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D3.2 - A Conceptual Human Factors Model of Decision-Making and Acting under Stress and in High-Risk Situation

SHOTPROS

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V2.6	27/01.2021	Vana Hutter (VUA)	Edits based on feedback from partners and collaborators, added an overview of the revisions made based on EC half time review

List of Acronyms and Abbreviations

Acronym / Abbreviation	
VR	Virtual Reality
DMA	Decision-Making and Acting
LEA	Law Enforcement Agency
HF	Human Factors
PSQ	Police Stress Questionnaire
PSS	Police Stress Survey

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Revisions based on EC Half-time Review

Section	Revisions
1. Executive Summary	• Added clarification how the conceptual model informs VR training
2. A Conceptual Human Factors Model of Police Officers' Decision-making and Acting in Stressful, High-Risk Situations	• Added conclusions and requirements for VR-training exploitable by LEA's and developers • Added a practical and visual illustration of the concepts of motor heuristics and embodied choices
3. The Conceptual Model: Input, Throughput, Output	• Added conclusion and requirements for VR-training exploitable by LEA's and developers • Added a summary of implications for VR training
4. Existing Evidence for the Proposed Links in the Model, from Studies with Police Officers	• Added clarification of how chapter 4 relates to and strengthen chapters 2 and 3, in which several implications for VR training were made
5. Research Agenda	• Added nine concrete research questions that are needed to provide input for VR development and VR training, and to test the efficacy of the proposed implications of the model for VR training. • Added a plan of action plan that presents the completed, ongoing, and planned studies and their specific contribution to the nine research questions based on the SHOTPROS conceptual model • Added a table with an overview of how the different studies contribute to the nine research questions

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1 Executive Summary

In this deliverable D3.2 we outline the conceptual model of decision-making and acting in stressful, high-risk situations. The conceptual model that was developed informs VR training, in the sense that it points to both technical requirements and content requirements to create efficacious training of decision-making and acting of police officers. The conceptual model posits that personal, contextual, organizational, and societal human factors influence the perception of the demands of a situation, the perception of capacities to deal with the demands, and the appraisal of any discrepancies between demands and capacities, collectively determining the level of stress of police officers. Importantly, it is the combination of stress and mental effort that determines attentional consequences of stress. Attentional consequences of stress and mental effort invested may be an alteration from goal-directed attentional processes to stimulus-driven processes. A final core tenet of the conceptual model is that decision-making and acting, as the endpoint of attentional processes, should be viewed as actions resulting from motor heuristics and embodied choices.

Ultimately, the conceptual model provides a basis for efficacious VR training of police officer's decision-making and acting in stressful, high-risk situations. The model has consequences for both the hardware required (e.g., ability to move naturally and thus learn to use ecologically valid sensory information, provide realistic action opportunities), as well as scenario content used by LEAs (e.g., accurate perceptual cues, evoke stress responses). The consequences of the model align well with the recommendations given in D3.1 concerning training in general and VR training specifically.

For the model to fulfill its functions in the project, and thus to be exploited by developers , a concise research agenda is proposed. For SHOTPROS to be of applicable value to LEAs, the core question is: How can VR training best be implemented? The research agenda to answer that core question addresses the following sub questions:

- How can the human factors proposed in the model be used to create realistic VR-training, in which proper levels of stress and adequate mental effort strategies are provoked, that help police officers develop goal-directed attentional strategies, and effective motor heuristics and embodied choices?
- Which features of VR training are particularly helpful in the training process for decision-making and acting of police officers?
- How can training concepts, training methods, and training didactics best be implemented for effective VR- training and assessment?

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The studies specified in the research agenda are part of the human factor studies in WP6 and provide validation of elements of the model which can be used in the further development of VR-systems and scenarios (WP5) as well as VR-training as part of the European Framework for Training and Assessment (D3.3).

