, et al., 2015; Andersen et al., 2016). However, instructors are critical of the resources available to them to create realistic training environments (Cushion, 2020). For example, having to use the same training locations and facilities for scenario training allows trainees to familiarize themselves with the settings, providing a less effective low-stress and low-variance training environment (Adang, 2012; Staller & Zaiser, 2015; Staller et al., 2022). To this end, instructors wish for more flexibility in location and facilities in which they can conduct training. As availability of resources plays a part in the limited level of realism in training, an additional issue might be that instructors lack the knowledge or skill to make training sufficiently realistic with the resources available to them. By relying solely on physical aspects of the training environment, instructors dismiss other opportunities to make training realistic; for instance, designing training tasks that allow for motor, verbal, and cognitive skills to be trained in conjunction (Di Nota & Huhta, 2019). To address the issue of limited realism in training, law enforcement agencies should consider three possible solutions. First, although unlikely in the present economic climate (Cushion, 2020), law enforcement agencies could provide instructors with the resources they need to create realistic training (Di Nota & Huhta, 2019). Second, law enforcement agencies may look for cost-effective innovations such as the use of VR for realistic training (Giessing, 2021; Murtinger et al., 2021). Lastly, law enforcement agencies can strive to elevate the knowledge and skill of instructors to create realistic training with the (limited) resources available to them (see for instance Cushion, 2020 for an alternative approach to reality-based training).

The assessment and testing of knowledge and skills of police officers, particularly during the continued professional development, is another common challenge of current practices amongst law enforcement agencies. While law enforcement agencies put assessments into place to ensure that police officers possess a certain standard of skill, our findings showed discrepancies in the consequences for underperformance during those assessments. For instance, when failing the physical competency test, there are no consequences for officers of one law enforcement agency. Further, the assessments in place are rarely representative of the on-duty work that police officers perform (Lonsway, 2003; Tipton et al., 2013; Petersen et al., 2016; Koedijk et al., 2021). Similar to the modular, segmented structure of training components in the training curricula, currently applied assessment and testing methods evaluate isolated skills such as static shooting on the shooting range or self-defense technique evaluations. Law enforcement agencies can aim to improve their assessment practices by implementing common standards for underperformance and by reevaluating the design of their assessment methods to include representative testing environments (Staller et al., 2017; Koedijk et al., 2020).

CONCLUSION

An overview of the current state of European police practices, their differences and commonalities, and strengths and challenges, depicts the landscape in which law enforcement agencies organize and deliver training. The findings emphasize the complexity of police training, including the common underlying principles that guide development and delivery of training, the administrative influence on developing and adjusting training curricula, and the wishes and needs of police coordinators and instructors for their training across law enforcement agencies.

European law enforcement agencies operate in diverse contexts and differ in the availability of resources to organize and deliver training. While the contexts and available resources differ, European law enforcement agencies face common challenges in training, such as having to undergo lengthy hierarchical, administrative processes to bring about changes to current training practices, achieving a limited level of realism in training, and having insufficient assessment standards. As each law enforcement agency has their distinct context in which they operate, a one-size-fits-all solution may not be helpful to overcome the challenges European law enforcement agencies share. To improve upon current training practices, generic recommendations, such as those provided in this paper (e.g., setting up a "input group" to influence administrative processes more concretely, providing additional training resources, alternative training systems, or trainer trainings to enhance the level of realism in training, and implementing common assessment standards and representative testing environments to enhance assessment practices), provide law enforcement agencies with initial directions for implementation of solutions. These generic recommendations can be adjusted by each law enforcement agency to encompass the wishes and needs, the distinct context of operation, and the available resources. Based on our findings on the strengths that European law enforcement agencies share, we are optimistic about improvements in police training. There is generally a solid structure by which training is organized and updated, law enforcement agencies possess self-critical and evaluative qualities at all levels involved with the daily practice of police training, and last, but certainly not least, police instructors are committed to optimizing the training environment for their trainees.


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VIRTUAL REALITY TRAINING FOR POLICE OFFICERS: A COMPARISON OF TRAINING RESPONSES IN VR AND REAL-LIFE TRAINING

Kleygrewe, L., Hutter, R. I., Koedijk, M., & Oudejans, R. R. (2023). Virtual Reality Training for Police Officers: A Comparison of Training Responses in VR and Real-life Training

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ABSTRACT

In policing, Virtual Reality scenario-based training (VR SBT) is being explored to complement real-life scenario-based training (RL SBT). We investigated whether relevant training responses in VR SBT, namely heart rate (HR), level of physical activity, mental effort, and perceived stress, resemble those in RL SBT. Utilizing a within-subject study design, we investigated the training responses of 237 police officers of the Dutch National Police. We found that the maximum HR and average level of physical activity were significantly higher in RL SBT, whereas invested mental effort was significantly higher in VR SBT. No significant differences were found in average HR and perceived stress. We also found that perceived stress in VR was predicted by participants' VR experiences such as engagement with VR and experience of negative effects, but not by participant characteristics. Participants' mental effort in VR was predicted by their VR experiences and participant characteristics, particularly gaming frequency. In conclusion, VR SBT can elicit perceived stress, mental effort, and average HR that resemble or exceed responses in RL SBT, providing a promising tool to complement police training.

Keywords: police training, training responses, virtual reality, mental effort, perceived stress

INTRODUCTION

Police officers respond to complex on-duty situations on a regular basis (Anderson et al., 2002; Gershon et al., 2009). For instance, when engaging in a domestic violence dispute, police officers are faced with a variety of demands: they have to establish the context of the situation, evaluate the risk of harm to themselves and others, communicate with dispatch, the possible perpetrator, the victim, and each other, and make decisions regarding the appropriate interventions (e.g., the need for use of force, arrest, medical services, etc.). While most routine police tasks, such as administrative duties or traffic respondence are likely to be non-violent (Famega, 2005), police officers also have to be prepared to respond to high-risk incidents such as escalating situations with armed perpetrators (MacDonald et al., 2003). Consequently, police officers have to be prepared for numerous situations ranging from regulated and routine tasks to complex, ambiguous, and potentially life-threatening encounters.

Through training, police agencies equip their officers with the knowledge and skills to respond to the wide range of situations encountered on duty. An established method to prepare officers for a variety of situations in training and replicate realistic and life-like on-duty incidents is scenario-based training (Baldwin et al., 2021; Di Nota & Huhta, 2019; Renden, Landman, et al., 2015). Real-life scenario-based training (RL SBT) aims to simulate on-duty incidents by constructing training environments that closely resemble on-duty situations. It incorporates immersive role-plays (e.g., actors that play the perpetrator and/or victims) and other props (e.g., a suitable training location mimicking a living room, sounds such as loud music) to replicate the on-duty situation as realistically as possible. By engaging in interactive and dynamic training scenarios, trainees learn to execute verbal, cognitive, and physical skills concurrently under representative conditions and can explore a variety of behavioral strategies to resolve complex situations in training (Di Nota & Huhta, 2019; Rajakaruna et al., 2017). Implementing RL SBT that repeatedly exposes police officers to the stress they experience during complex on-duty tasks helps officers to gain familiarity with stress and may enhance performance under those conditions (Nieuwenhuys & Oudejans, 2011).

Although RL SBT enhances officers' performance of on-duty tasks under stressful circumstances (Andersen & Gustafsberg, 2016; Andersen et al., 2016; Baldwin et al., 2021), several issues with the implementation of realistic RL SBT into practice remain, such as inadequate delivery and resource- and labor-intensiveness (Cushion, 2022, 2020; Rajakaruna et al., 2017). For example, police instructors require suitable locations that fit the training scenarios (e.g., an apartment building for a domestic violence scenario), actors, experienced instructors, or well-instructed trainees that play the role-player (e.g., to play the victims or perpetrator), functional gear that resembles the operational gear (e.g., FX systems that replicate the operational weapon but use non-lethal munition), and sufficient training time to set-up the scenario and complete it with multiple trainees. Thus, limitations in delivery and resource availability make the efficacious application and implementation of RL SBT in police training challenging (Kleygrewe et al., 2022).

The use of virtual reality training – scenario-based training using a virtual simulator (VR SBT) — offers new ways to complement RL SBT (Haskins et al., 2020; Murtinger et al., 2021). Immersive VR training systems provide a 3D environment in which trainees can freely move about and interact with simulated surroundings (Scarfe & Glennerster, 2019). VR SBT provides the advantage that it can be performed largely independent of a training location as it relies only on sufficient space to set up a VR system. Additionally, police instructors can control the content of the scenarios and create a wide variety of simulated environments without needing additional resources such as props or different training locations. Most VR systems offer an after-action review in which instructors and trainees can play back the scenario from various perspectives while also providing a variety of performance data (e.g., shots fired, targets hit, bystanders flagged). Having these after-action review options from the VR system may enhance the way instructors provide and trainees receive feedback, as the objective and visual information provided during the review is less abstract compared to verbal feedback after RL SBT. Using VR SBT may thus provide the opportunity to negate some of the challenges that RL SBT poses (Giessing, 2021).

In recent years, researchers have investigated the efficacy of VR as a training tool in practice. Groer et al. (2010) demonstrated that simulated environments (i.e., a video projected onto a wall) can elicit similarly high levels of stress reactivity to lethal use of force as those experienced during real-life incidents. With evolvement in technology, Bertram et al. (2015) showed that the training transfer (measured by a complex task in reality) is similar in VR SBT and RL SBT indicating that training in VR may lead to similar performance outcomes as training in real-life. More recently, VR has been used to explore police officers' psychophysiological responses (i.e., electroencephalographic and heart rate variability parameters) to firearm shooting tasks (Muñoz et al., 2020). Moreover, Binsch et al. (2022) found that preparation for police surveillance tasks was more effective for performance and recovery when done in VR compared to real-life. Taken together, these findings highlight that VR can be an effective tool for training cognitive-perceptual skills (Harris et al., 2021) and retaining and applying police-specific knowledge (Saunders et al., 2019). However, little is known about how police officers respond to dynamic, interactive VR SBT physically and psychologically.

On-duty, police officers engage in physically and psychologically demanding tasks (Andersen et al., 2016). In training, these task demands should be reflected in the responses of police officers to prepare them for duty (Di Nota & Huhta, 2019; Kleygrewe et al., 2022). Training modalities such as RL SBT and VR SBT should therefore elicit physical and psychological training responses that expose officers to experiences they may have in the field. Physical training responses such as heart rate and level of physical activity give insights into the cardiovascular demands and amount of movement required during the training. Eliciting physical training responses is relevant because police officers are required to perform under high physical strain (Andersen et al., 2016; Baldwin et al., 2019) and benefit from experiencing this type of strain in training. Similarly, psychological training responses such as mental effort and perceived stress (Houtman & Bakker, 1989; Zijlstra, 1993) provide insights into the cognitive processes that trainees experience during the training. For instance, according to attentional control theory (Eysenck et al., 2007), investing mental effort is a compensatory strategy to negate the influence of stress and anxiety on performance and has been shown to provide a potentially effective strategy for police officers after training in high-anxiety conditions (Nieuwenhuys & Oudejans, 2011). Therefore, training modalities such as RL SBT and VR SBT should provoke psychological responses to familiarize police officers with the influence of perceived stress and mental effort in training. While research has extensively investigated RL SBT in police (e.g., Andersen et al., 2016; Baldwin et al., 2021; Cushion, 2022; Jenkins et al., 2021), insights into physical and psychological training responses to VR SBT are sparse. Understanding these training responses to VR SBT enhances the use of VR in police and provides information on how VR SBT differs from RL SBT to determine where the two modalities could complement each other to improve current training practices.

As VR is a fairly new training tool in policing, police officers are likely to encounter VR as a training modality for the first time. Some officers may find it easy to be immersed and engaged from the start, others may have difficulties adjusting to the virtual environment and require additional training time in VR to become sufficiently immersed and engaged. It is likely that overall knowledge about and frequent use of technology, as well as prior experience with VR, may make it easier for police officers to engage with VR as a training tool (Pletz, 2021). Other factors such as being prone to cybersickness or experiencing other adverse effects may negatively influence the way in which police officers experience and engage with VR (Weech et al., 2019). Yet, little is currently known about how police officers engage with VR as a training technology and whether specific protocols should be in place to make VR SBT more efficient and effective for police officers. Investigating factors such as sense of presence (i.e., the feeling of 'being there' in the virtual environment; Lessiter et al., 2001), cybersickness, and user characteristics related to technology affinity may specify how VR training can be adjusted to engage police officers and consequently improve the application of VR in police.

The current study aims to close the research gaps surrounding VR for police, particularly regarding police officers' training responses to VR SBT and their experiences with VR as a training tool. First, we investigate physical (i.e., heart rate, level of physical activity) and psychological (invested mental effort and perceived stress) training responses of police officers to VR SBT and RL SBT. Inherent differences between RL SBT and VR SBT exist (see for instance Giessing, 2021); therefore, we investigate the differences of the two training modalities as they are currently used in police practice (e.g., short sequences of VR scenarios; long, extensive reality-based scenarios). Examining the physical and psychological responses to the two types of training may highlight the strengths and weaknesses of each and how they can be used to complement each other. Second, we investigate factors (i.e., participant characteristics and VR-specific experiences) that we hypothesize to influence the psychological training responses (i.e., invested mental effort and perceived stress) of police officers. Understanding how participant characteristics (such as age or experience with technology) and VR-specific experiences (such as sense of presence or the experience of negative effects) relate to or influence psychological training responses may provide initial guidelines on how VR SBT can be tailored to be integrated into existing training frameworks. Thus, the current study takes a first step at investigating the application of VR for dynamic, interactive SBT and how police officers (physically and psychologically) respond to and experience VR as a training technology.

METHODS

This study was conducted in collaboration with the Dutch National Police. We conducted our experiment around the annual training days of the special intervention unit with a primary focus on close protection tasks (e.g., ensuring safety of clients, assessing security, and providing surveillance). By conducting our experiments as part of the annual training days, we were able to test and assess the training modalities RL SBT and VR SBT as they are applied in practice. This means that we utilized a large-scale scenario set-up with various role-players and props in the RL SBT, followed by a verbal debrief with the instructor. Comparatively, for VR SBT we utilized three short scenarios (to highlight the possibility of training a variety of adaptable scenarios in a short time) in combination with the possibility to receive an objective after-action review after each scenario. Hence, this study was not set up to compare identical trainings in real-life and VR environments but to compare the physical and psychological training responses to RL SBT and VR SBT as applied in practice.

Participants

In total, 237 street patrol officers of the Dutch National Police with additional tasks in the Dutch special intervention unit (227 male, 8 female, and 2 other; *M* age = 39.39, *SD* = 7.82) participated in this study. The participants' experience on the job ranged from 3 to 42 years (*M* years = 15.16 years, *SD* = 6.78). Participants provided informed consent before the start of the experiment. Ethical approval was obtained from the Social and Societal Ethics Committee of the Katholieke Universiteit Leuven as part of the SHOTPROS project which is funded by the European Union's Horizon 2020 Research and Innovation Programme (Grant number: 833672).

Design

We utilized a within-subject study design. All participants completed RL SBT and the VR SBT in their respective training groups. To counterbalance the training order, half of the training groups in this study completed the RL SBT followed by the VR SBT; the other half of the training groups completed the VR SBT followed by RL SBT. The training groups consisted of 12 to 16 participants depending on the size of the operational unit. For the RL SBT, the training group of 12 to 16 participants executed one large training scenario. The training scenario took on average 40 minutes. For the VR SBT, the operational unit was split into two training groups consisting of six to eight participants (depending on the initial size of the operational unit). This was done to allow sufficient computing power in the VR. Each group of six to eight participants completed a sequence of three VR SBT scenarios which on average took six minutes each (total VR SBT time on average 18 minutes).

In this study, we assessed three main measures: physical training responses (HR, physical activity), psychological training responses (perceived stress, mental effort), and VR experiences (participant characteristics, sense of presence). Due to the training schedule of the Dutch police, the set-up of the study was such that some participants were unable to complete all three study measures (without causing a delay in the training schedule). In addition, due to limited availability of measurement equipment (i.e., Zephyr Bioharness devices), we could not monitor the physical activity and heart rate of all participants. Thus, we utilized three distinct sub-samples for the three measures we recorded in this study. A total of 210 participants completed the VR experience measures, a total of 114 participants completed the measures of psychological response measures, and a total of 54 participants took part in the measures of physical responses. The overlap of participants taking part in the measures can be found in Figure A1 in the Appendix; descriptive statistics of the sub-samples can be found in Table A1 in the Appendix. There are no notable differences in the demographic distribution of the sub-samples (see Table A1).

Training set-up

All training took place at a training facility consisting of multiple empty buildings rented specifically for the purpose of the training. The VR SBT took place in a large hangar. The RL SBT took place on the outside and inside of an empty office-like building. As this training was conducted for police officers in the Dutch special intervention unit with tasks as close protection officers, the overall training objective focused on protection tasks; particularly on patrolling to ensure safe surroundings, protecting the entrances of buildings, and spotting suspicious behavior. Training scenarios in VR and RL were adjusted to accommodate for the training objectives while also remaining suitable for the particular training modality. For instance, to use VR effectively, we selected three shorter training scenarios that combined building protection, patrolling, and spotting of suspicious behavior, using different virtual environments in each of the scenarios. For RL SBT, we utilized one large-scale cohesive scenario that combined the same training objectives as VR.

Real-life scenario-based training (RL SBT)

RL SBT was designed together with experienced training instructors of the Dutch National Police. The scenario was staged around an empty one-story building consisting of various rooms and one main entrance. The front side of the building faced a street. Participants wore their regular patrol gear, protective helmets, vests, earplugs, and protective glasses for use with FX cartridges. Participants were equipped with FX weapons (rifle-type) and FX non-marking cartridges, non-lethal training ammunition. Props used in the scenario included smoke bombs, police cars, civilian cars, and scooters. For the scenario, various role-play actors were hired to act in the following roles: a lawyer, a police officer, two suspects (equipped with FX handguns and non-marking cartridges, protection equipment), and four bystanders. The role-players were well rehearsed and adhered to the scenario script developed by the police instructors.