2 A Conceptual Human Factors Model of Police Officers' Decision-making and Acting in Stressful, High-Risk Situations

The main aim of the SHOTPROS project is to advance the training of decision-making and acting of police officers in stressful situations. For this aim, it is imperative to understand the human stress response, its consequences for perception, decision-making and action, and mechanisms to mitigate the stress response. Without this understanding developing VR training systems and scenarios can become merely a trial and error process. Therefore, a conceptual model of decision-making and acting in stressful, high-risk situations is outlined. The model will serve as a guide for both research and development of training within the SHOTPROS project. Research and training based on the model should, in the end, enhance decision-making and problem solving of officers in high risk situations, and enable judicious and effective use of force.

The integrated model of anxiety and perceptual-motor performance of Nieuwenhuys and Oudejans (2012; 2017) forms the basis of the conceptual model developed. The model is expanded and adapted in several ways, outlined below, to specifically suit the scope of the SHOTPROS project. This involves human factors that play a role in evoking and experiencing stress (input of the model) and how stress affects police officers' decision-making and acting, in the model specified as motor heuristics and embodied choices (output of the model).

2.1 The Integrated Model of Anxiety and Perceptual-Motor Performance

Based on an extensive review of empirical literature, as well as their own experiments with both athletes and police officers, Nieuwenhuys and Oudejans (2012) developed an integrated model of anxiety and perceptual-motor performance. The model is based on contemporary views of anxiety, attention, and perceptual-motor skill acquisition and execution. Perceptual-motor behavior is seen as integrated cycles of perception, selection (of action possibilities), and action. For a full description the reader is referred to Nieuwenhuys and Oudejans (2012;2017), but because the model forms the basis of the conceptual model guiding SHOTPROS, a brief explanation of the model is provided in this deliverable. After the

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explanation of the original model, various adaptations and extensions of the model are proposed and explained, to arrive at SHOTPROS' conceptual human factors model of police officers' decision-making and acting in stressful, high-risk situations.

The original model (Nieuwenhuys & Oudejans, 2012; 2017) posits that anxiety is evoked by a combination of situational factors and dispositional factors. High levels of anxiety, if not dealt with, lead to changes in attentional processes. More specifically, anxiety leads to a shift in the balance between goal-directed attentional control, in which a situation is perceived, processed and responded to in a goal-directed manner, to stimulus-driven attentional control. Under stimulus-driven control, attention is "drawn" by task-irrelevant stimuli, instead of guided by the goal of the behavior. According to the model, if an individual is anxious and this leads to more stimulus-driven attentional control, then attention is drawn to threatening stimuli that are not necessarily relevant for the goal or task (threat-related attention). Additionally, it becomes harder for the individual to maintain or switch attention to other, possibly more relevant, stimuli. Furthermore, under stimulus-driven control, the individual is also more inclined to interpret stimuli as threatening (threat-related interpretation). Lastly, a number of physical responses occur (threat-related physical response) (a) to heighten action readiness (e.g., increases in muscle tension, adrenalin, heart rate frequency), and (b) to align responses with emotions (e.g., moving away from scary stimuli), both leading to altered movement control. These changes in attention, interpretation, and responses that result from anxiety, impact all components of perceptual-motor behavior (perception, selection of action possibilities, and action).

Anxiety, however, also leads to motivation to counteract any debilitative effects of anxiety. When stakes are high and individuals need to perform well, they will strive to minimize the effect of anxiety on their actions. Therefore, according to the model, mental effort will be invested to (try to) push the attentional control back from more stimulus-driven to more goal-directed control, thus restoring changes in attention, interpretation, and response, and maintaining more normal execution of the perceptual-motor behavior.

The combined effect of anxiety *and* the mental effort invested to counteract anxiety, determines the way attention is controlled, which in turn steers perceptual-motor behavior (that is, the cycle of perception, selection, and action).

The Original Model, in Brief:

- Anxiety is the result of situational and dispositional factors combined
- Anxiety leads to a shift from more goal-directed attentional control to more stimulus-driven control

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- Anxiety may also lead to investment of more mental effort to maintain or shift attentional control back to goal-directed
- The result of anxiety plus mental effort determines attentional control, ranging from stimulus-driven to goal-directed control.
- Attentional control, through the operational levels of attention, interpretation, and response formation, directs perception, selection, and action.