In the training scenario, participants were tasked with protecting a lawyer (role-player) and securing the lawyer's office (the empty one-story building on the training premise). Participants took on various tasks according to their roles in their operational protection unit. Some participants were positioned outside the building to spot suspicious behavior of people or suspicious vehicles approaching the building. Another group of participants was positioned inside the building to provide personal protection for the lawyer. Additional participants were positioned at the main entrance to only give cleared people (role-players) access to the building. In the first 25 minutes of the scenarios, various people (role-players) would approach the building, attempting to get access. After 25 minutes passed, a police car arrived with a police officer as a role-player who exited the car. Meanwhile, two civilian cars approached the building and stopped in the middle of the road. The two civilians (role-players) left the car and threw smoke bombs and started shooting at the building to gain access. The police officer (role-player) who left the police car appeared to be shot and acted seriously injured. The participants' task was to control the situation (e.g., attend to the injured officer and protect the lawyer). The training instructors who oversaw the training session were in charge of ending the scenario, typically as soon as the suspects were arrested or the threat was stopped.

Virtual reality scenario-based training (VR SBT)

The VR system used in this experiment was provided by RE-liON (www.re-lion.com). Participants were equipped with RE-liONs' Blacksuit consisting of a binocular head-mounted display (including microphone, sound effect, radio chatter), a smart vest with full-body tracking, a computing box (backpack style), and replica rifle. Figure 3.1 shows the VR equipment used in this study. In addition to the VR equipment, there was one VR system operator and two police instructors guiding the training. To ensure the safety of the participants and avoid falls, collisions, and limit the occurrence of cybersickness, the participants were instructed not to run during the VR SBT.

Figure 3.1. RE-liON's Blacksuit – VR Equipment.
Note: The VR equipment was provided by RE-liON.

The training group of 12 to 16 participants was split into two smaller groups of six to eight participants to train the VR scenarios in small units ensuring sufficient computing power. The two small groups underwent calibration of the VR suits and equipment together and then completed a 5-minute instruction and familiarization scenario in the system. Next, the first small unit (in the following referred to as Group 1) started the first VR scenario while the other small unit (in the following referred to as Group 2) had the option to view the scenario from the outside on a large screen. Once Group 1 finished the first VR sequence, the second group started their first VR sequence. While Group 2 prepared for the first training scenario, Group 1 received an after-action review with a police instructor on a large screen next to the VR station. Once Group 2 started the training scenario, Group 1 had the option to view the scenario from the outside on a large screen. Once Group 2 finished their VR SBT sequence, the groups would swap again, and Group 2 received the after-action review while Group 1 prepared for the next training scenario. This process was repeated until all participants completed three VR SBT scenarios.

The VR scenarios depicted a large, square, multi-story building surrounded by parking lots and small streets, as can be seen in Figure 3.2. The participants' task was to patrol around the building to spot suspicious behavior, engage perpetrators when necessary, and resolve any altercations accordingly. Various non-player characters (NPCs) with predetermined behaviors were placed in the scenarios and controlled by an operator from RE-liON who – under the guidance of an instructor – directed which threat would appear when and where. These on-the-fly scenario variations allowed the adjustment of the level of complexity to the performance of the participants in the scenarios, ensuring that participants completed three slightly different VR scenarios, while keeping the overall structure and objective of the training the same for all participants. On average, one VR scenario lasted approximately six minutes.

Figure 3.2. VR Training Environment.

Note: The left picture shows the top-down layout of the VR training environment. The right picture shows the VR environment looking at the main entrance of the building. Pictures were provided by RE-liON.

Measures

In this study, we assessed three main measures: physical training responses (average heart rate, maximum heart rate, activity), psychological training responses (mental effort, perceived stress), and experiences in VR (sense of presence). The specific sub-measures are described below.

Physical training responses

Heart rate (HR)

Average and maximum heart rate (HR) in beats per minute (bpm) were recorded using a Zephyr Bioharness 3.0 device (www.zephyranywhere.com) at a recording frequency of 1 Hz. HR recordings of the active training time in the training scenarios for VR and RL were extracted and analyzed. HR Confidence (degree of validity of HR value, as a %) provided in the Zephyr output were used for data correction: data points at or below 25% HR Confidence were considered invalid and were removed from analysis (see 'Heart Rate Confidence', *OmniSense Analysis Help*, 2016). Physical inspection of extreme bpm values (outside of a realistic HR range, e.g., 0 bpm) were removed from analysis.

The Zephyr Bioharness device provides valid and reliable HR measurements (Nazari et al., 2018) and is frequently used in police research (e.g., Andersen & Gustafsberg, 2016; Bertilsson et al., 2019). In police research, HR has consistently been used as a common parameter to assess police officers' cardiovascular response to stress (Andersen & Gustafsberg, 2016; Andersen et al., 2016; Anderson et al., 2002; Anderson et al., 2019; Baldwin et al., 2019; Bertilsson et al., 2020; Vonk, 2008).

Level of physical activity

Level of physical activity was obtained using the Zephyr Bioharness 3.0 device (www.zephyranywhere.com). The Zephyr Bioharness contains a 3-axis accelerometer that records vertical, lateral, and sagittal acceleration magnitudes. The level of physical activity was quantified as velocity magnitude units (VMU), measured in g. VMU = $\sqrt{x^2 + y^2 + z^2}$ where x, y, and z are the averages of the three axial acceleration magnitudes over the previous 1-second epoch, sampled at 100 Hz. A VMU of higher than .2 indicates a walking equivalent activity, and a VMU of higher than .8 indicates a running equivalent activity (*OmniSense Analysis Help*, 2016).

Psychological training responses

To assess psychological training responses, we utilized visual analogue scales (VAS) to assess mental effort and perceived stress. In police research, VAS for mental effort and perceived stress (originally anxiety) have been frequently used to quantify self-perceived psychophysiological experiences during training and complex police tasks (e.g., Giessing et al., 2019; Nieuwenhuys et al., 2009; Oudejans, 2008; Wilson et al., 2007).

Mental effort

Subjective ratings of mental effort were obtained using the VAS 'Rating Scale for Mental Effort' (RSME; Zijlstra, 1993) at the end of the RL and VR SBT (once after all VR scenarios were completed). The RSME was assessed on a VAS from 1 to 150. According to Zijlstra (1993), the RSME has adequate test-retest reliability with correlation coefficients between 0.78 in work settings and 0.88 in laboratory settings.

Perceived stress

Subjective ratings of perceived stress were obtained using the VAS for anxiety (adjusted to 'stress' instead of anxiety; Houtman & Bakker, 1989) at the end of the RL SBT and VR SBT (after all VR scenarios were completed). Perceived stress refers to the participants' subjective experience of stress during the training scenarios. The stress scale was assessed on a VAS from 1 to 100. The original anxiety scale has a fair validity and test-retest reliability with correlation coefficients ranging between 0.60 and 0.78 (Houtman & Bakker, 1989).

Experiences in VR

Sense of presence

The experiences in the virtual environment were assessed using the ITC-Sense of Presence Inventory (ITC-SOPI; Lessiter et al., 2001). Each item of the inventory is rated on a Likert-scale from 1 'strongly disagree' to 5 'strongly agree'. The ITC-SOPI results in four factors. Spatial presence refers to the sense of being part of the virtual environment. Engagement refers to the feeling of involvement with the content and feeling psychologically engaged. Ecological validity or naturalness refers to the tendency of perceiving the virtual environment as life-like and natural. Negative effects refer to the experience of any adverse physiological experiences such as dizziness or headaches (Lessiter et al., 2001).

According to Lessiter et al. (2001), the ITC-SOPI has good internal consistency. The Cronbach alpha coefficient for spatial presence was .94, for engagement .89, for ecological validity .76, and for negative effect .77. In the current study, the Cronbach alpha coefficient for the factor spatial presence was .89, for the factor engagement .80, for the factor ecological validity .74, and for the factor negative effect .83.

In addition to assessing sense of presence factors, the ITC-SOPI contains a section in which the participant's background information is obtained. Specifically, participant characteristics such as age, level of computer experience, gaming frequency, prior experience with VR, and knowledge about VR.

Statistical analysis

To investigate whether VR and RL SBT elicit differences in training responses in police officers, we conducted five paired-samples t-tests using each of the training response variables (average HR, maximum HR, average activity, invested mental effort, perceived stress). To further examine whether the psychological training responses in VR were influenced by factors that are hypothesized to impact the VR experience (e.g., age, technology experience, cybersickness in VR as obtained with the ITC-SOPI), we performed two separate hierarchical multiple linear regression analyses for invested mental effort in VR and perceived stress in VR. For each of the models, the predictor variables were entered in two pre-determined steps. First, we entered participants characteristics consisting of age, VR knowledge, gaming frequency, and prior VR experience. Second, we entered the VR sense of presence factors from the ITC-SOPI consisting of spatial presence, engagement, ecological validity, and negative effects. Entering the predictors in two separate steps allowed us to investigate the change in explained variance for each block of predictors and evaluate the relative importance of each predictor with each step. For each model, we conducted residual analyses to ensure no violations of assumptions. To check for multicollinearity, we used correlation coefficients above 0.7 among independent variables, Variance Inflation Factor (VIF) above 10, and Tolerance values of less than .10 as indicators for multicollinearity (Miles, 2005). To detect multivariate outliers, we used visual inspection of the scatterplot of the standardized residuals (cut-off for outliers > 3.3 or < −3.3), Mahalanobis Distance (critical value of Chi-Square for eight predictor variables = 26.13 at $p = .001$) and Cook's Distance (critical value > 1; Tabachnick & Fidell, 2018) (critical value > 1; Tabachnick & Fidell, 2018). P-values of < 0.05 were considered statistically significant. Cohen's *d* was calculated as an estimate for effect size. A value of $d = 0.2$ indicated a small effect size, a value of $d = 0.5$ indicated a medium effect size and a value of $d = 0.8$ indicated a large effect size (Cohen, 1969). All statistical analyses were performed using IBM SPSS, version 27.

RESULTS

Differences in training responses between RL SBT and VR SBT

Paired-samples t-tests were conducted to investigate differences in training responses between VR SBT and RL SBT. No statistically significant difference was found in average HR (bpm). Maximum HR (bpm) was significantly higher in RL (M = 136.96, SD = 16.82) than in VR (M = 126.28, SD = 16.23), $t(53) = -4.2$, $p < .001$, $d = 0.65$. Average level of physical activity (VMU) was significantly higher in RL (M = 0.08, SD = 0.02) than in VR (M = 0.06, SD = 0.01), $t(53) = -5.71$, $p < .001$, $d = 1.20$. Invested mental effort (RSME) was significantly higher in VR (M = 52.64, SD = 25.57) than in RL (M = 46.11, SD = 21.17), $t(113) = 2.68$, $p = .008$, $d = 0.28$. No statistically significant difference was found in perceived stress. Detailed statistics of the paired-samples t-tests can be found in Table 3.1.

Table 3.1. Paired-samples t-test results.

	VR SBT			**RL SBT**			**Mean Difference**	**95 % CI**		***df***	***t***	***p***	**Cohen's *d***
	n	***M***	***s***	***n***	***M***	***SD***		**Lower**	**Upper**				
Average HR	54	90.91	12.84	54	88.63	13.22	2.28	-0.92	5.49	53	1.43	.159	0.18
Maximum HR	54	126.28	16.23	54	136.96	16.82	-10.69	-15.78	-5.58	53	-4.2	<.001	0.65
Average Activity	54	0.06	0.01	54	0.08	0.02	-0.02	-0.03	-0.01	53	-5.71	<.001	1.20
Mental Effort	114	52.64	25.57	114	46.11	21.17	6.53	1.71	11.34	113	2.68	.008	0.28
Perceived Stress	114	36.10	20.37	114	38.98	19.90	-2.89	-7.11	1.34	113	-1.35	.179	0.14

Note: Average and maximum HR in bpm. Average (physical) activity in VMUs. Mental effort (RSME) on a visual analogue scale from 1 to 150. Perceived stress on a visual analogue scale from 1 to 100.

Variance in mental effort in VR explained by participant characteristics and VR experience factors

Hierarchical multiple regression was used to assess whether sense of presence indicators in VR (spatial presence, engagement, and negative effects) predicted mental effort (VAS RSME) in VR after controlling for the influence of participant characteristics (age, VR knowledge, gaming frequency, prior VR experience). Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity, and homoscedasticity. Due to high correlation coefficients amongst the predictor variables spatial presence and ecological validity (.80) indicating violations of the assumptions of multicollinearity, we omitted ecological validity from the model (resulting in a higher adjusted R squared compared to a model retaining ecological validity as a predictor). Age, VR knowledge, gaming frequency, prior VR experience were entered at Step 1, explaining 10% of the variance in mental effort. After entry of VR spatial presence, VR engagement, and VR negative effects at Step 2 the total variance explained by the model as a whole was 31%, F (7, 126) = 8.21, $p < .001$. The sense of presence indicators explained an additional 21% of the variance in mental effort after controlling for participant characteristics, R squared change =.21, F change (3, 126) = 12.92, $p < .001$. In the final model, only one participant characteristic variable was statistically significant, with gaming frequency recording a semipartial correlation value of −.25 ($p < .001$), indicating that trainees with a high gaming frequency exerted less mental effort in VR. Two of the sense of presence indicators in VR were statistically significant, with engagement recording the highest semipartial correlation value (sr = .37, $p < .001$), closely followed by VR negative effects (sr = .28, $p < .001$). Therefore, only gaming frequency, VR engagement, and VR negative effects have unique contributions to the invested mental effort (RSME) after statistically removing the overlapping effects of all other variables. Table 3.2 provides an overview of all predictor variables and the two steps of the hierarchical multiple regression model predicting mental effort in VR. Descriptive statistics and correlation coefficients can be found in the Appendix in Tables A2 and A3, respectively.

Table 3.2. Hierarchical Multiple Regression Analysis Summary Predicting Mental Effort in VR With Age, VR Knowledge, Gaming Frequency, Prior VR Experience, VR Spatial Presence, VR Engagement, and VR Negative Effects

Step and predictor variable	*B*	*SE B*	Beta	*sr*	Change in R^2	R^2	Adjusted R^2
Step 1					.10*	.10	.07
Constant	76.48	13.68					
Age	-0.57	0.27	-.18*	-.17			
VR Knowledge	5.44	2.79	.18	.16			
Gaming Frequency	-6.90	2.03	-.31**	-.28			
Prior VR Experience	1.01	4.64	.02	.02			
Step 2					.21**	.31	.28
Constant	-18.90	21.80					
Age	-0.46	0.24	-.14	-.14			
VR Knowledge	3.12	2.53	.11	.09			
Gaming Frequency	-6.26	1.82	-.28**	-.25			
Prior VR Experience	0.27	4.12	.01	.00			
VR Spatial Presence	-11.80	6.01	-.23	-.14			
VR Engagement	30.71	6.14	.61**	.37			
VR Negative Effects	8.31	2.19	.30**	.28			

Note: sr = semipartial correlation coefficient. * $p < .05$. ** $p < .001$.

Variance in perceived stress in VR explained by participant characteristics and VR experience factors

Hierarchical multiple regression was used to assess whether sense of presence indicators in VR (spatial presence, engagement, and negative effects) predicted perceived stress in VR after controlling for the influence of participant characteristics (age, VR knowledge, gaming frequency, prior VR experience). Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity, and homoscedasticity. When checking for multicollinearity, we observed high correlation coefficients amongst the predictor variables spatial presence, engagement, and ecological validity (>.70, see Table A5 in Appendix) indicating possible violations of the assumptions of multicollinearity. While VIF and Tolerance values were well below critical threshold, we rebuilt two iterative models omitting ecological validity in the first and engagement in the second model. Both models yielded a lower adjusted R^2 (.163 and .172, respectively) than the initial model that contained all sense of presence indicators as predictors (.174); thus, we retained the initial model with all four sense of presence indicators. During the check for multivariate outliers, we have identified two cases that exceeded the maximum Mahalanobis distance value (cut-off value of 26.13 for eight predictors, see Tabachnick & Fidell, 2018, Table C4) and omitted the two cases from further analysis. Age, VR knowledge, gaming frequency, prior VR experience were entered at Step 1, explaining 3% of the variance in perceived stress ($p = .460$). After entry of VR spatial presence, VR engagement, and VR negative effects at Step 2 the total variance explained by the model as a whole was 23%, F (8, 123) = 4.45, $p < .001$. The sense of presence indicators explained an additional 20% of the variance in perceived stress after controlling for participant characteristics, R squared change =.20, F change (4,123) = 7.80, $p < .001$. In the final model, none of the participant characteristic variables were statistically significant. However, two of the sense of presence indicators in VR were statistically significant, with engagement recording a slightly higher semipartial correlation value ($sr = .224$, $p = .006$) than VR negative effects ($sr = .218$, $p = .007$). Therefore, only VR engagement and VR negative effects have unique contributions to the perceived stress in VR after statistically removing the overlapping effects of all other variables. Table 3.3 provides an overview of all predictor variables and the two steps of the hierarchical multiple regression model predicting perceived stress in VR. Descriptive statistics and correlation coefficients can be found in the Appendix in Tables A4 and A5, respectively.

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Table 3.3. Hierarchical Multiple Regression Analysis Summary Predicting Perceived Stress in VR With Age, VR Knowledge, Gaming Frequency, Prior VR Experience, VR Spatial Presence, VR Engagement, and VR Negative Effects

Step and predictor variable	*B*	*SE B*	Beta	*sr*	Change in R^2	R^2	Adjusted R^2
Step 1					.03	.03	.00
Constant	25.26	11.78					
Age	.13	.23	.05	.05			
VR Knowledge	4.13	2.43	.17	.15			
Gaming Frequency	-1.27	1.78	-.07	-.06			
Prior VR Experience	.74	4.00	.02	.02			
Step 2					.20**	.23	.17
Constant	-60.99	19.73					
Age	.28	.21	.11	.10			
VR Knowledge	2.62	2.26	.11	.09			
Gaming Frequency	-1.28	1.64	-.07	-.06			
Prior VR Experience	-.24	3.64	-.01	-.01			
VR Spatial Presence	-7.65	6.35	-.17	-.10			
VR Engagement	16.12	5.72	.38*	.22			
VR Ecological Validity	10.09	5.55	.25	.14			
VR Negative Effects	5.31	1.94	.23*	.22			

Note. *sr* = semipartial correlation coefficient. * $p < .05$. ** $p < .001$.

DISCUSSION

In the present study, we compared the training responses police officers experienced during RL SBT and VR SBT. Because police officers engage in physically and psychologically demanding tasks in the field, this should also be reflected and implemented in police training (Andersen et al., 2016; Di Nota & Huhta, 2019). Thus, we operationalized physical (i.e., average and maximum HR, activity level) and psychological (i.e., mental effort, perceived stress) responses to capture and compare the training responses of police officers to RL SBT and VR SBT. We further investigated what other factors (i.e., participant characteristics, sense of presence in VR) influence psychological responses of police officers to VR SBT.

We found that police officers had higher maximum HRs and higher levels of activity in RL SBT compared to VR SBT. These may, at least partly, be explained by the training instructions, the first-time experience with VR of most officers, and the inherent characteristics of VR systems such as bulky equipment leading to movement constraints (Giessing, 2021). During VR SBT, trainees were asked not to run with the VR equipment to ensure safety. Comparatively, in the RL SBT, participants had to promptly perceive the severity of the situation (i.e., being under attack) and quickly put on their protection gear (running to put on heavy protection plate, helmet, etc.)

leading to significantly higher peak levels of activity and maximum HRs. Additionally, first-time VR exposure can induce initial postural instability (da Silva Marinho et al., 2022), thus forcing further inhibition of fast or vigorous movement in VR that is not present in RL.

Further, we found that average HRs did not differ between the two training modalities. In our study, police officers experienced similar average levels of cardiovascular responses to VR and RL SBT. This suggests that, in their current state of application, VR and RL are both capable of producing training situations that induce physiological responses to external stressors. However, compared to the literature reporting HR in police training (e.g., Armstrong et al., 2014; Oudejans & Pijpers, 2009), the average HRs elicited in our study were fairly low (on average 91 bpm in VR and 89 bpm in RL). This may be explained by the overall training objective of training officers in protecting a building and spotting suspicious behavior rather than placing them in physically demanding situations. This training objective led to training scenarios comprised of largely stationary tasks (i.e., officers positioning themselves to protect a building and look for threats, with occasional patrolling, and encountering attackers) which is also reflected in the low levels of activity during both RL and VR and recorded VMUs that are well below values that would indicate a continuous walking equivalent activity (*OmniSense Analysis Help*, 2016). Note that largely stationary tasks are not uncommon in police work (see Famega, 2005), which is why stationary task components were implemented in the scenarios of this study.

Overall, the differences in physical responses to the training modalities seem to be dependent on the training objective and thus tasks within the training scenarios, as well as the inherent characteristics of VR systems and the safety requirements that trainees should adhere to when wearing the VR equipment. Therefore, when aiming to train scenarios that require high levels of physical activity (i.e., running), it appears most appropriate to train these tasks using RL SBT.

Regarding psychological responses elicited by RL SBT and VR SBT, we found that police officers experienced similar levels of perceived stress during RL SBT and VR SBT. Akin to the average HRs found in our study, the recorded levels of perceived stress are relatively low compared to studies that looked at perceived anxiety or stress of police officers during low- and high-stress training conditions (e.g., Giessing et al., 2019; Oudejans, 2008; Wilson et al., 2007). Nonetheless, we found that police officers perceived VR SBT to be as stressful as RL SBT, closely aligning with existing literature showing that training in VR can elicit significantly elevated psychological and physiological stress responses (van Dammen et al., 2022). These findings suggest that while VR SBT may not be appropriate for training objectives that require high levels of physical activity, VR SBT is suited for the training of mentally demanding tasks that put additional strain on the officer by providing ecologically valid training environments.

Since participants in our study experienced similar levels of perceived stress during VR SBT and RL SBT, we would expect that participants invest similar amounts of mental effort during both training modalities. Because high levels of (perceived) stress can negatively influence the performance of police officers, a compensatory strategy to negate the influence of stress is the investment of extra mental effort (see attentional control theory, Eysenck et al., 2007). Thus, similar levels of perceived stress would require similar levels of mental effort to negate the stress responses. In contrast, we found that participants invested more mental effort during VR SBT compared to RL SBT. A possible explanation for this finding may be that VR SBT places more extraneous cognitive load on trainees than RL SBT does (Mugford et al., 2013). In accordance with the cognitive load theory (CLT; Van Merrienboer & Sweller, 2005), extraneous cognitive load refers to the demands a trainee experiences that are not relevant for and potentially harmful to learning (Clark et al., 2011; Paas et al., 2003). During VR SBT, it may be that participants experience additional extraneous cognitive load and had to invest more mental effort to get used to the newness of the virtual environment, VR equipment, and VR as a training tool. To test this reasoning, we further investigated whether factors such as participants' level of prior use of technology and VR experiences affect invested mental effort in VR.

Indeed, we found that invested mental effort in VR SBT was related to participant characteristics that are suggestive of technological affinity. This relation between participants characteristics such as age, VR knowledge, gaming frequency, or previous VR experience was only found for mental effort and not for perceived stress. We therefore (precautiously) infer that during VR SBT mental effort is invested as a strategy to process information of the virtual environment, rather than for stress mitigation alone, and that experience with VR and gaming makes navigating the VR environment mentally less demanding. This notion is in line with existing research (Rosa et al., 2016), indicating that trainees with a high gaming frequency need to invest little mental effort to get used to and engage with the virtual environment. Similarly, people with more gaming experience have been shown to recover from cybersickness better than people with little gaming experience (da Silva Marinho et al., 2022). Thus, police trainers have to be aware that trainees with differing characteristics (e.g., trainees with much gaming experience vs. trainees with little gaming experience) may have different psychological experiences in the VR SBT.

Next to participant characteristics that influence the psychological responses of trainees during VR SBT, the momentary experiences of the virtual environment during the training also appears to play a vital role in the psychological responses that officers experience during VR SBT. Investigating VR experience-specific factors like those measured by the ITC-SOPI (i.e., spatial presence, engagement, ecological validity, and negative effects) provides insights into the trainees' experience with VR as a training tool and whether the experience with the training tool itself influences the psychological responses of trainees. Of the predictor variables measured in this study, we found that the VR experience variables explained the greatest single proportion of variance in perceived stress and mental effort (20% and 21%, respectively). When police officers experienced more engagement with the virtual environment and more negative effects, they perceived higher levels of stress and invested more mental effort. The relation between experiencing negative effects in VR and the psychological responses provoked by VR indicates that, in order for VR SBT to elicit similar psychological responses to RL SBT, the experience of negative effects in VR should be reduced as much as possible. To this end, any available technical, content, and human-factor solutions should be considered to minimize the risk of cybersickness and other adverse effects (e.g., Chang et al., 2020). Similarly, the relation between engagement and psychological responses to VR suggests that VR SBT requires sufficient levels of engagement with the virtual environment and content. To increase engagement, findings of Pengnate et al. (2020) showed that VR environments that have an interactive, narrative design result in higher engagement compared to VR that did not have a narrative-based environment (for practical recommendations on how to design a VR scenario that promotes engagement, see section 5, 'Concluding remarks').

Limitations and future directions

Although the study aimed to investigate VR and RL SBT in an operational field-training environment to obtain ecologically valid results, the design and application have limitations. First, the current study aimed to investigate differences in the training modalities of VR and RL SBT as they are currently used in police practice. To take advantage of the inherent differences in the training modalities, a direct comparison between the two training modalities and inferences about their effectiveness compared to each other was not possible as the training set-ups differed in scenario repetition, task, context, duration, and number and intensity of confrontations in the scenarios. Additionally, modality-specific instructions such as the safety instruction to avoid running during VR SBT provided differences in training delivery of the modalities. While the scenarios in VR SBT and RL SBT were based on pre-written scenario-scripts, the developments of the scenarios were based on the actions of the trainees leading to differences in scenario execution and timing of events even within training groups. Thus, if the goal is to achieve a one-to-one comparison of the training modalities in terms of their effectiveness in producing a certain training response (and other measures of interest), future studies may want to standardize the training set-ups as much as possible. In this study, however, we wanted to gain initial insights into (i) the application of the modalities (taking into account that the two types of training are inherently different), (ii) show that VR can elicit training responses that are similar to those elicited in RL SBT, and (iii) derive implications of how and where VR and RL SBT can supplement each other based on the assessed measures (see section 5, 'Concluding remarks').

Second, due to the strict training schedule, we were not able to obtain HR baseline measures. Thus, in this experiment, we did not compare the elicited HRs to the basal levels of the participants and therefore could not examine how responses in VR and RL SBT were similar to either basal levels or the heightened responses in-situ. Due to the difference in scenario length and development between RL SBT and VR SBT, the averaging of HR over the length of the scenario may also limit the concrete comparability of the obtained values. However, using a within-subject design, we were able to make general inferences regarding the differences in HR responses from VR SBT to RL SBT; particularly, as VR SBT and RL SBT took place on the same day and were counterbalanced in sequence to avoid the influence of an order effect. Nonetheless, research in the field of police training has demonstrated that RL SBT is able to elicit HRs up to 150 bpm (e.g., Baldwin et al., 2021). It is yet to be shown whether VR SBT is able to elicit comparable HR levels in order to facilitate training objectives that require extreme physiological stress reactivity experienced on-duty and during RL SBT. Future work on VR SBT in police should obtain valid and reliable baseline measures and consider assessing additional measures such as heart rate variability as an objective method of quantifying acute operational stress (Corrigan et al., 2021). In addition, future studies should, next to physical and psychological training responses, investigate behavioral responses to VR SBT. Behavioral responses may provide valuable insights into the action possibilities of police officers in VR and therefore inform police agencies for which training areas and tasks VR is suitable.

CONCLUDING REMARKS

VR SBT is becoming an increasingly popular topic for police agencies. In this paper, we have taken the first steps to explore how VR SBT compares and fits into existing training practices. To this end, our results revealed that VR SBT is capable of eliciting similar training responses in police officers as RL SBT does, providing initial considerations for the implementation of VR SBT to complement current RL SBT practices. For instance, when a training objective requires officers to exert high levels of physical activity (such as chasing, apprehending, and arresting a suspect), these objectives should be trained using RL SBT as it allows for more flexibility in movement and physical interaction with a role-player. To complement such training, VR can be used to broaden the scope of the objective. For example, while chasing and apprehending a suspect are important skills, police officers also have to be able to spot suspects and suspicious behavior in novel and disorganized environments. For tasks like these, VR offers valuable training opportunities (see, for instance, Harris et al., 2021 for use of VR in police room searching procedures). It allows for the adjustment and variation of virtual environments and the use of multiple NPCs (including groups usually not easily integrated in training such as children) and role-players that can take on various avatars making them less identifiable as suspects (as is oftentimes a problem with RL SBT due to the protective equipment worn by suspect role-players). Based on our findings, VR SBT may even be tailored to specific trainee characteristics to be more effective. For instance, trainees with technology affinity can start VR SBT rather quickly whereas first-time users with little technology experience may need additional VR tutorials and more training time to get used to VR. To ensure that VR SBT elicits psychological responses that are similar to RL SBT, factors such as the occurrence of negative effects and the engagement in VR should be considered and addressed beforehand. For instance, to minimize the risk of cybersickness in VR, particularly for first-time users, the structure of the VR SBT should be adjusted so that the initial exposure duration is brief and becomes gradually and incrementally longer to aid adaptation to VR (da Silva Marinho et al., 2022). Additionally, in setting up a VR training, instructors should ensure sufficient break time (for instance, for performance feedback) before re-immersion into the next VR scenario. To increase engagement with and sense of presence in VR, the training scenarios should take place in an interactive narrative-based virtual environment (Pengnate et al., 2020). For example, when designing training scenarios for VR, police trainers should, just as for RL SBT, develop scenario scripts that specify the task the trainees should perform, include realistic soundscapes (e.g., police car sirens), and interactive features such as role-players and NPCs.

Further systematic investigation of how the practical recommendations provided in this section impact physical, psychological, and behavioral training responses is critical for the effective implementation of VR SBT in police training practices. Investigating and validating how practical recommendations such as the structure, delivery, and scenario design of VR SBT influence training responses (e.g., HR, physical activity, perceived stress, mental effort, behavior) and the VR experience (i.e., sense of presence, occurrence of cybersickness) provides police agencies with clear guidelines on how they can effectively implement and apply VR SBT into current training curricula. Taken together, we foresee that with continuous technological developments and further systematic investigation, VR SBT will play an important role in enhancing current police training practices.


POLI

04

NO PAIN, NO GAIN? THE EFFECTS OF ADDING A PAIN STIMULUS IN VIRTUAL TRAINING FOR POLICE OFFICERS

Kleygrewe, L., Hutter, R. I., & Oudejans, R. R. D. (2023). No Pain, No Gain?
The Effects of Adding a Pain Stimulus in Virtual Training for Police Officers

Ergonomics

ABSTRACT

Virtual training systems provide highly realistic training environments for police. This study assesses whether a pain stimulus can enhance the training responses and sense of the presence of these systems. Police officers ($n = 219$) were trained either with or without a pain stimulus in a 2D simulator (VirTra V-300) and a 3D virtual reality (VR) system. Two (training simulator) × 2 (pain stimulus) ANOVAs revealed a significant interaction effect for perceived stress ($p = .010$, $\eta_p^2 = .039$). *Post-hoc* pairwise comparisons showed that VR provokes significantly higher levels of perceived stress compared to VirTra when no pain stimulus is used ($p = .009$). With a pain stimulus, VirTra training provokes significantly higher levels of perceived stress compared to VirTra training without a pain stimulus ($p < .001$). Sense of presence was unaffected by the pain stimulus in both training systems. Our results indicate that VR training appears sufficiently realistic without adding a pain stimulus.

Keywords: police training, virtual reality, virtual environment, simulation training, pain stimulus

INTRODUCTION

Training technologies, such as virtual training simulators, are becoming increasingly popular in police agencies (Arble & Arnetz, 2021). Virtual training simulators allow police agencies new opportunities to advance their training. Using a virtual training simulator, complex and high-risk scenarios can be trained in a safe and controllable environment. Vulnerable populations (such as children, the elderly, mentally ill people) that cannot easily be included in real-life training can be simulated in virtual environments (Kent & Hughes, 2022; Murtinger et al., 2021). Scenario locations and content can be designed and adjusted almost at will (Giessing, 2021). The increased safety and flexibility of using virtual simulators in training makes these technologies particularly interesting for police agencies.

A variety of virtual training simulators exist, from basic 2D screen, video-based simulators, to interactive 2D screen simulators, to advanced, interactive virtual reality (VR) systems (de Armas et al., 2020). Even in their most basic form, virtual simulators have been shown to effectively induce realistic responses. For instance, by projecting pre-recorded scenarios onto a wall using a laptop and projector, Groer et al. (2010) demonstrated that virtual simulators elicit acute psychophysiological stress responses in police officers. Moreover, interactive VR systems have been used to train advanced skills, such as firearm shooting in the military (Bhagat et al., 2016), laparoscopic surgery in medicine (Alaker et al., 2016), or table tennis skills in racquet sports (Michalski et al., 2019). Thus, virtual training simulators seem able to elicit similar psychophysiological responses as real-life training does and support the development of advanced (motor) skills. These two effects of virtual training simulators, eliciting psychophysiological responses and supporting skill development, are promising and desirable for police training, particularly in the context of realistic training.

Virtual simulators offer benefits, such as flexibility and safety in training; however, there are also limitation to the application of these technologies. Because the training simulations take place in a virtual environment, the interaction with that environment offers limited multi-sensory experiences (Giessing, 2021). Even in advanced interactive VR systems, the interaction with the virtual environment is generally limited to audiovisual stimuli (Melo et al., 2020). Steps are being taken to include further sensory feedback, such as tactile stimuli (for instance, using a weapon or other equipment in the virtual environment or receiving haptic feedback from virtual obstacles) and olfactory stimuli (for instance, implementing smells, such as gasoline). Despite advancements in multisensory integration in virtual simulators (e.g. Marucci et al., 2021), there are theoretical and practical limitations that make it difficult to simulate sensory experiences in a virtual environment; for instance, the simulation of localised smells that only occur in a specific area of the virtual environment or the realistic interaction with simulated objects through haptic force feedback (Gallace et al., 2012; Scarfe & Glennerster, 2019).

Police agencies aim to create training situations that closely resemble real-world experiences (i.e. realistic or representative training). Current training practices rely heavily on scenario-based training—a method of designing training scenarios that replicate on-duty encounters and exposing trainees to duty-like experiences in training (Kleygrewe et al., 2022). By doing so, trainees learn to perform skills, such as situational awareness, communication, and decision-making concurrently while also experiencing psychophysiological stress (Andersen et al., 2016; Di Nota & Huhta, 2019). Training in a context that representatively reflects on-duty experiences has been shown to improve the performance of police officers on duty (Beinicke & Muff, 2019).

When creating training contexts that resemble on-duty situations, similar constraints as those experienced on duty should be integrated into the training environment (Brunswik, 1956; Davids et al., 2013). For example, Nieuwenhuys and Oudejans (2010) included an opponent who occasionally shot back at the police officers with colored-soap cartridges in their study design. Compared to a less representative situation in which the opponent was non-threatening and did not shoot back, the police officers who could get shot by the opponent showed shooting behaviour and psychophysiological responses that resembled on-duty experiences much more closely: the police officers experienced significantly higher heart rates, had higher anxiety scores, acted faster, made themselves smaller, and blinked more often (Nieuwenhuys & Oudejans, 2010). These findings (amon others, see Nieuwenhuys & Oudejans, 2011; Renden et al., 2014) show that including representative constraints in a training setting, for instance, by adding an opponent who can physically threaten the police officer, induces on-duty-like responses and behaviours. Experiencing these responses and their influence on behaviour in training allows police officers to effectively prepare for duty (Di Nota & Huhta, 2019). Thus, designing training situations that closely resemble on-duty experiences should be as much of a goal for virtual simulation training as it is for real-life practice.