2.2 The Conceptual Human Factors Model of Police Officer's Decision-making and Acting in Stressful, High-Risk Situations

The conceptual model that forms the basis of SHOTPROS is an adaptation and extension of Nieuwenhuys and Oudejans' model explained above. We will discuss different parts of the conceptual model first, and present the model in full after.

2.2.1 Defining "Stressful"

The conceptual model needs to predict police officer's behavior in stressful, high-risk situations. Therefore, it is important to first clearly define what we mean by stressful and high-risk. In everyday life the term 'stress' is oftentimes used for phenomena that in traditional scientific terms (and indeed in the original model of Nieuwenhuys and Oudejans, 2012; 2017) would be labelled as anxiety, and the world of police is no exception to this.

Stress in scientific jargon is traditionally defined as a discrepancy between the perceived demands of a situation and the perceived abilities to cope with these demands. Stress occurs if the perceived demands outrank the perceived abilities of an individual. In this view, stress in itself could be a positive experience, when an individual labels the experienced discrepancy as challenging, for example. Stress becomes a negative experience when the perceived discrepancy between demands and abilities is threatening to the individual's mental or physical well-being, and anxiety then occurs. It is usually this negative interpretation and appraisal (and thus experience) of stress that we mean when we are talking about stressful situations, or about being stressed.

Lazarus (in his cognitive motivational relational theory, e.g., 1999) distinguishes two types of appraisals in the evaluation of a situation as stressful or not. By primary appraisal individuals assess the significance of what is happening for their well-being, leading to an appraisal of the event being irrelevant, benign, or stressful to well-being. By secondary appraisal individuals evaluate coping opportunities and amount of control over the situation,

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arriving at appraisal of the event as controllable by self, controllable by others, or uncontrollable.

For the conceptual model, and to enable a shared understanding in the SHOTPROS project, we define the term stress as the emotional response of a police officer to an event that is appraised as threatening (as opposed to irrelevant or benign) to well-being and in which the officer perceives limited coping possibilities or control. This definition provides a shared language and shared understanding of developers, LEAs and researchers when we are talking about training under stress. This common ground will be further elaborated in the next sections of this deliverable.

2.2.2 What Makes a Situation Stressful and High Risk?

In line with our definition of stress, a situation is stressful for an individual if the demands of the situation are perceived to be higher than the capacities the individual believes to possess, the individual experiences little or no control over this discrepancy, and it forms a threat to mental or physical well-being. Clearly, stress defined in this way is highly personal and situational.

The original model mainly focused on the effects of an anxiety-provoking event, and left the antecedents of anxiety relatively undiscussed. SHOTPROS aim is to investigate human factors that evoke stress, and accompanying decision-making and acting of police officers. Therefore, more attention is needed for human factors that determine whether stress occurs or not, and whether officers are able to handle the stress.

One of the aims of WP 2 of the SHOTPROS project was to identify relevant human factors, that should be included in the conceptual model and, where possible, reckoned with in training. Through a number of qualitative investigations with experts from law enforcement agency, human factors were identified that influence how stressful or risky a situation is perceived (for details see deliverable D2.1. Planning, Setup and Methodology for Collection of User Requirements, Needs, and Expertise). The investigators categorized the identified human factors as personal (e.g., personality and skill), contextual (e.g., loss of overview, bystanders), organizational (e.g., rules and regulations and personnel deficit), or societal (e.g., media and reputation). The contextual human factors are of particular relevance in scenario creation by developers and LEAs, whereas the personal human factors are both relevant as the entry level/situation of police officers that LEAs have to take into account in their training, as well as providing endpoints of training (I.e. improved skill and more resilient personality characteristics).

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The conceptual model incorporates the findings of WP2. The conceptual model posits that personal, contextual, organizational, and societal human factors influence the perception of the demands of a situation, the perception of capacities to deal with the demands, and the appraisal of any discrepancies between demands and capacities. Moreover personal, contextual, organizational, and societal human factors are thought to influence the ability to mitigate effects of stress through employment of attentional strategies.

Last, but certainly not least, the relationship between human factors on one hand, and stress responses and mental effort on the other hand, is seen as bidirectional. Stress responses and the investment of mental effort are influenced by human factors, but in turn human factors are impacted by acute or chronic stress in police and the need to employ mental effort to mitigate the consequences of stress.