In our current study, we investigate the addition of a pain stimulus to virtual training simulators in police training. We argue that adding a pain stimulus to the virtual simulators influences the representativeness of the virtual training environment. We expect that a more representative training context provokes stronger psychophysiological responses and would lead to an increased sense of 'being there' (i.e. sense of presence) in the virtual environment compared to a less-representative training context (North & North, 2016). Hence, our first hypothesis states that the addition of a pain stimulus to virtual training simulators increases the physical and psychological training responses of police officers. Similar to the study by Nieuwenhuys and Oudejans (2011), the pain stimulus in our study simulates the shooting back of a threatening opponent. To determine whether the addition of a pain stimulus influences the training responses of police officers, we assess physical responses, such as heart rate, and psychological responses, such as perceived stress and mental effort during the training simulation in groups that train with and without a pain stimulus. Secondly, we hypothesise that by adding a pain stimulus to the virtual training simulator (i.e. adding the sensory modality of nociceptive stimulation), the sense of presence in the virtual environment is enhanced compared to a training simulation without the pain stimulus (Gallace et al., 2012). Sense of presence refers to the experience of being or feeling physically present in a simulated environment (North & North, 2016). As such, higher levels of sense of presence contribute to realistic display of behaviour in a virtual simulation and thus provide more representativeness to training contexts (Slater, 2009).

We investigated whether the addition of a pain stimulus influences the training responses and sense of the presence of police officers utilising two different types of virtual training simulators: an interactive 2D simulator consisting of five screens arranged in 300 degrees (VirTra V-300) and an advanced, interactive 3D VR training systems specifically designed for police (Refense). We selected a 2D and 3D training simulator to examine if any effects of the pain stimulus rely on the type of simulator used for training. Particularly as immersion, presence, and skill acquisition appear to differ between 2D and 3D simulations (Ashraf et al., 2015; Gąsiorek et al., 2019), we aimed to explore whether the effect of a pain stimulus would differ between simulators. By investigating the influence of a pain stimulus on the training responses and sense of presence in different types of virtual training simulators, we aim to support the development of virtual training for police practice.

METHODS

Participants

This study was conducted in collaboration with the Stadtpolizei Zürich (City Police Zurich). In total, 219 police officers of the Stadtpolizei Zürich (180 male, 35 female, and 4 other; *M* age = 38.22, *SD* = 9.16) participated in this study. The participants' experience on the job ranged from 2 to 37 years (*M* years = 12.57 years, *SD* = 8.98). 83 of the study participants (64 male, 17 female, and 2 other) provided additional information on their technology experience: 23 participants experienced VR in the form of gaming or as a commercial product before. 60 participants had never experienced VR before the training.

Participants provided informed consent before the start of the experiment. Ethical approval was obtained from the Social and Societal Ethics Committee of the Katholieke Universiteit Leuven as part of the SHOTPROS project which is funded by the European Union's Horizon 2020 Research and Innovation Programme (Grant number: 833672).

Design

We utilised a 2 (training simulator; within-subjects) × 2 (pain stimulus; between-subjects) mixed study design. Participants completed Virtual Reality training (VR) and training with the VirTra V-300 (VirTra) simulator on the same day. Due to the availability of training locations, all participants completed the training in the same order: VR training followed by VirTra training. Half of the participants completed the VR and VirTra training with the pain stimulus, the other half trained in both training simulators without a pain stimulus. The experiment was conducted over a span of 8 weeks as part of the annual training days for the police officers of the Stadtpolizei Zürich; thus, we were able to test and assess the training simulators as they are applied in practice.

On each training day, training groups consisting of 8 police officers participated in the two training sessions. On each day of the experiment, the use of the pain stimulus alternated (i.e. on odd training days, participants trained in VR and VirTra with the pain stimulus; on even training days, participants trained in VR and VirTra without the pain stimulus).

The objective of the training was 3-fold: (i) training of tactical procedures and movement, (ii) training of de-escalation techniques, and (iii) training of communication skills. The scenarios for the VR and VirTra training were developed and selected based on these training objectives.

Due to the set-up of the training schedule of the Stadtpolizei Zürich, some participants were unable to complete all measures at the prescribed time points without causing a delay to the schedule. Thus, we proceed with our analysis with three distinct sub-samples: 83 participants completed the sense of presence measures for both simulators, 166 participants completed the measures of psychological responses for both simulators, and 87 participants took part in the measures of physical responses for both simulators.

The VirTra V-300 training system has been used by the Stadtpolizei Zürich before this research; therefore, most of the participants had previous experience with the VirTra training. For all participants, this was their first time performing operational police training in VR.

Experimental set-up

The independent variables of the study were training simulator (VR, VirTra) and pain stimulus (with, without). The set-up and training scenarios for the training in VR and VirTra, as well as the use of the pain stimulus for both training simulators are described below.

Virtual reality training (VR)

The VR system used in this experiment was provided by Refense (www.refense.com). Participants were equipped with the Refense VR suit consisting of a binocular head-mounted display, microphone and audio provided via over-ear headphones, radio chatter, hand- and foot sensors for motion tracking, a computing box (backpack style; weighing 5 kg), and a replica rifle. The size of the VR training area was 15 × 15 m. Figure 4.1 shows the VR equipment used in this study. The training group of eight participants was split into two smaller groups of four participants to train the VR scenarios in small units. On average, the completion of the VR scenario took 13 min. Before the training scenario began, participants underwent calibration of the VR sensors and equipment and completed a short instructional tutorial in VR. The instructional tutorial contained a replication of a specific training location of the Stadtpolizei Zürich that the participants are familiar with from their regular real-life training practices. When entering this environment in VR, participants are guided through specific tasks (e.g. walking a certain distance, opening and closing doors, interacting with others, and using their replica rifles on target boards) by the instructor. The familiarisation process took, on average, 5 min. After completing the tutorial, participants had a brief break (~30–45 s) to prepare for calibration of the actual training scenarios.

Figure 4.1. Refense VR equipment.

Note: The VR equipment was provided by Refense.

The VR training scenario depicted a three-story building, shown in Figure 4.2. The first floor displayed the entrance of a bank, the second floor contained multiple small offices and work areas, and the third floor depicted a residential apartment. The scenario entailed non-player characters (NPCs) that were placed throughout the virtual environment in the form of bystanders, injured bystanders, bank tellers, and perpetrators. All encounters of participants were with NPCs. To make the encounters with the perpetrators as dynamic and interactive as possible, the voice of the perpetrator was taken over by an instructor. All other NPCs that participants interacted with in the scenario were steered by experienced VR instructors of the Stadtpolizei Zürich.

The participants started the scenario on a large square outside of the building. The square replicated a well-known location in Zurich (Paradeplatz) and was filled with police cars with flashing blue lights and car sirens. The participants received the dispatch information that two armed perpetrators entered the bank. The participants then entered the bank in which bystanders and bank tellers were hectically running around. The bank tellers told the participants that the perpetrators had moved to a higher floor. To avoid stairs in the virtual environment, the participants were told that the stairs were blocked and had to use the elevator to enter the offices on the second floor. Exiting the elevator, the participants found injured bystanders who alerted the officers to an armed perpetrator on the floor. The participants' task was to secure the floor and stop the perpetrator from hurting further bystanders. When participants arrested or eliminated the perpetrator, they received the dispatch information that the second perpetrator entered the apartment on the third floor. Once participants entered the apartment through the elevator, they were tasked with identifying the perpetrator. The perpetrator was taking the resident of the apartment hostage on the balcony. The task of the participants was to verbally de-escalate the situation and arrest the perpetrator without causing harm to the hostage.

Figure 4.2. VR training environment.

Note: The picture shows the layout of the first, second, and third floors of the VR training environment. Pictures were taken from an initial run-through of the VR environment during the construction phase of the training scenario.

VirTra training (VirTra)

The VirTra V-300 (https://www.virtra.com/simulator/law-enforcement-v-300/) is a shooting simulator comprised of five 2D screens that are arranged at 300 degrees to create an immersive and interactive training platform (see Figure 4.3). Participants can use their service weapons with a drop-in laser recoil kit during the training scenarios. The training group of eight participants was split into four groups of two participants. Each pair of participants completed a sequence of three VirTra training scenarios which, on average, accumulated to 10 min of active training time in the VirTra V-300.

Figure 4.3. VirTra V-300 shooting simulator.
Note: This image is the property of VirTra (www.virtra.com).

VirTra V-300 comprises a range of pre-recorded videos that contain a variety of branching options. These branching options allow for the development of the scenarios to be dynamic and interactive (i.e. a variety of responses and actions of the bystanders and suspects can be chosen by the instructor at various points of the scenario). The scenario was steered by experienced instructors to react as closely as possible to the actions of the participants (i.e. when the officer shoots at a suspect, the suspect appears injured and falls to the ground without delay; the bystanders or suspects verbally respond appropriately to the requests of the officers, etc.).

The instructors selected training scenarios from the VirTra scenario menu that aligned with the overall training objectives (i.e. tactical procedures and movement, de-escalation techniques, and communication skills) and closely resembled the training tasks of the VR training. In the first scenario, participants were placed in an urban environment in which they had to identify sudden threats in the 300-degree environment, communicate their surroundings to each other, and decide whether to engage in any of the threats or call for back up (e.g. when they saw an armed perpetrator through the window of a building). In the second scenario, the participants entered a school building in which an active shooter had to be identified and eliminated. In the third scenario, the participants faced an armed suspect who threatened to kill herself with a knife. The participants had to use tactical movement, communication, and de-escalation skills to resolve the situations safely. After the participants performed a scenario, they received short feedback on their performance before they proceeded with the next scenario.

Pain stimulus

All participants in the pain stimulus conditions wore a pain stimulus device during the VR and VirTra training, irrespective of whether a pain stimulus was delivered or not.

In VR, the pain stimulus was delivered using the StressX PRO belt from StressVest (www.stressvest.com). Participants wore the belt around the hip so that a safe, localised electrical stimulus *via* six electrodes on the device would be delivered to the lower abdomen. The device features an adjustable shock level (1 = low to 5 = extreme). For this experiment, the shock level setting 2 was used for all participants who trained with the pain stimulus.

In VirTra, the pain stimulus was delivered using the V-Threat-Fire (https://www.virtra.com/tool/law-enforcement-threat-fire/), an electric feedback device that is integrated into the VirTra V-300 simulator. The device was clipped onto the participant's belt or placed in the back pocket of the participants' pants (depending on the participant's preferences).

In both conditions, the localised stimuli were delivered by the trainer in accordance with the development of the scenario; for instance, when a participant was shot by a perpetrator in the scenario, the trainer would deliver the pain stimulus immediately to simulate getting shot. The electric impulses elicited by both devices were strong enough that the participants momentarily recoiled. All participants were familiar with the use and sensation of a pain stimulus from previous trainings.

Participants were given the option to refrain from wearing a pain stimulus in the training and hence be excluded from the experiment. None of the participants refused to train with the pain stimulus.

Dependent variables

Physical training responses

Heart rate

Average and maximum heart rate (HR) in beats per minute (bpm) were recorded using a Zephyr Bioharness 3.0 device (www.zephyranywhere.com) at a recording frequency of 1 Hz. HR recordings of the active training time in the training scenarios for VR and RL were extracted and analysed. HR Confidence (degree of validity of HR value, as a %) provided in the Zephyr output was used for data correction: data points at or below 25% HR Confidence were considered invalid and were removed from analysis (see 'Heart Rate Confidence', *OmniSense Analysis Help*, 2016). Bpm values outside of a realistic HR range (e.g. 0 bpm, values > 220 bpm) were removed from analysis through inspection of the data.

The Zephyr Bioharness device provides valid and reliable HR measurements (Nazari et al., 2018) and is frequently used in police research (e.g. Andersen & Gustafsberg, 2016; Bertilsson et al., 2019). In police research, HR has consistently been used as a common parameter to assess police officers' cardiovascular response to stress (Andersen & Gustafsberg, 2016; Andersen et al., 2016; Anderson et al., 2019; Anderson et al., 2002; Baldwin et al., 2019; Bertilsson et al., 2019; Vonk, 2008).

Psychological training responses

To assess psychological training responses, we utilised visual analogue scales (VAS) to assess mental effort and perceived stress. In police research, VAS for mental effort and perceived stress (originally anxiety) have been frequently used to quantify self-perceived psychophysiological responses to training and complex police tasks (e.g. Giessing et al., 2019; Nieuwenhuys et al., 2009; Oudejans, 2008; Wilson et al., 2007).

Mental effort

Subjective ratings of mental effort were obtained using the VAS 'Rating Scale for Mental Effort' (RSME; Zijlstra, 1993) at the end of the RL and VR training (once after all VR scenarios were completed). The RSME was assessed on a VAS from 1 to 150. According to (Zijlstra, 1993), the RSME has adequate test-retest reliability with correlation coefficients between 0.78 in work settings and 0.88 in laboratory settings.

Perceived stress

Subjective ratings of perceived stress were obtained using the VAS for anxiety (adjusted to 'stress' instead of anxiety; Houtman & Bakker, 1989) at the end of the RL and VR training (after all VR scenarios were completed). The stress scale was assessed on a VAS from 1 to 100. The original anxiety scale has a fair validity and test-retest reliability with correlation coefficients ranging between 0.60 and 0.78 (Houtman & Bakker, 1989).

Sense of presence

The experiences in the virtual environment were assessed using the ITC-Sense of Presence Inventory (ITC-SOPI; Lessiter et al., 2001). Each item of the inventory is rated on a Likert-scale from 1 'strongly disagree' to 5 'strongly agree'. The ITC-SOPI results in four factors. Spatial presence refers to the sense of being part of the virtual environment. Engagement refers to the feeling of involvement with the content and feeling psychologically engaged. Ecological validity or naturalness refers to the tendency of perceiving the virtual environment as life-like and natural. Negative effects refer to the experience of any adverse physiological experiences, such as dizziness or headaches (Lessiter et al., 2001).

According to (Lessiter et al., 2001), the ITC SOPI has good internal consistency. The Cronbach alpha coefficient for spatial presence was .94, for engagement .89, for ecological validity .76, and for negative effect .77. In the current study, the Cronbach alpha coefficient for the factor spatial presence was .89, for the factor engagement .80, for the factor ecological validity .74, and for the factor negative effect .83.

Procedure

Each experimental day started at the location of the Stadtpolizei Zürich. At the start of the experiment, participants received information about the training day, the training objectives, and general information about the experiment. Participants then provided written informed consent. Next, participants were taken to the VR training location. At the VR location, participants took off their police-specific gear (weapon, belt, vest), were equipped with a Zephyr heart rate monitor (for those training with the pain stimulus, they were also equipped with the pain belt), and then got fitted into the VR gear. The first four participants completed the VR training scenarios. After the VR training was completed, participants took off the VR gear (and pain belt, if training with pain stimulus) and received a short after-action review of their training performance (~5 min). Because the after-action review was considered an integral part of the training session, participants filled in the visual analogue scales and the ITC-SOPI questionnaire using iPads right after the review was completed (instead of immediately after the scenario execution). As soon as the first group of four participants completed the training scenario, the second group of four participants completed the same sequence. Once the second group finished the training, the 5-min after-action review, and filled in the questionnaires, participants were taken back to the training location of the Stadtpolizei Zürich where the VirTra training simulator was located. The eight participants were split into pairs. The VirTra instructors took the first pair into the training simulator to complete the training. After the VirTra scenarios were completed, the participants received feedback on their performance while still in the system (~5 min). When the first pair finished their VirTra training, the second pair started to train. In the meantime, the first pair returned their heart rate belts and filled in the visual analogue scales and the ITC-SOPI questionnaire using iPads at the VirTra training location. This sequence was completed until all eight participants had finished the VirTra training and filled in the questionnaires. (During their waiting time, participants were given the opportunity to train medical first aid skills at various pre-prepared stations). To ensure that participant groups could not observe each other perform during the training in VR and VirTra, the training areas were set up in such a way that the participant groups who waited to perform the trainings were in a preparation room that was separated from the execution areas.

Statistical analysis

2 (training simulator: VR, VirTra) × 2 (pain stimulus: with, without) ANOVAs were performed with training simulator as the within-subjects factor and pain stimulus as the between-subjects factor. The 2 × 2 ANOVAs were performed on average heart rate (BPM), maximum heart rate (BPM), mental effort scores, perceived stress scores, and scores for spatial presence, engagement, ecological validity, and negative effects. p-Values of <0.05 were considered statistically significant. Partial eta squared was calculated as an estimate for effect size. A value of $\eta_p^2 = 0.01$ indicated a small effect size, a value of $\eta_p^2 = 0.06$ indicated a medium effect size, and value of $\eta_p^2 = 0.14$ indicated a large effect size (Cohen, 1969). All statistical analyses were performed using IBM SPSS, version 27.

RESULTS

Mixed design ANOVAs were conducted to assess the impact of a pain stimulus on participants' training responses (heart rate, mental effort, perceived stress) and sense of presence (spatial presence, engagement, ecological validity, negative effects) during the training with virtual training simulators (VR and VirTra). Descriptive statistics are presented in Table 4.1. For reasons of readability in this section, we only discuss statistically significant results and present full statistics of all measures in Table 4.2.

Table 4.1. Descriptive statistics.

			With Pain Stimulus			Without Pain Stimulus		
	Variable	**Training**	***n***	***M***	***SD***	***n***	***M***	***SD***
Training Effort	Average Heart Rate	VR	37	104.55	18.28	50	104.90	14.41
		VirTra	37	90.10	14.55	50	89.13	13.02
	Maximum Heart Rate	VR	37	129.54	20.46	50	128.54	16.54
		VirTra	37	121.16	17.79	50	115.40	16.27
	Mental Effort	VR	80	71.04	23.23	88	70.22	29.02
		VirTra	80	74.17	25.22	88	64.13	27.45
	Perceived Stress	VR	80	61.76	20.27	88	62.11	23.32
		VirTra	80	65.38	18.75	88	53.89	20.53
Sense of Presence	Spatial Presence	VR	39	3.41	0.59	44	3.69	0.46
		VirTra	39	3.07	0.72	44	3.11	0.65
	Engagement	VR	39	3.55	0.57	44	3.73	0.47
		VirTra	39	3.51	0.49	44	3.51	0.58
	Ecological Validity	VR	39	3.44	0.61	44	3.70	0.53
		VirTra	39	3.48	0.64	44	3.40	0.71
	Negative Effects	VR	39	1.79	0.61	44	1.88	0.68
		VirTra	39	1.48	0.54	44	1.50	0.47

Note: Average and maximum heart rate in BPM. Mental effort (RSME) on a visual analogue scale from 1 to 150. Perceived stress on a visual analogue scale from 1 to 100. Sense of presence measures on a Likert-scale from 1 to 5.

Table 4.2. Results of the 2 (training simulator: VR, VirTra) × 2 (pain stimulus; with, without) ANOVAs on training response measures and sense of presence measures.

	Training Simulator	**Pain Stimulus**	**Training Simulator x Pain Stimulus**
Average Heart Rate	**$F(1,85) = 208.455, p < .001$, ηp 2 = .710**	$F(1,85) = .010, p = .921$, ηp 2 = .000	$F(1,85) = .393, p = .532$, ηp 2 = .005
Maximum Heart Rate	**$F(1,85) = 47.325, p < .001$, ηp 2 = .358**	$F(1,85) = .939, p = .335$, ηp 2 = .011	$F(1,85) = 2.317, p = .132$, ηp 2 = .027
Mental Effort	$F(1,166) = .313, p = .576$, ηp 2 = .002	$F(1,166) = 3.048, p = .083$, ηp 2 = .018	$F(1,166) = 3.059, p = .082$, ηp 2 = .018
Perceived Stress	$F(1,166) = 1.037, p = .310$, ηp 2 = .006	**$F(1,166) = 5.928$, $p = .016$, ηp 2 = .034**	**$F(1,166) = 6.825$, $p = .010$, ηp 2 = .039**
Spatial Presence	**$F(1,81) = 24.825, p < .001$, ηp 2 = .235**	$F(1,81) = 2.834, p = .096$, ηp 2 = .034	$F(1,81) = 1.652, p = .202$, ηp 2 = .020
Engagement	$F(1,81) = 3.186, p = .078$, ηp 2 = .038	$F(1,81) = 1.013, p = .317$, ηp 2 = .012	$F(1,81) = 1.553, p = .216$, ηp 2 = .019
Ecological Validity	$F(1,81) = 1.748, p = .190$, ηp 2 = .021	$F(1,81) = .787, p = .378$, ηp 2 = .010	$F(1,81) = 3.085, p = .083$, ηp 2 = .037
Negative Effects	**$F(1,81) = 20.650, p < .001$, ηp 2 = .203**	$F(1,81) = .261, p = .610$, ηp 2 = .003	$F(1,81) = .221, p = .639$, ηp 2 = .003

Note. Significant results are shown in bold.

Training responses

The ANOVAs on training response measures showed a significant interaction between the training simulator and pain stimulus for perceived stress, $F(1,166) = 6.825$, $p = .010$, $\eta_p^2 = .039$ (see Figure 4.4). *Post-hoc* pairwise comparisons with Bonferroni corrections showed a significant difference in training without the pain stimulus in VR and VirTra ($p = .009$), indicating that when no pain stimulus was used during the training, VR provoked significantly higher levels of perceived stress compared to VirTra (mean difference in perceived stress = 8.23). In addition, *post-hoc* pairwise comparisons with Bonferroni corrections revealed that there was a significant difference between training with or without the pain stimulus in VirTra ($p < .001$), indicating that VirTra training with a pain stimulus provokes significantly higher levels of perceived stress compared to VirTra training without a pain stimulus (mean difference in perceived stress = 11.49).

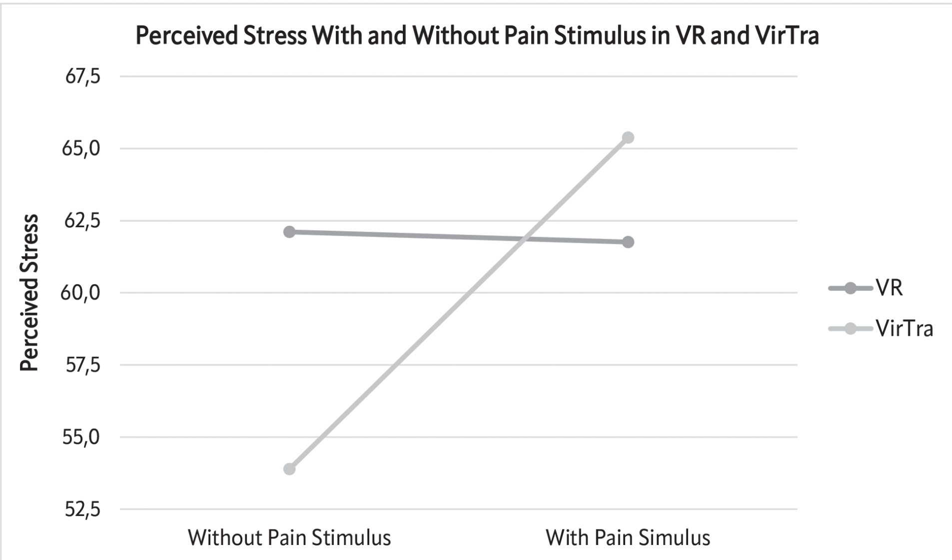

Figure 4.4. Disordinal interaction between training simulator and pain stimulus for perceived stress. Note: Perceived stress was assessed on a visual analogue scale ranging from 1 to 100.

There were significant main effects for the training simulator on all physical training response measures, indicating that VR training elicited higher average heart rates and maximum heart rates compared to VirTra. Note that these differences were likely caused by the inherent differences between the training simulators (e.g. larger area for movement, the additional weight of the VR gear in VR training). The ANOVAs showed no other significant interaction effects between the training simulator and pain stimulus or main effects for pain stimulus (see Table 4.2 for statistics).

Sense of presence

The ANOVAs revealed significant main effects for the training simulator, indicating that spatial presence and negative effects were experienced significantly higher/more frequently in VR compared to VirTra. ANOVAs on the sense of presence measures showed no statistically significant interactions between the training simulator and pain stimulus. No statistically significant main effects were found for pain stimulus (see Table 4.2 for statistics).

DISCUSSION

In the present study, we investigated the influence of a pain stimulus on the training responses and sense of presence in two different types of training simulators: the interactive 2D simulator VirTra V-300 and the 3D police-specific VR system from Refense. We expected that adding a pain stimulus to the virtual training simulator would have an effect on representativeness as it adds (i) a physical threat that is also present in real life to the training and (ii) a sensory stimulus to the audiovisual stimuli present in virtual training simulators. Thus, we first hypothesised that training responses with a pain stimulus would be higher than without a pain stimulus. Secondly, we hypothesised that the sense of presence with a pain stimulus would be higher than without a pain stimulus.

First, to address hypothesis 1, we found that the addition of a pain stimulus influenced the perceived stress of police officers in the VirTra training whereas it did not in VR training. Police officers who trained in the VirTra simulator with the pain stimulus experienced significantly higher perceived stress compared to those who did not train with a pain stimulus in VirTra. Additionally, we found that perceived stress was significantly higher in VR compared to VirTra when no pain stimulus was used. A main difference between the two virtual training simulators seems therefore to be the psychological training responses the simulators themselves provoke. While perceived stress and mental effort were relatively low in the VirTra training without a pain stimulus, they are comparatively high in VR without a pain stimulus and do not significantly increase when adding a pain stimulus. However, adding a pain stimulus to VirTra increases psychological training responses and matches the level of responses in VR (see Figure 4.4). A possible explanation for this effect may be that in VR, the psychological training responses are already at such a high level that adding a pain stimulus may not influence the perceived stress or mental effort any further. Compared to recent literature assessing perceived stress in police officers in high-threat conditions (see for instance, Bélanger & Blanchette, 2022, perceived induced stress = 46; Nieuwenhuys et al., 2015, perceived stress in high threat condition = 65) the elicited levels of perceived stress were relatively high in our study even without the pain stimulus (VR = 62). This supports the notion that perceived stress was already at a level at which a pain stimulus may not have added anything further. One reason for this difference in perceived stress between VR and VirTra may be due to the different training configurations. In VR, police officers performed in groups of four using rifles, which is done when police officers respond to high-threat operational situations. Comparatively, in the VirTra training, police officers use their own service weapons and performed in pairs, which is similar to their on-duty experience. Thus, it may be possible that the set-up of the VR training induced higher levels of perceived stress while in VirTra the familiarity with the training context contributed to lower levels of perceived stress. Moreover, the addition of a pain stimulus did not influence any of the physical training responses assessed in our study. (Nieuwenhuys & Oudejans, 2011) demonstrated that, in a real-life setting, a threatening opponent who shot back at officers with colored-soap cartridges provoked higher heart rates, and higher anxiety and mental effort scores compared to an opponent who does not shoot back. Therefore, we anticipated to see heightened physical responses in response to a pain stimulus in virtual training as well. Similar to the explanation for psychological training responses, it may be that due to the already high training load (particularly in VR), we observe a potential ceiling effect. Another possible explanation may be that the pain stimulus was seldomly used in VR (8% of participants in the pain stimulus condition received a pain stimulus in response to getting hit by an opponent) compared to the frequent use in VirTra (64% of participants in the pain stimulus condition received a pain stimulus in response to getting hit by an opponent). Note however that the presence of a physical threat alone (with just an occasional pain stimulus, just as in VR in the current study) has been found to elicit higher levels of stress and anxiety in police officers in earlier studies (Nieuwenhuys et al., 2012; Nieuwenhuys & Oudejans, 2010). To conclude, hypothesis 1 is not fully supported by our data—the addition of pain stimulus to virtual training simulators influenced the training responses only minimally. Only in VirTra did the addition of a pain stimulus heighten the perceived stress during the training.

Addressing the second hypothesis, we found that sense of presence measures seemed to be unaffected by the addition of a pain stimulus. Particularly regarding ecological validity (one of the four sense of presence factors assessed in our study) we hypothesised that the addition of a pain stimulus would increase the perception of the naturalness of the virtual environment. However, our findings showed that neither in VR (low-frequency use of the pain stimulus) nor in VirTra (high-frequency use of the pain stimulus) the spatial presence, engagement, or ecological validity were affected by the addition of a pain stimulus. One reason why the addition of a pain stimulus may not have influenced the sense of presence is that a nociceptive stimulus provides information about the body itself (i.e. interoceptive function) rather than information about the environment, as auditory and visual stimuli do (i.e. exteroceptive function; Craig, 2002; Ogden et al., 2015). Thus, while the virtual environment is primarily experienced through exteroceptive senses like auditory and visual experiences, adding a stimulus like pain that is experienced interoceptively may not influence the sense of presence (i.e. the feeling of fully being there in the virtual environment) as much as exteroceptive stimuli would. Taken together, a pain stimulus may not be the most relevant sensory stimulus to add to the virtual environment to enhance the sense of presence, as it provides limited information about the environment itself. It should, however, be considered that the possibility of getting hit by an opponent appears to influence the behavioural responses of police officers, such as adjusting their posture to make themselves smaller to avoid getting hit (Nieuwenhuys & Oudejans, 2010). Therefore, while the pain stimulus may not have influenced the feeling of 'being there' in the virtual environment, it may have influenced how police officers reacted to the virtual environment on a behavioural level. These behavioural responses may also give an indication of how present someone feels in the virtual environment because realistic behavioural responses are more likely to occur when presence is high (Slater, 2009). Whilst not explored in this study, the addition of a pain stimulus to virtual training simulators may support eliciting duty-like behavioural responses. Future studies in VR should therefore explore the influence of a pain stimulus on behavioural responses and in conjunction with presence. To conclude, hypothesis 2 is not supported by our data—the addition of pain stimulus to virtual training simulators did not influence the sense of presence in the virtual environment. This may also be due to a ceiling effect as the sense of presence (spatial presence, engagement, ecological validity) was relatively high in both simulators.

In addition to investigating the influence of a pain stimulus on the training responses and sense of presence in virtual training simulators, our analysis also revealed differences in training responses between the two training simulators. When looking at the physical training responses between the simulators, VR provoked significantly higher average HR and max HR compared to VirTra. This difference is likely explained by the inherent lack of similarity of the training simulators: VR training offers the greater possibility for movement as trainees have more space to move about. Additionally, in VR, trainees wear VR gear that adds an increased physical load, thus, increasing cardiovascular responses to the VR training compared to the VirTra in which trainees do not have any additional gear. Further, differences in sense of presence between the simulators exist as well: police officers experienced more spatial presence in VR, while also experiencing more negative effects compared to VirTra. These findings indicate that the training environment of a VR training simulator provides a realistic and immersive training environment, yet the occurrence of cybersickness also has to be considered, particularly compared to a 2D simulator where these appear much less (Naqvi et al., 2013). Although differences between the two systems exist in terms of physical training responses and sense of presence, both virtual training simulators provoked psychological training responses similar to responses found in studies of real-life training (VR provoking higher levels without a pain stimulus; addition of a pain stimulus to VirTra could match the VR levels; Nieuwenhuys et al., 2015; Oudejans & Pijpers, 2009). Conclusively, both systems, due to their inherent technological differences, elicit different training responses and sense of presence experiences. A virtual training simulator may therefore be selected based on the training goal. For instance, for trainings that aim to elicit high levels of physical training responses and require a high level of immersion, a VR system appears most fitting. For a training that requires little movement, high levels of psychological training responses, and little negative effects, a VirTra simulator (with a pain stimulus) may better support the training goal.

The current study has limitations. First, the factor of pain stimulus was a between-subjects factor, with one group of participants doing the scenarios without and one group with a pain stimulus. While we assigned participants to the pain stimulus condition randomly, a stronger design for such a factor would be to have without and with pain stimulus as a within-subject factor, implying an intra- rather than inter-person comparison of the experience of pain. Statistically, a between-subjects factor involves relatively larger standard deviations, making it more difficult to find significant differences. Second, because the training schedule of the police was arranged in such a way that participants first completed VR training followed by VirTra training, it is possible that an order effect may have influenced the results. Lastly, the design of the training scenarios in VR and VirTra training did not allow us to balance the number of hits that participants experienced during the trainings with the pain stimulus. Thus, our results provide limited insights into the influence of applying a pain stimulus in VR training (as only 8% of participants received a pain stimulus in response to getting hit by an opponent).

In conclusion, the use of a pain stimulus may have a place in virtual simulation training, particularly in situations where the experience of a pain stimulus is likely and suitable and when virtual simulation training without a pain stimulus elicits relatively low levels of stress. For virtual simulation training that already elicits representative levels of stress, the addition of a pain stimulus seems less efficacious, at least in terms of increasing stress, mental effort, and presence. In real-life training, the inclusion of a physical threat to an opponent appears to influence the behavioural responses of police officers like adjusting the posture to avoid getting hit, reacting faster, and blinking more often (Nieuwenhuys & Oudejans, 2010). These behaviours are likely to occur during on-duty encounters with a threatening opponent. Therefore, it is relevant to explore whether the addition of a pain stimulus in virtual training simulators elicits similar behavioural responses; further clarifying the need or redundancy of a pain stimulus in virtual training simulators.


POLI

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CHANGING PERSPECTIVES: ENHANCING LEARNING EFFICACY WITH THE AFTER-ACTION REVIEW IN VIRTUAL REALITY TRAINING FOR POLICE

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Changing Perspectives: Enhancing Learning Efficacy with the After-Action Review in Virtual Reality Training for Police

Ergonomics

ABSTRACT

The After-Action Review (AAR) in Virtual Reality (VR) training for police provides new opportunities to enhance learning. We investigated whether perspectives (bird's eye & police officer, bird's eye & suspect, bird's eye) and line of fire displayed in the AAR impacted the officers' learning efficacy. A 3 x 2 ANOVA revealed a significant main effect of AAR perspectives. Post hoc pairwise comparisons showed that using a bird's eye view in combination with the suspect perspective elicits significantly greater learning efficacy compared to using a bird's eye view alone. Using the line of fire feature did not influence learning efficacy. Our findings show that the use of the suspect perspective during the AAR in VR training can support the learning efficacy of police officers.

Keywords: police training, virtual reality, after-action review, learning efficacy

INTRODUCTION

Virtual Reality (VR) is becoming an increasingly popular training tool for police agencies (Zechner et al., 2023; Uhl et al., 2022). Utilizing high fidelity VR tools, police instructors are able to simulate various complex situations (e.g., Fejdyś et al., 2022). They can do so by utilizing a wide variety of locations, select a range of avatars to appear the virtual environment, and include different sounds to create realistic training scenarios (Kleygrewe, Hutter, Koedijk, et al., 2023; Zechner et al., 2023). VR therefore provides police agencies the opportunity to train their officers for complex tasks in a safe and versatile environment (Giessing, 2021). In the field of policing, VR has been used to teach police officers a variety of skills. For instance, VR training was conducted to investigate police officers' helping behavior toward victims of police racial aggression (Kishore et al., 2022). Police officers trained firearms skills in VR under light, moderate and frustrating difficulties (Muñoz et al., 2020) and were taught breathing regulation techniques in stressful situations (Brammer et al., 2021). Thus, VR appears to be a versatile training tool in which police officers can train and perform relevant police-specific tasks while being exposed to stress-inducing environments (Caserman et al., 2022; Garcia et al., 2019).

VR offers the opportunity to provide objective, technology-enhanced feedback on training performance (Cosman et al., 2002). By recording the virtual training scenarios, VR systems enable instructors and trainees to review the training using the VR after-action review (AAR). AAR is a common debrief procedure in military and other fields that rely on performance reviews to enhance learning (Raemer et al., 2011). While originally designed as a debrief tool for real-life combat training exercises, the AAR has been adapted to simulation-based environments in different fields (e.g., health care education, Sawyer & Deering, 2013). In a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of VR for police training, Giessing (2021) points out that the VR AAR provides police instructors and trainees with unique feedback capabilities to foster the learning experience of virtual training sessions. For instance, technical features such as perspective taking may foster learning by providing concrete visual performance feedback and thus make the debrief with the VR AAR less abstract than a verbal debrief after real-life training. Similar prospects of the AAR to enhance learning through the use of objective performance feedback have been discussed in a SWOT analysis of CBRNe training (i.e., training to prepare for Chemical, Biological, Radiological, Nuclear, and explosives incidents) in virtual environments (Murtinger et al., 2021). Whilst the potential of the VR AAR to enhance learning has been noticed, empirical research on the influence of feedback through simulation-based debriefing in police training is sparse.