2.2.3 Consequences of Stress

The consequences of the stress response for police officers' decision-making and action depend on the way officers adapt to the stress response. Humans are normally able (and in stressful, high risk situations highly motivated) to counteract some of the debilitative effects of stress, thus maintaining more or less accurate levels of decision-making and acting, despite experiencing stress. For reasons of clarity we will first discuss what happens, according to the conceptual model, if the stress response is unmitigated. We will then explain how officers can counteract (some of) the debilitative effects of stress described. Finally, we explain that the combination of stress response and mental effort impacts on attentional control.

2.2.3.1 Unmitigated Stress Response

In the conceptual model we propose the same effects of the stress response on attentional control as Nieuwenhuys and Oudejans (2012;2017) outline for anxiety. The stress response, if unmitigated, changes the attentional control from more goal-directed processes to more stimulus-driven processes. Attention is the capacity to detect and process information from external (environment) and internal (e.g., body, thoughts) sources. Under goal-directed attentional control, detection and processing of information is guided by the goal an individual is trying to achieve. The individual actively or passively picks up on information that is relevant for the task and that is needed to achieve the goal. For a police officer the goal can for example be to handcuff a suspect safely, with a proportionate amount of exertion. Under goal-directed attentional control attention will (among other things) be paid to the positions of the wrists of the suspect, verbal and non-verbal communication of the suspect, the direct surroundings such as environment, colleagues and bystanders, etc., and the estimated control over the movements of the suspect. The information coming from these sources is interpreted

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appropriately; for example, a swearing suspect, in combination with full control over the movements of the suspect, is interpreted as still a safe situation in which handcuffing can continue normally with the current amount of force. Or alternatively, a struggle to manoeuvre the wrists in a position for handcuffing, verbal and non-verbal signs that the suspect will not cooperate and try to flee and approaching bystanders, will be adequately interpreted as a need to speed up the process and scale up the use of force to do so. Behavior in this situation is goal-directed, that is, executed in the most efficient and effective way to achieve the goal.

The stress response may shift the attentional control from goal-directed to stimulus-driven. Attention is drawn by task-irrelevant stimuli, rather than guided by the goal of the officer, for example, to handcuff the suspect. More specifically, the individual is more easily distracted and it becomes harder to redirect attention. By distraction we mean that the individual pays attention to stimuli that are not relevant for the task at hand. By redirecting attention we mean that an individual disengages from the stimuli that drew attention away from the task and engages with task-relevant stimuli. In other words, under stimulus-driven control, attention tends to get fixated on (or in more popular terms 'hijacked' by) stimuli that are not relevant for the task. Moreover, the interpretation of stimuli changes under stimulus-driven attentional control. Individuals are inclined to interpret stimuli as threatening. Building up on the example above, the handcuffing officer may interpret the swearing of the suspect as dangerous, or as signs that the suspect will start to fight, even though the officer still has full control over the movements of the suspect. Stimulus-driven attentional control additionally alters behavioral responses to the stimuli. Physiological and neurological responses occur, such as heightened muscle tension, and lower impulse control. For the handcuffing example this may result in excessive force used in handcuffing and a tendency to place speed over accuracy of movement. From this part of the model we can infer that in VR training both relevant and irrelevant stimuli can be included, to experience the difference between goal-directed attention and stimulus-driven attention and train goal-directed attention in the presence of task-irrelevant stimuli.

2.2.3.2 Mitigating the Stress Response: Investment of Mental Effort

Not every stressful situation ends up an unmitigated disaster. Au contraire, in most stressful situations police officers manage to solve the situation, perhaps not perfectly, but certainly professionally and adequately. Apparently, police officers are able to maintain acceptable standards of performance, despite being confronted with stressful circumstances. The conceptual model (in the same vein as the original model of Nieuwenhuys & Oudejans, 2012; 2017) proposes three different mechanisms by which the debilitative effects of the altered attentional control in stressful circumstances are mitigated. All three mechanisms require that