In practice, police instructors can use the VR AAR tool to share training experiences on an external screen where instructors and trainees can review the training performance. The VR AAR offers the opportunity to replay the recorded training scenarios from various perspectives, for instance, from the birds' eye view, from the view of the suspect, officer, or a bystander. During the review, the instructor and trainees can jump to specific incidents of the scenario and replay the scene using a variety of feedback features. Instructors can select to show the line of fire of the weapon, the viewing field of the trainees and various avatars, and the snake lines of the walking routes that trainees took during the VR scenario. In addition, the AAR may provide key performance indicators (e.g., shots fired, shots missed, target hits, number of bystanders flagged) that provide objective information on the training performance. Having a large range of options, police instructors can deliver visually supported and objective feedback using the AAR of the VR system and combine it with their personal expertise and the self-assessment of trainees.

Providing feedback effectively enhances learning (Hattie & Timperley, 2007). Following the ecological dynamics framework, learning refers to the emergence of an adaptive, functional relationship between a trainee and their environment (Araújo & Davids, 2011). In the context of police work, learning ensues that police officers can transfer knowledge and skills acquired in training to novel operational situations (Di Nota & Huhta, 2019). Learning is therefore ideally assessed as performance of the taught knowledge and skills in a relevant on-duty context (Staller & Koerner, 2022). Whilst the present study design did not allow for the assessment of learning outcomes in on-duty situations, this study examined the police officers' learning efficacy. Learning efficacy refers to the trainees' level of confidence in the application of their acquired knowledge and skills in real-life situations (Srivastava et al., 2019). Learning efficacy has been shown to enhance engagement and motivation (Linnenbrink & Pintrich, 2003), and appears to be correlated with higher levels of performance (Klobas et al., 2007; Schunk, 1996). We assessed learning efficacy with a self-designed questionnaire aimed to capture the officers' efficacy of applying the skills practiced during the virtual training to relevant on-duty situations.

In the current study, we investigate whether features of the VR AAR enhance the learning efficacy in police officers. In particular, we examined a) whether review perspectives ([i] combination of bird's eye view and suspect perspective, [ii] combination of bird's eye view and officer perspective, [iii] bird's eye view) influence learning efficacy and b) whether using the line of fire of the weapon during the AAR influences learning efficacy.

- Our first hypothesis states that reviewing the VR training scenario from the suspect perspective elicits the highest learning efficacy in police officers.

Reviewing one's performance from a perspective where one can see themselves act improves learning (Fukkink et al., 2011; Guadagnoli et al., 2002). Because police officers are able to review their performance from the perspective of the suspect, they are able to see how effective their performance and behaviors are from the perspective of the person they engage. They seldomly have access to the suspect perspective — as compared to their own perspective, from which they view, albeit normally not review, their actions on duty and in training all the time —, and therefore we expect most 'added value' to learning from the suspect perspective. To investigate whether reviewing one's performance from the suspect or officer perspective during engagements with suspects influences the learning efficacy, we used the bird's eye view only throughout the entire training scenario as a control condition.

- Our second hypothesis states that using the line of fire of the weapon during the AAR review enhances learning efficacy compared to not using the line of fire.

The line of fire provides important performance feedback on the handling of the service weapon and thus informs police officers on how well they used their service weapon. For instance, reviewing the VR scenario with the line of fire, officers can see if or when they flag (i.e., point their weapon at something they should not) a bystander or colleague. In addition, particularly when performing in a team, police officers can see how well they cover each other with their line of fire when they make contact with a suspect. This objective feedback on flagging is not routinely available to officers; thus, having this information available during the AAR is expected to be of added value for police officers.

Investigating the effectiveness of the various AAR features on the learning efficacy of police officers may improve the development and implementation of VR training for police agencies. VR providers can utilize and implement perspectives and features that enhance learning efficacy in their technical developments and provide VR training tools that benefit learning. Moreover, knowing which perspectives and features provide the highest learning efficacy, police agencies can utilize these in their feedback procedure and provide targeted performance feedback. Therefore, this research aims to enhance development and delivery of virtual training in the police sector.

METHODS

Participants

413 police officers of the City Police Zurich, Switzerland (Stadtpolizei Zürich) (342 male, 66 female, and 5 other; *M* age = 37.54, *SD* = 8.96) participated in this study. The participants' experience on the job ranged from 2 to 37 years (*M* years = 11.50 years, *SD* = 8.50). Participants

provided informed consent before the start of the experiment. Ethical approval was obtained from the Social and Societal Ethics Committee of the Katholieke Universiteit Leuven as part of the SHOTPROS project which is funded by the European Union's Horizon 2020 Research and Innovation Programme (Grant number: 833672).

Design

We utilized a 3 (AAR perspectives: bird's eye & police officer, bird's eye & suspect, bird's eye) x 2 (AAR line of fire: Off, On) between-subjects study design. Each participant completed the VR training and received the AAR from one of the three perspectives with the line of fire of their weapon either turned on or off. The experiment was conducted over a span of 7 weeks as part of the yearly training of the City Police Zurich. The training coordinator scheduled for police officers to attend the training on a particular training day in advance based on the officers' availability. Eight instructors were selected for the experiment and rotated on a daily basis (two instructors were present daily, the pairings of instructors were also rotated).

The AAR perspectives changed biweekly (e.g., Week 2 & 3 = bird's eye & police officer, Week 4 & 5 = bird's eye & suspect, Week 6 & 7 = bird's eye only). During Week 1, police instructors involved in this study received special training to familiarize themselves with the steering of the VR scenario and of the AAR and its features (participants of Week 1 were not included in this study). The AAR line of fire alternated on a daily basis: participants of the first training day trained with the line of fire off, participants on the second training day trained with the line of fire turned on, etc. In this way, the participants were randomly assigned to the experimental groups.

Virtual reality training (VR)

The VR system used in this experiment was provided by Refense (www.refense.com). Participants were equipped with the Refense VR suit consisting of a binocular head-mounted display, microphone and audio provided via over-ear headphones, radio chatter, hand- and foot sensors for motion tracking, a computing box (backpack style), and a replica rifle. The size of the VR training area was 15x15 meters. Figure 1 shows the VR equipment used in this study. Participants completed the VR scenario in groups of four. The completion of the VR scenario took on average 13 minutes. Before the start of the training scenario, participants underwent calibration of the VR sensors and equipment and completed a short instructional tutorial in VR. The same VR set-up and training scenario was used in a previous study by Kleygrewe, Hutter and Oudejans (2023).

Figure 5.1. *Refense VR Equipment*
Note. The VR equipment was provided by Refense.

The objective of the VR training consisted of the training of tactical procedures and movements, training of de-escalation techniques, and training of communication skills. The VR scenario contained three different layers in which participants trained these skills. The scenario was spread over a three-story building that contained a bank on the first floor, an office area on the second floor, and a residential apartment on the third floor. Participants were tasked with identifying and arresting two armed suspects that were located on the second and third floor. The suspects threatened bystanders or themselves. All encounters in the virtual environment were with non-player characters (NPCs). These NPCs were steered by experienced VR instructors of the City Police Zurich via an external control station consisting of a computer, an external screen, and a specialized keyboard to control the behaviors of the NPCs. From this control station positioned right next to the VR training pitch, the instructors could steer the virtual scenario and observe the participants on the physical training ground. During encounters with an NPC suspect, the instructors took over the voice of the NPC to create dynamic interactions. To keep the interactions with NPCs as standardized as possible, the VR instructors were provided with a script. During the dynamic voice-over interactions, the VR instructors could slightly deviate from the script if the interaction with the police officers necessitated it. For more information on the scenario, we refer readers to Kleygrewe, Hutter and Oudejans (2023).

Independent variable

AAR Perspective

The AAR perspectives used after the VR training consisted of (i) bird's eye view in combination with police officer perspective, (ii) bird's eye view in combination with suspect perspective, and (iii) bird's eye view (as control condition). For perspectives (i) and (ii), the instructors were tasked with switching from a bird's eye view, adopted during general movement through the virtual environment, to the specific perspective (i.e., police officer or suspect) whenever the participants made contact with a suspect. For perspective (i) this meant that the instructor selected the most relevant police officer perspective from the four team members during the engagement with the suspect (most often, instructors selected the officer who engaged in verbal communication). Perspective (iii), the bird's eye view, was utilized as a control condition: participants reviewed their performance from the bird's eye view for both engagement with the suspect and general movement through the environment. Figure 2 shows the different perspectives used in this study.

Figure 5.2. AAR Perspectives: police officer perspective (top), suspect perspective (middle), bird's eye view (bottom)

Line of fire

The AAR line of fire of the weapon the participants carried during the VR training was turned off or turned on during the entire AAR. The line of fire provided participants with information about the positioning and pointing of their own and their team member's weapons. Because participants were equipped with a rifle-type weapon, participants were tasked with handling their weapon intentionally throughout the scenario (i.e., pointing the weapon only in high-threat situations). The weapons were never holstered (as might be the case with service pistols), therefore, the line of fire of the weapon is visible throughout the entire scenario, also when the weapon was safely pointing to the ground.

Dependent variable

Learning efficacy

We assessed learning efficacy using a self-developed questionnaire specific for police training in virtual training systems. The questionnaire contains three items: (i) "how confident are you that you can put into practice what you have learned in this training?" (ii) "if one of the situations trained with this system occurs on-duty, I will be better able to master it," (iii) "thanks to the training in the virtual system, I will be able to handle demanding operational situations more safely in the future." These items were selected in accordance with the definition of learning efficacy — the participants' level of confidence in the application of their acquired knowledge and skills in real-life situations (Srivastava et al., 2019). Participants assessed these items on a 5-point Likert-type scale where 1 = extremely uncertain/strongly disagree and 5 = extremely certain/strongly agree. The average score of the three items was used for data analysis.

To assess the internal consistency reliability of the scale, we computed McDonald (1999) omega using RStudio 2022.07.02 which returned an ω value of .75, implying good internal consistency based on the minimum standard of reliability .70 (Nunnally & Bernstein, 1994).

Procedure

Each data collection day started at the location of the City Police Zurich. Participants were scheduled to attend on specific training days by the training coordinator of the City Police Zurich in advance. At the start of the experiment, participants received information about the training day, the training objectives, and general information about the experiment. Participants then provided written informed consent. Next, participants were taken to the VR training location. At the VR location, participants took off their police-specific gear (weapon, belt, vest) and got fitted into the VR gear. Teams of four participants completed the VR training scenario. After the VR training was completed, participants took off the VR gear and received the AAR of their training performance in their teams of four. The police instructor who steered the training scenario provided the AAR. Instructors were equipped with points of references for the AAR feedback. The points of reference related to the three training objectives of tactical procedures and movements, training of de-escalation techniques, and training of communication skills Once completed, participants filled in the learning efficacy questionnaire using iPads.

Statistical Analysis

A two-way ANOVA was conducted on the influence of two VR AAR features (AAR perspective, AAR line of fire) on learning efficacy. AAR perspective included three levels (bird's eye & police officer, bird's eye & suspect, bird's eye) and AAR line of fire consisted of two levels (line of fire off, on). Where appropriate, post hoc pairwise comparisons were conducted with Bonferroni-adjusted p-values and 95% confidence intervals. P-values < 0.05 were considered statistically significant. Partial eta squared (ηp^2) was calculated as an estimate for effect size. A value of $\eta p^2 = 0.01$ indicated a small effect size, a value of $\eta p^2 = 0.06$ indicated a medium effect size and value of $\eta p^2 = 0.14$ indicated a large effect size (Cohen, 1969). The statistical analysis was performed using IBM SPSS, version 27.

RESULTS

Descriptive statistics of learning efficacy of all groups are reported in Table 5.1.

The two-way ANOVA revealed a statistically significant main effect of AAR perspective on learning efficacy, $F(2, 407) = 4.284$, $p = .014$, partial $\eta^2 = .021$. Pairwise comparisons on AAR perspective revealed a statistically significant difference between bird's eye view & suspect perspective and bird's eye view alone, $p = .013$, 95% CI [.030, .343], mean difference on learning efficacy = .186. There was no statistically significant difference between bird's eye view & police officer perspective and bird's eye view & suspect perspective, $p = 1.000$, 95% CI [-.197, .100], mean difference on learning efficacy = -.049. Similarly, the difference between bird's eye view & police officer perspective and bird's eye view alone did not reach significance, $p = .112$, 95% CI [-.021, .296], mean difference on learning efficacy = .137.

There was no statistically significant main effect of line of fire on learning efficacy, $F(1, 407) = .026$, $p = .871$, partial $\eta^2 = .000$, nor a significant interaction between AAR perspective and AAR line of fire, $F(2, 407) = 0.387$, $p = .679$, partial $\eta^2 = .002$. For a graphical output, see Figure 3.

Table 5.1. Descriptive statistics of learning efficacy of the different groups.

AAR Perspective	Line of Fire	Mean	*SD*	N
Bird's Eye View & Police Officer	Off	3.98	0.52	83
	On	4.01	0.50	59
Bird's Eye View & Suspect	Off	4.03	0.47	91
	On	4.05	0.51	60
Bird's Eye View	Off	3.89	0.56	46
	On	3.82	0.57	74

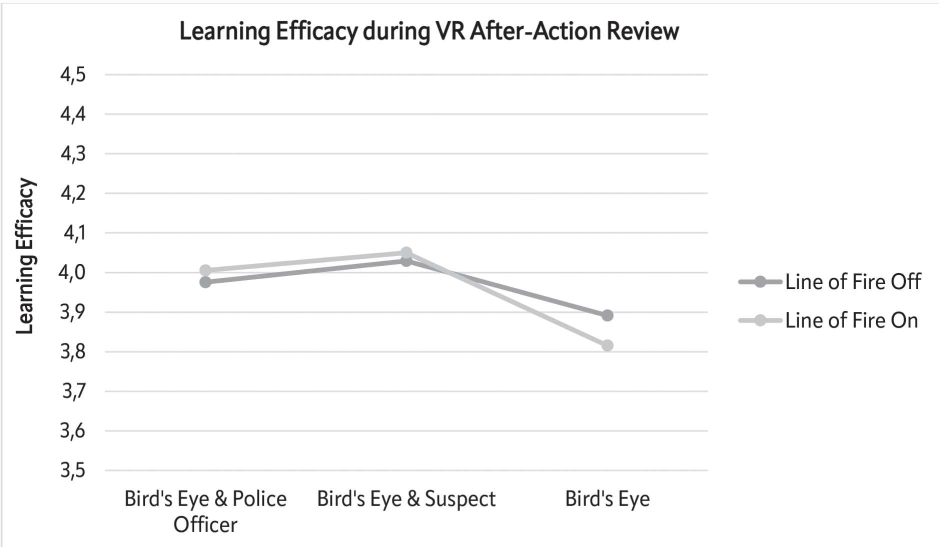

Figure 5.3. Learning efficacy according to AAR perspective and line of fire feature.

DISCUSSION

In the present study, we investigated the influence of AAR features in VR on learning efficacy of police officers. We defined learning efficacy as the trainees' level of confidence in the application of their acquired knowledge and skills in real-life situations (Srivastava et al., 2019). To examine the influence of AAR features on learning efficacy, we investigated two hypotheses: first, we examined whether using the AAR perspective from a suspect view enhances learning efficacy more than other perspectives such as a review from the police officer perspective or from the bird's eye view only. Second, we hypothesized that turning on the line of fire of the weapon of the police officers during the AAR would enhance learning efficacy compared to not using this feature during the AAR. Both hypotheses rely on the premise that they provide police officers with relevant information about their behaviors and performance during the VR training scenario that is not routinely available to them on duty or in normal practice and would thus enhance learning efficacy.

Addressing the first hypothesis, we found that the learning efficacy of police officers was significantly greater when using the combination of bird's eye view and suspect perspective compared to bird's eye view alone. We therefore infer that viewing one's performance from the suspect perspective — a perspective that police officers seldomly have access to — provides officers with new information about their performance and behavior and thus enhances learning efficacy. In addition, we found that learning efficacy of police officers did not significantly differ when they reviewed their performance using the combination of bird's eye view and police officer perspective and the combination of bird's eye view and suspect perspective, implying that both distinctive perspectives appear to provide officers with information that supports their learning efficacy. Note, however, that the difference in learning efficacy of officers receiving the bird's eye view and officer perspective and bird's eye view alone did not reach significance, presumably due to high standard deviations. Nonetheless, we argue that reviewing performance from the suspect perspective and possibly the officer perspective appears to provide more detailed information on individual behaviors than bird's eye view alone. In the bird's eye view, police officers can obtain movement-specific information on a group level (which may provide valuable feedback on the training objective of tactical movements). Using distinctive perspectives (i.e., suspect and possibly officer) provides more detailed information related to the other training objectives (i.e., de-escalation techniques and communication skills). The combination of bird's eye view and distinctive perspectives seems to provide visual feedback that gives detailed information covering all three training objectives. Receiving detailed feedback from multiple perspectives appears to be more beneficial for learning efficacy (Fukkink et al., 2011; Guadagnoli et al., 2002). In addition, receiving feedback on an individual level is more personal and confronts the trainee directly, allowing the trainee to have a more active and engaged role in their learning process (Chan & Lam, 2010). In comparison, the bird's eye view invites feedback on a team level. Conclusively, police officers who have received a combination of bird's eye view and a distinctive perspective have received feedback on an individual and team level, providing a broader range of relevant performance feedback and addressing personal efficacy directly. This appears particularly pertinent when utilizing the suspect perspective since police officers receive novel information about the impact of their behavior. Thus, hypothesis 1 is supported by our data: reviewing the training performance from the AAR perspective bird's eye view in combination with suspect perspective enhances learning efficacy of police officers.

Testing the second hypothesis, we found that learning efficacy did not significantly differ during the AAR with and without the line of fire of the weapon of the police officers. It is possible that the line of fire feature did not provide information relevant for the performance of the police officers within the scenario and therefore was not relevant for learning. Another reason may be that the discussion of line of fire is sufficient when done verbally; thus, not relying on visual support to provide further information on performance. Lastly, processing feedback right after high-arousal training may be cognitively demanding for trainees (Jenkins et al., 2020). If too many visual features are used while trainees recover from the arousal of a scenario and already receive verbal and visual performance feedback, the additional use of visual features such as the line of fire may not enhance learning further. It is therefore possible that while cognitive abilities are limited at the time of the AAR, the information provided by additional AAR features may not be processed properly (Mugford et al., 2013). Conclusively, the second hypothesis is not supported by our data: the line of fire feature of the AAR did not enhance learning efficacy in police officers.

Limitations

While the results presented in our study provide valuable insights for practice and development of VR training in police, the study also has limitations. First, in this study, we assessed learning efficacy via a self-designed questionnaire. Ideally, learning and transfer would be assessed objectively on a behavioral level in a novel performance context. This was not feasible within this study. Therefore, the question regarding learning and the transfer of VR training to operational situations remains to be explored.

Second, the study's focus was placed on the features that the VR AAR provides. Thus, the influence of verbal feedback and expertise of instructors was not explicitly controlled for. To standardize the feedback that instructors provide during the VR AAR, instructors received reference points for providing feedback. Nonetheless, police instructors still have individuals ways of delivering feedback (Kleygrewe et al., 2022). Because the type and modality of feedback influence learning (Hattie & Timperley, 2007; Zhu et al., 2020), the way that instructors provide feedback may play a role in how officers perceive their learning experience. While all police instructors who participated in this study were experienced and well-instructed to use the VR AAR, their personal feedback style may have, in some way, contributed to the learning efficacy police officers experienced.

Lastly, learning efficacy was assessed on an individual level. This study did not explore team effects or team dynamics that can influence learning efficacy. For instance, four-person teams with experienced team leaders and police officers may have had a different learning experience and thus learning efficacy than teams of different compositions (Paoline III & Terrill, 2007). In addition, gender of police officers may also influence learning efficacy. For instance, female police officers experience differences in operational task assignments (Rabe-Hemp, 2009; Morash & Haarr, 2012) and thus may take unfavorable roles in team compositions, reducing their learning efficacy.

CONCLUSIONS

In conclusion, the AAR appears to be a promising feature of VR and provides police agencies with feedback opportunities that are difficult to simulate in real-life training (Murtinger et al., 2021). Reviewing training performance from various perspectives and utilizing additional features to underscore performance makes the AAR an effective training tool that supports police instructors when giving feedback. To further enhance the use of the AAR in practice, police agencies should aim to identify AAR features that align with the learning objective of the training when setting up the VR training (Bennell et al., 2020). For instance, when trainees are tasked with clearing and searching various rooms, police instructors may utilize AAR features such as the walking routes the officers took, and display of gaze areas that were covered. In the AAR, the instructors and trainees can then review and compare which paths they took to clear a room, the areas their gaze covered, and whether the strategies to conduct a clearance changed from room to room. Similarly, instructors should avoid using AAR features that do not align with the training and learning objective. For example, during a training aimed at verbal de-escalation or taking cover to observe a suspects' behavior (i.e., a training that has no intention to rely on the service weapon), showing the line of fire would distract from the objective of the training. Thus, utilizing too many features provides trainees with information that may not be relevant to them or the purpose of the training (Bennell et al., 2020).

VR providers can further support the implementation of AAR in police practice by developing context-specific review features. For instance, next to enabling trainees to view their performance from a first-person perspective and a suspect perspective, features such as showing the hit zones after using a service weapon may be relevant performance indicators. VR providers for police training should therefore consider developing these context-specific features in collaboration with police instructors. Lastly, to make the debrief process efficient and effective, VR providers should design an accessible AAR tool that makes it easy for police instructor to select and use the relevant features during the debrief. Because "feedback is one of the most powerful influences on learning" (Hattie & Timperley, 2007), designing and implementing VR AAR effectively in police training can enhance the delivery of feedback and subsequently improve learning and performance of police officers.


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EPILOGUE

This thesis focuses on the implementation and application of Virtual Reality (VR) training for police officers. VR is an emerging training technology amongst police agencies. With its flexibility in scenario creation and its independence of physical training locations and props, VR gives police agencies the opportunity to supplement and enhance current real-life training practices flexibly and safely. VR is currently being used in a variety of domains within police training; for instance, in de-escalation training, tactical training, and use-of-force training (Kent, 2022; Kleygrewe, Hutter, & Oudejans, 2023; Garcia, 2019; McAllister et al., 2022). Research has demonstrated VR's effectiveness for training cognitive-perceptual and applied, police-specific skills. However, there is currently no evidence on how to implement VR training into existing training practices and how VR training should be applied to benefit the training of police officers. For VR training to be as effective and efficient as possible, evidence-based standards guiding the implementation and application of VR training for police are needed. This thesis investigates the use of VR in the context of scenario-based training for stressful and high-risk situations (e.g., hostage situations, armed shooter in public spaces). VR training enables the simulation of situations and environments that are difficult or unsafe to simulate in real-life training. This thesis focuses on the use of VR to create training environments that can be used to train a variety of skills (e.g., tactical procedures, communication, situational awareness, decision-making and acting) in combination with stressful or high-risk components (e.g., presence of virtual weapons or explosives).

The studies in this thesis aim to capture (VR) police training from an interdisciplinary, context-dependent, and evidence-based perspective. Therefore, this thesis presents findings from collaborations with European law enforcement agencies in Belgium, Germany, the Netherlands, Romania, Sweden, and Switzerland. In this thesis, two different VR systems for police training were used to investigate the training experience with VR. This close collaboration with law enforcement agencies and VR technology providers demonstrates the operational reality of police training in practice as well as the possibilities of state-of-the-art technology for police training.

To get an overview of what current European police training looks like in practice, the first study of this thesis (**Chapter 2**) investigates the strengths and challenges of police training practices. We examined current European police training practices by interviewing training coordinators and police trainers from six law enforcement agencies located in the Netherlands, Germany, Sweden, Romania, and Belgium. Based on the interviews, we determined the current strengths and challenges of European police training. The strengths include the implementation of yearly content-specific training contexts, critical evaluation of the current state of training practices, and the diverse expertise of police instructors. The challenges of current training practices include the hierarchical structure of law enforcement agencies which make modifications to training practices a slow process, the level of realism that police instructors are able to achieve with the resources available to them, and the current testing practices of isolated skills. In Chapter 2, we provide evidence of similarities and differences in training practices of European police agencies.

In **Chapter 3**, we compared police officers' training responses to VR and real-life scenario-based training. Specifically, we investigated physical training responses such as heart rate and movement data, as well as psychological training responses such as mental effort and perceived stress. We showed that there were no significant differences in the psychological training responses of police officers to VR and real-life training. During real-life training, however, police officers experienced significantly higher levels of maximum heart rate and average level of physical activity compared to VR training. In addition, we assessed whether the sense of presence (i.e., the feeling of 'truly' being there in the virtual environment) and participant characteristics would predict the mental effort and perceived stress of police officers during VR training. We have shown that sense of presence (particularly VR engagement and the experience of negative effects) predicted perceived stress, while participant characteristics did not. Conversely, both sense of presence (particularly VR engagement and the experience of negative effects) and participant characteristics (particularly gaming frequency) predicted the mental effort exerted in VR. Thus, in Chapter 3, we have shown that VR training is experienced and perceived differently than real-life training and therefore requires a different instructional design.

In **Chapter 4**, we added a pain stimulus to virtual training simulators, including VR, to determine whether a pain stimulus increases the representativeness of virtual training environments. We utilized a 2D training simulator (VirTra) and a VR training system (VR) to assess the training effort and sense of presence of police officers during the virtual training with and without a pain stimulus. We found a significant interaction between the training simulator and pain stimulus for perceived stress: When officers trained without a pain stimulus in the VR and VirTra, VR provoked significantly higher levels of perceived stress compared to VirTra. Only in the VirTra, training with a pain stimulus provokes significantly higher levels of perceived stress compared to training without a pain stimulus. The addition of a pain stimulus had no effect on any other training response measures (i.e., average HR, maximum HR, mental effort) or sense of presence in both training systems. Thus, in Chapter 4, we show that VR training may provide a sufficiently stressful training environment without the addition of a pain stimulus, while other training simulators like the VirTra may benefit from a pain stimulus to increase the representativeness of the training environment.

In **Chapter 5**, we examined the feedback features of the after-action review of VR training. VR training systems provide the opportunity to replay the recorded virtual training scenarios from different perspectives (e.g., bird's eye view, police officer view, suspect view) and enhance it with a variety of features such as indicating the line of fire of the weapon. This retrospective performance review provides police instructors and trainees with objective information about the events that have taken place in the training scenarios. We investigated whether perspectives (bird's eye & police officer, bird's eye & suspect, bird's eye) and line of fire displayed during the after-action review influenced the learning efficacy of police officers after training in VR. Police officers experienced a significantly greater learning efficacy when reviewing their training performance using a bird's eye view in combination with the suspect perspective compared to using bird's eye view alone. Using the line of fire of the weapon during the after-action review did not influence the learning efficacy of police officers. Hence, in Chapter 5, we provide evidence that some features of the after-action review in VR enhance learning efficacy.

CONCLUSIONS AND IMPLICATIONS

Taken together, the studies in this thesis answer the two main questions of this thesis: (a) how VR training can improve and supplement current police training practices, and (b) how VR training can be applied to enhance the training and learning experience of police officers. In accordance with the epistemology of the author, this thesis highlights the relevance of conducting applied research to inform practice. The experiments presented in each chapter were conducted in collaboration with law enforcement agencies and executed within existing training structures of the agencies. The results of these experiments therefore reflect the reality of police practice, representing the natural setting of police training as closely as possible. Hence, the conclusions and implications of the applied and collaborative approach to research provide information that can be readily utilized and translated in the context of existing police training. For instance, as police training is confined by the availability of resources (Kleygrewe et al., 2022), VR training needs to be efficiently conducted within the finite training time that is available to police instructors and trainees. Approaching research with an interdisciplinary and context-dependent perspective takes these complexities into account and allows for the results of the experiments to reflect the reality of the state of police practice. Hence, the conclusions and implications of this applied and collaborative approach to research provide information that can be readily utilized and translated in the context of existing police training. In the following, I outline how the results of this thesis provide evidence-based recommendations on how to implement and apply VR training to police practice.

Implementation of VR Training into Police Practice

The implementation of VR training into police practice refers to the integration of VR as a training technology into existing training curricula and structures of the police agency. To implement VR training as an effective training tool, police agencies have to carefully examine the content, frequency, and duration of training as specified in their training curricula. In addition, police agencies need to consider the current organizational context including the resources that can be devoted to VR training (e.g., personnel to run the VR system, education of instructors, available training time). Most importantly, the advantages that VR training offers (e.g., simulation of a variety of locations, props, and individuals; for more see Giessing, 2021) need to provide a clear benefit to currently implemented real-life training practices. To this end, Chapters 2 and 3 provide guidance for the implementation of VR into police training.

In **Chapter 2**, we show that European law enforcement agencies employ enthusiastic police instructors with diverse expertise and provide training with community-relevant content-specific foci. However, challenges of training are apparent on the organizational and delivery level. First, the inherent hierarchical structure of law enforcement agencies provides hurdles and additional administrative effort when attempting to make changes to existing training structures. Particularly when aiming to implement VR into training practices, convincing relevant stakeholders of governmental organizations may provide a challenge. On the level of training delivery, police instructors struggle with the available resources to create realistic training environments. In real-life scenario-based training, instructors rely on available training locations, facilities, props, and actors to recreate realistic and stress-inducing training environments. Utilizing VR as a training tool allows police instructors to create training scenarios independent of training location, facilities, and props. VR training allows exposure to a variety of different scenarios and environments within the same training session. VR training may thus provide a solution to the commonly experienced challenge of limited variance in training environments in European police training.

Chapter 3 investigates how police officers respond to VR scenario-based training and real-life scenario-based training. Based on training responses to real-life scenario-based training and VR scenario-based training, VR training seems to be a useful training tool for training objectives that require cognitive engagement and the experience of stress. Thus, training objectives that include decision-making and acting in stressful situations can be trained well using VR. Physical safety and the occurrence of cybersickness should also be considered when utilizing VR as a training tool; therefore, training objectives that require high levels of physical output and activity, such as chasing, apprehending, or physically performing arrest skills may not (yet) suitable for VR training. **Chapter 3** also showed that VR experiences (i.e., engagement and negative effects) and participant characteristics (i.e., gaming frequency) influenced police officers' experience of mental effort. New and advanced VR systems produce less negative or adverse effects and, due to high fidelity, increase the level of engagement of the user (Buttussi & Chittaro, 2017). Next to technical VR features, the characteristics of the training group itself should be considered. Police officers who reported a high gaming frequency invested less mental effort compared to officers who had little gaming experience. Generally, younger VR users (e.g., police cadets or young officers) are likely to have higher levels of technology affinity and immerse in VR training more easily (Kleygrewe, Hutter, Koedijk, et al., 2023; Liu et al., 2020). Older users, however, may require additional sessions for habituation and more specific introductory tutorials. Hence, VR training and instructional training designs should thus be adjusted to the stage at which it is intended to be implemented (e.g., police academy, continued professional development, etc.).

By evaluating current European training practices and training responses to VR and real-life training, **Chapter 2** and **3** provide evidence-based results on how VR training can improve and supplement current police training practices. In sum, VR training improves and supplements current police training practices by providing a training tool that:

- is not reliant on the availability of standard training resources (e.g., training locations, facilities, props);
- allows training to be conducted in safe and controlled (virtual) environments (particularly for high-risk situations like active-shooter incidents or hostage situations);
- can simulate a variety of realistic training environments and avatars that are difficult to simulate in real-life training;
- gives police a suitable alternative to fulfil training objectives aiming at decision-making and acting, tactical procedures, and de-escalation procedures;
- elicits psychophysiological stress and requires police officers to cognitively engage in training (i.e., invest mental effort);
- supplements real-life motor skill training (e.g., shooting skills) through a variety of scenarios that can simulate different contexts in which these skills have to be applied.

Application of VR Training in Police Practice

The application of VR training in police practices refers to the delivery and use of VR as a training technology. For the effective use of VR as a training tool, the training objective should align with the benefits that VR training has to offer. To this end, Chapters 4 and 5 provide evidence on how the application of VR can be enhanced by investigating how drawbacks of VR (e.g., sensory fidelity) can be mitigated and advantages (e.g., objective After-Action Review) can be further maximized.

Chapter 4 showed that the addition of a pain stimulus to VR training did not influence the training responses and sense of presence of police officers. Thus, while the addition of a pain stimulus to real-life training appears to elicit additional stress responses (Nieuwenhuys & Oudejans, 2010), adding a pain stimulus to VR training did not influence the perception of stress and sense of presence in VR. Specifically, VR training appears to elicit sufficiently high levels of perceived stress and mental effort without adding a pain stimulus to the virtual environment. Thus, in line with findings in **Chapter 3**, VR training appears to be cognitively demanding to the point that adding additional features such as a pain stimulus may not further influence the experience in VR. Trainees need to have sufficient cognitive capacity available for learning to take place. If all capacity of the trainees is absorbed by navigating the VR environment, then learning police-specific skills is confined. Hence, considering cognitive load — and thus the recommendations of cognitive load theory (CLT; Mugford et al., 2013) — is particularly important for VR training. CLT distinguishes between extraneous load (i.e., cognitive load imposed by factors unrelated to the learning task), intrinsic load (i.e., inherent complexity of the learning material), and germane load (i.e., information directly relevant to the learning task), with the aim to minimize extraneous load and maximize germane load (Van Merrienboer & Sweller, 2005; Sweller, 2011). To minimize extraneous load during VR training, particularly for trainees with little previous VR experience, sufficient time for familiarization with movements and interactions with the virtual environment is necessary. Providing trainees with sufficient time to explore how to utilize the VR hardware and move within the virtual environment before executing training scenarios reduces the focus on how to utilize the features of VR to execute tasks. After the initial familiarization, trainees can focus on the scenario and the task at hand rather than being concerned with navigating the virtual environment. Next to minimizing extraneous load in VR, instructors may also design VR training to maximize germane load (i.e., the amount of mental effort required to process information in working memory during a learning task) (Mugford et al., 2013). For example, in VR, instructors can develop variable and diverse training contexts to allow trainees to apply their skills across different contexts. The application of skills in diverse contexts to enhance learning — also known as variability effect — is particularly applicable to VR, since VR provides freedom and flexibility in scenario creation and execution (Paas & Van Merriënboer, 1994; Giessing, 2021). Additionally, instructors can maximize germane load in VR training by priming trainees to learning-relevant attentional foci; for instance, by manipulating the virtual environment in relation to the training objective and level of experience of the trainees. When training with novices, the instructor could ensure that the environment is very clean (e.g., tidy rooms, few bystanders or distracting objects) initially. In subsequent trials, the instructor could systematically manipulate the amount of non-relevant stimuli to include more complexity (e.g., messy rooms, more complex buildings, blind spots, etc.), making it increasingly difficult for the trainee to spot suspicious behavior.

In **Chapter 5**, we examine the influence of different features of the After-Action Review in VR to enhance the learning efficacy of police officers. Police officers who reviewed their training performance from the bird's eye perspective in combination with the suspect perspective experienced the highest learning efficacy. This informs instructors on features to use in the After-Action Review of VR training. For instance, when reviewing the training scenario, tactical movement through a space could be portrayed using the bird's eye view to allow a full view on all team members in relation to their surroundings and each other. During interaction with suspects or perpetrators, the perspective could then be switched to the suspect view (i.e., when aiming to show certain behaviors of the trainee). Next to changes in perspectives, the After-Action Review provides additional performance indicators such as the line of fire of the service weapon. Results of **Chapter 5** show that using the feature of line of fire did not enhance the learning efficacy of police officers. Hence, while the After-Action Review provides a variety of features, not all of them enhance the learning efficacy. Police instructors should select the features based on the training objectives. For instance, if the aim is to train tactical movements of room clearance procedures, turning on the After-Action Review feature of snail trails — colored tracking lines of movement of each trainee — would show trainees their movements from one room to the next over time. Similarly, if trainees learn to position themselves effectively in teams to avoid blocking firing options of a colleague, utilizing the feature of the line of fire in the AAR would be beneficial. In accordance with findings on cognitive load elicited by VR in **Chapter 3** and **Chapter 4**, utilizing too many features at the same time may be distracting from the learning objective. Instructors are therefore tasked with not only designing the scenario content and scenario repetitions according to the training objective but also the protocol for the After-Action review. Subsequently, selecting and utilizing the After-Action Review features effectively maximizes the advantages of VR training and benefits the learning experience of police officers.

Taken together, **Chapters 4** and **5** provide evidence-based results on how VR training can be applied to enhance the training and learning of police officers. In sum, VR training enhances the training and learning experience of police officers by providing a training tool that:

- is cognitively demanding and elicits sufficient levels of perceived stress and sense of presence without additional multi-sensory features such as a pain stimulus;
- enables flexible maximization of germane load (i.e., cognitive effort needed to process learning-relevant information) by creating diverse training contexts and scenarios;
- enables instructors to use a variety of objective feedback features in the After-Action Review;

- enables instructors and trainees to review the training performance from a variety of perspectives such as the bird's view, suspect perspective, or police officer perspective;
- offers various objective performance indicators such as a line of fire, snail trails, and locations of shots fired.

Theoretical Implications

The studies in this thesis provide evidence-based insights into the implementation and application of VR training in police practice. The design of the studies and the interpretation of its results were based on theoretical foundations, particularly focusing on the integrated model of perceptual-motor performance and anxiety (Nieuwenhuys & Oudejans, 2012, 2017), representative learning design (Davids et al., 2013), and cognitive load theory (Van Merrienboer & Sweller, 2005; Mugford et al., 2013). In line with the epistemology of this thesis (see Introduction: "Epistemology of the Author and this Thesis"), practice should inform theory and theory should inform practice. Therefore, this section comprises the theoretical implications of the findings of this thesis. Findings of **Chapter 3**, **Chapter 4**, and **Chapter 5** show that police officers experience virtual reality training differently compared to real-life training.

Based on the integrated model of perceptual-motor performance and anxiety (Nieuwenhuys & Oudejans, 2012, 2017), human factors play a central role for the onset of anxiety, the investment of extra mental effort, and the resulting attentional processes. **Chapter 3** has demonstrated that, in VR, additional factors have to be considered to encompass the experience of perceived stress and the investment of mental effort. Thus, when applying the integrated model of perceptual-motor performance and anxiety in the context of VR, this thesis showed that additional human factors, particularly gaming frequency, and the experience of negative effects in VR need to be considered when using the model to make inferences about perceived stress and anxiety for VR training. Moreover, according to the model, attentional changes due to anxiety can be mitigated by investing mental effort. To apply the model to VR training, it may need to be adapted to distinguish between mental effort invested to navigate the VR environment and mental effort invested to mitigate stimulus-driven attentional processes evoked by anxiety (Kleygrewe, Hutter, Koedijk, et al., 2023).

Scenario-based police training, whether in real-life or in VR, should aim to provide representative training contexts. When applying a representative learning design to VR, instructors can readily vary the constraints of the virtual environment to create a realistic performance context (Davids et al., 2013). For instance, scenarios can be designed to include various numbers of NPCs, the physical attributes of NPCs can be changed, lighting and other external conditions can be varied easily. However, **Chapter 4** has demonstrated that factors that enhance representativeness in real-life, may not enhance representativeness in VR. VR training elicited high levels of heart rate and perceived stress without the addition of a pain stimulus. When adding a pain stimulus to simulate the possibility of getting hit by an opponent in VR, it did not increase the trainees heart rates or the level of perceived stress further, oppositely to what has been shown during real-life training (Nieuwenhuys & Oudejans, 2011). When aiming to apply the representative learning design to VR, the theoretical considerations of representativeness have to be reconsidered. Like in real-life, trainees should be able to utilize key features and characteristics of the actual performance context. In VR, however, using too many features (e.g., pain stimulus) to create a representative performance environment may not have any additional benefit or possibly overstimulate trainees. Thus, the theoretical implications for representative learning design in VR entail a larger focus on factors like the cognitive load the virtual environment itself imposes on trainees on top of focusing predominantly on designing or adding characteristics that resemble the performance context as closely as possible.

On the job, police officers perform a variety of skills and tasks under the influence of stress. To this end, and in line with representative learning design, real-life and VR training should provide challenging situations in which trainees can safely prepare for on-duty incidents. Cognitive load theory (CLT) describes how cognitive resources can be managed to increase learning (Van Merrienboer & Sweller, 2005; Mugford et al., 2013). CLT can therefore provide a theoretical framework for effective instructional design of training. In **Chapter 3**, we have shown that during VR training, police officers experience higher extraneous load compared to real-life training. Thus, particularly for VR training, it is important to reduce extraneous load (e.g., learning-irrelevant demands placed on the trainee by the newness of the VR technology) as much as possible, increase germane load, and manage intrinsic load for optimal learning (Mugford et al., 2013). In VR, extraneous load can be reduced by providing sufficient time for familiarization with the VR equipment and environment. During the familiarization period, police instructors should provide specific instructions that help the trainee to navigate the environment. This approach increases germane load and prepares trainees for the execution of the training scenarios. Police trainers should design VR based on a training design that adheres to incremental exposure to VR with sufficient break time in between to reduce extraneous load and the occurrence of cybersickness — an additional factor that is cognitively demanding (da Silva Marinho et al., 2022). To manage intrinsic load (i.e., the inherent difficulty of the task and the complexity of the information to be learned), VR as a training tool provides various possibilities for differentiation. In VR, the intrinsic cognitive load can be managed by adjusting the complexity of the training scenarios through the various options that VR provides: initial scenarios can be low in complexity by designing an environment low in external stimulation, consisting of few NPCs. The scenarios can, from trial to trial, increase in complexity by adding additional NPCs, determining more complex NPC behavior, and adjusting environmental conditions (e.g., from daylight to nighttime). Taken together, VR training inherently places additional cognitive load on trainees by being a medium through which an environment is perceived. Yet, VR training also provides various opportunities to manage cognitive load and improve learning that real-life training does not.

This thesis showed that VR elicits high levels of cognitive load and draws theoretical implications from CLT for the application of VR in practice. Yet, an additional benefit of VR is that it provides a suitable tool to empirically test postulates of various theories in a very precise way. Due to the ability to systematically, yet naturalistically (i.e., with high context-dependency) manipulate variables and control for constraints, VR can be employed to investigate theoretical presumptions. For instance, in VR, the different types of loads (i.e., intrinsic, germane, or extraneous load) can be manipulated to investigate how to effectively increase learning in VR based on CLT. Similarly, environmental constraints can be manipulated in VR to test which VR features effectively enhance representativeness of the virtual environment and which features hamper the learning experience of trainees. Other than in a reductionistic lab-based experiment, VR provides a tool that allows for reality-based experimentation including complex learning in realistic contexts with systematic manipulation of features.

Theoretical implications beyond the context of police training

The aforementioned theoretical models (i.e., the integrated model of perceptual-motor performance and anxiety, representative learning design, and cognitive load theory), in particular, have informed the research design of the studies in this thesis. Based on its findings, this thesis has demonstrated how the results can further inform the theories presented above. In addition, however, the findings of this thesis for the implementation and application of VR training for police officers also contain other theoretical implications:

First, the development of evidence-based standards for the implementation and application of VR training for police officers can contribute to the advancement of instructional design (e.g., the use of the After-Action Review in **Chapter 5**) and learning theories. This can further enhance the effectiveness and efficiency of VR training and improve the overall training practices in domains such as military, emergency medicine, and first responders.

Second, the investigation of the sense of presence experienced by police officers during VR training (**Chapter 3** and **Chapter 4**) can provide insights into the mechanisms underlying the effectiveness of VR training. This can contribute to the development of theories on presence, immersion, and virtual embodiment, which are important concepts in the field of VR and can have implications for other domains such as healthcare (e.g., training medical first responders to perform under stress), education, and entertainment (e.g., VR arcades).

Third, the examination of the training responses and sense of presence of police officers during VR and real-life training (**Chapter 3**) can provide insights into the differences between the two modes of training and their respective strengths and weaknesses. This can contribute to the development of theories on simulation and training transfer, which are important concepts in the field of training and can have implications for other domains such as aviation, military, and healthcare.

Overall, the theoretical implications of this thesis can contribute to the advancement of knowledge and understanding in the fields of instructional design, model-learning, provision of feedback, presence, simulation, and training management, and can have implications for various domains and industries beyond law enforcement.

DIRECTIONS FOR FUTURE RESEARCH

Virtual Reality as a training tool for first responders, particularly in the context of complex, stressful, and high-risk situations is becoming increasingly popular (Zechner et al., 2023; Binsch et al., 2022). With the increase in popularity, research surrounding the topic of VR is emerging (see for instance Garcia, 2019; McAllister et al., 2022; Kent, 2022; Kent & Hughes, 2022; Harris et al., 2021; Saunders et al., 2019). Most research until now has focused on the advantages of VR for first-responder training (e.g., Giessing, 2021; Murtinger et al., 2021; Hsu et al., 2013), immersion of VR (e.g., Skarbez et al., 2018; Stevens & Kincaid, 2015; Garcia, 2019), and the responses that VR elicits (Kleygrewe, Hutter, Koedijk, et al., 2023). In addition to the existing body of research, future research should consider assessing (i) VR experiences on a behavioral level, (ii) the influence of multi-sensory experiences, and (iii) the efficacy of VR to promote specific skills and knowledge.

First, to advance the use and efficacy of VR as a training tool for police practice, future research should investigate the behavioral responses of police officers to VR training. Police officers have to perform a variety of behaviors on the job (Koedijk et al., 2021); police officers should therefore be able to produce and respond with the same behaviors during a virtual training. Taking a behavioral approach to assessing the efficacy of VR as a training tool provides insights into how the performance during training transfers to on-the job performance. Scarfe and Glennerster (2019) suggest that instead of assessing a VR-specific measure such as sense of presence based on a numerical scale, it should be assessed based on how physiological and behavioral responses correspond across a real-world task and a simulated version of that task. Based on this strategy, VR training may be sufficiently realistic or representative if police officers respond identically to the simulated and real-life task.

Second, many modern VR systems allow for the tracking of gaze behavior. In accordance with the integrated model of perceptual-motor performance and anxiety (Nieuwenhuys & Oudejans, 2012, 2017) it has been shown that anxiety affects attention, including visual attention (Nieuwenhuys & Oudejans, 2010, 2011). Future research should therefore utilize gaze tracking with VR to systematically investigate whether visual attention is affected when engaging in stressful simulated environments. Moreover, gaze tracking in VR could be utilized to examine the effects of VR training on maintaining or improving (task-relevant) attention.

Third, the application of and interaction with VR is limited to audiovisual stimuli (Melo et al., 2020). As specified in **Chapter 4**, the limited multi-sensory fidelity of VR may constrain the level of representativeness that VR elicits. Particularly in police work where tasks that include tactile stimuli (such as the use of handcuffs) and olfactory stimuli (such as the smell of alcohol from a suspects' breath) provide important cues for action possibilities, multi-sensory experiences in VR should be investigated more specifically. Evidence-based results on the influence of multi-sensory experiences in VR — particularly on a behavioral level — may further inform how VR training can be designed, implemented, and applied to improve performance of police officers (Kleygrewe, Hutter, & Oudejans, 2023; Zechner et al., 2023).

Finally, practice would benefit from research investigating the efficacy of VR for specific learning objectives such as tactical movement, communication, situational awareness, or decision-making and acting. Currently, research has mostly focused on the broader context of suitable training areas to which VR could be applied (e.g., for disaster management, see Sharma et al., 2014; Yu et al., 2022). Additional research is needed to investigate how VR can be used to develop and foster specific learning objectives. Determining the efficacy of VR training to foster skill development and learning allows police agencies to implement VR more specifically into existing training curricula.


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SUMMARY

The aim of this thesis was to gain insights into the implementation and application of VR training for police agencies. In current police training practices, police agencies employ scenario-based training to simulate on-duty tasks. While the use of scenario-based training allows trainees to prepare for on-duty situations in training, the organization and delivery of real-life scenario-based training is resource-intensive. Training technologies — particularly Virtual Reality (VR) — present a new training tool for scenario-based training. Immersive VR for police training allows police agencies to simulate a broad range of environments and scenarios without the need for specific training locations or props. In addition, VR allows police trainers to safely integrate vulnerable populations (e.g., children, animals, elderly) and high-risk material (e.g., explosives) in training. Specifically using full-body motion tracking, police officers can move about in the simulated environments and utilize their equipment (e.g., weapon belts) as they would in real-life training and on-duty. Research investigating the efficacy of VR is becoming more prevalent; nonetheless, the evidence on common training standards for the successful use of VR for police training is scarce. The studies presented capture VR police training from an interdisciplinary, context-dependent, and evidence-based perspective.

The first study in this thesis (Chapter 2) shows that existing European training practices struggle with the resource intensiveness of real-life scenario-based training and the level of realism they can achieve. Interviewing police trainers and training coordinators of six European law enforcement agencies, results show that training content and resources are regulated by primary authorities such as governmental structures or police executive boards. Thus, implementing new or changing existing training structures requires administrative effort. Additionally, police instructors have to conduct and design training with the resources available to them. The limited availability of recourses such as training time, training facilities, training equipment, and personnel make it difficult for police instructors to design representative training environments. These findings of the current state of European police training are the starting point for examining where VR training may provide opportunities to complement current police training.

Chapter 3 addressed police officers' training responses to VR and real-life training. Police officers of the Dutch National Police executed a real-life scenario-based training and a VR training during which their average and maximum heart rates, and their level of physical activity were measured. After each training, the police officers rated their level of perceived stress and mental effort. Additionally, after the VR training, the police officers rated their sense of presence (i.e., the feeling of truly "being" there in the virtual environment) and provided information on their technology experience (e.g., gaming frequency). The results showed that police officers had a higher level of average physical activity and higher maximum heart rate

in the real-life training compared to VR. The level of average heart rate and perceived stress did not significantly differ between VR and real-life training. During VR training, police officers invested more mental effort compared to real-life training. Mental effort was predicted by the VR experience of police officers (particularly the experience of engagement and negative effects), as well as participant characteristics (particularly gaming frequency). Findings in Chapter 3 demonstrate that VR training can be a useful tool for training under stress and that the VR training session may be experienced differently based on the quality of the VR system and the participant's technology affinity.

Taken together, Chapter 2 and Chapter 3 provide insight into the implementation of VR into existing police training practices. It is shown that the advantages of VR (i.e., flexibility in scenario design, independence of training location) mitigate the drawbacks of current European police training practices (i.e., limited training facilities, level of realism in training). Similarly, VR was shown to elicit training responses — such as average heart rate and perceived stress — that were similar to what police officers experienced during real-life training. Thus, VR training should be implemented to supplement existing training practices as a tool that creates stressful and flexible virtual environments.

Chapter 4 investigates how virtual training simulators can be made more representative through the addition of a pain stimulus. VR system generally rely on audio-visual stimuli as primary information sources about the environment. In real-life, police officers experience haptic information, olfactory stimuli, and nociception. Thus, the representativeness of VR and the responses to the virtual environment may be enhanced by adding a pain stimulus that simulates a threatening opponent. The results showed that the addition of pain stimulus to VR did not further enhance the already high levels of perceived stress, mental effort, heart rate, or sense of presence. Considering the highly immersive and cognitively demanding environment for trainees should be inherent to the design of virtual police training.

Chapter 5 shows how the After-Action Review tool of a VR system can be used to enhance the learning efficacy of police officers. The After-Action Review tool allows police instructors and trainees to give and receive objective performance feedback of the training scenarios. This study has demonstrated that using the bird's eye view in combination with the suspect perspective enhances the learning efficacy of police officers over the use of the bird's eye view only. The bird's eye view in combination with the police officer perspective also elicited high level of learning efficacy — although not as high as the combination of bird's eye view and suspect perspective. Using the feature of the line of fire of the service weapon did not influence learning efficacy of police officers. Hence, when using the After-Action Review tool to provide objective performance feedback, instructors should ensure that the information presented relates to the content that trainees are to learn during the VR training.

Taken together, Chapter 4 and Chapter 5 provide insight into the application of VR training for police practice. It is shown that enhancing the level of representativeness of VR training is different from real-life training. In VR, the cognitive load is already at a high level due to the newness of the VR technology. When adding a multi-sensory feature such as a pain stimulus — which, in real-life training, has been shown to elicit on-duty-like responses — the high levels of cognitive load in VR have to be considered. Similarly, when utilizing VR-specific tools such as the After-Action Review, activating features that do not align with the training objective may not enhance learning efficacy. Thus, when applying VR as a training tool for police training, the use of features (e.g., pain stimulus, after-action review features) should align closely with the training objective.

Conclusively, the chapters highlight considerations and evidence-based guidelines for implementing and applying VR to existing police training. In this way, this thesis contributes to the advancement and innovation of police training practices.


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ABOUT THE AUTHOR

Lisanne Kleygrewe (1996) was born in Gütersloh, Germany. She concluded her High School degree (Abitur) at Gymnasium Nepomucenum Rietberg, Germany.

In 2014, she started her undergraduate studies at Louisiana Tech University, USA with a Division 1 NCAA soccer scholarship. She graduated *summa cum laude* with a major in Psychology and a double minor in Exercise Science and in Health.

In 2018, she was accepted into the Vrije Universiteit Amsterdam Fellowship Programme and began her master's studies at the Faculty of Human Movement Sciences at Vrije Universiteit Amsterdam, the Netherlands. Specializing in Sport and Performance Psychology, Lisanne began conducting research with the Dutch National Police under the supervision of dr. R.I. Hutter and dr. M. Koedijk. In her master's thesis, she investigated the psychological competencies of Dutch police officers using a latent class analysis approach.

In September 2019, she started her PhD work at the Faculty of Human Movement Sciences at the Vrije Universiteit Amsterdam under the supervision of dr. R.R.D. Oudejans and dr. R.I. Hutter. Her PhD focused on implementing and applying Virtual Reality to operational police training. Her PhD research was embedded in the European project "SHOTPROS" which aimed to improve the decision-making and acting of European police officers under stress and in high-risk situations utilizing Virtual Reality.



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BOOK CHAPTERS

Hutter, R.I.(V.), Renden, P.G., Kok, M., Oudejans, R.R.D., Koedijk, M. & Kleygrewe, L. (in press). *Criteria for high quality training of police officers.* In M.S. Staller, S. Koerner, & B. Zaiser (Eds.), Police Conflict Management, Volume II: Training and Education. Palgrave Macmillan.


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Cheers, howdy, and onto the next milestone!

Gratefully,
Lisanne

Amsterdam Movement Sciences

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Amsterdam Movement Sciences conducts scientific research to optimize physical performance in health and disease based on a fundamental understanding of human movement in order to contribute to the fulfillment of a meaningful life.