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police officers expend extra mental effort to restore or maintain goal-directed behavior as much as possible, and all mechanisms can be practiced through training. First, with mental effort, goal-directed processing of information can be enforced. This requires active information seeking and processing of the officer, for example, paying conscious and deliberate attention to stimuli that are relevant for the task (in the handcuffing example, forcing themselves to scan the body position and language of the suspect, to evaluate the control over the movements of the suspect, etc.). VR training may be particularly useful with regard to this mechanism, because it provides opportunities to efficiently and rapidly manipulate stimuli present or absent in training. As a second mechanism to mitigate the stress response, the officer can inhibit stimulus-driven processing, for example, by checking their interpretation of the situation as dangerous by making a quick rational risk assessment (restoring interpretation), or by taking a deep breath to lower excessive muscle tension (restoring (aspects of) response tendencies). Training of this mechanism requires the presence of various levels of threat, and the ability to act (actualizing/realizing response tendencies). Third, the officer can try to reduce the stress response itself, and thereby enabling the goal-directed attentional control by prevention/reversion of the shift to stimulus-driven attention. Various stress-reduction techniques may be useful to this end. For VR training to build on this mechanism, stress needs to be provoked in police officers and the scenarios should allow (time, physical and/or cognitive ability) to execute stress-reduction techniques.

Taken together the model posits that it is the combination of the stress response with the investment of mental effort that determines how much the attentional control is shifted from goal-directed to stimulus-driven. Attentional control subsequently impacts on decision-making and acting of police officers in stressful, high-risk situations. This underlines the importance of measuring stress and mental effort in human factor studies that feed into the training concepts and the DMA model (WP3) and the assessment and modelling of training experience in VR (WP4).

2.2.4 Action: Decision-Making and Acting

The output that the conceptual model should predict is decision-making and acting of police officers. We posit that decision-making and acting are inseparable, and borrow from the work of Raab (2017) to emphasize the intertwined nature of decision-making and action. The need for this emphasis stems from two main concerns with decision-making and acting as components of behavior. First, decision-making and acting may, implicitly or intuitively, suggest sequential and conscious steps in behavior, giving the impression that an individual first (consciously) decides and only then acts. This view overlooks the fact that decision and

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action can coincide (decision *in* action, instead of decision *for* action), or acting may even precede a conscious decision (decision *through* action).

Second, decision-making and acting have traditionally been studied in separate scientific fields, obscuring a holistic understanding of goal-directed behavior. Raab (2017) points out that decision-making is about what to do, and acting about how to do it, and argues that the "what" has typically been the domain of cognitive sciences, and the "how" the domain of movement sciences. By separately studying cognitive performance (i.e., decision-making, the "what") and movement performance (i.e., acting, the "how"), performance as a whole cannot adequately be understood. Or, as Araújo and colleagues, phrase it "action is not a ready-made implementation selected 'off the shelf', but a true choice behavior emerging from a range of action opportunities" (Araújo, Hristovski, Seifert, Carvalho, & Davids, 2019, p. 18). Fortunately, the separation between cognitive performance and movement performance is losing ground, and more holistic views of behavior proposed. For (VR) training and research on training of police officers it is also high time to view decision-making and acting as inseparable, and to abandon the (implicit) idea of conscious decision making followed by acting, that seems present in typical debriefing of training scenarios by LEAs.

In the original model of Nieuwenhuys and Oudejans (2012; 2017) behavior was already depicted as an integrated cycle of perception, selection of action possibilities, and action. In the SHOTPROS conceptual model we take the holistic view on decision-making and acting a step further, and propose that decision-making and acting is best captured by motor heuristics and embodied choices, terms coined by Raab (2017) to merge cognitive and movement sciences views on perceptual-motor behavior. By adopting the concepts of motor heuristics and embodied choices (explained below) in the conceptual model, we underline the inseparable, intertwined nature of decision-making and acting, and emphasize that the aim of training for performance under stressful consequences is to equip police officers with simple and proper action selection skills

2.2.4.1 Motor Heuristics

The concept of motor heuristics (Raab, 2017) takes its starting point in cognitive sciences and introduces a movement aspect (i.e., "motor") to the cognitive construct of heuristics. Heuristics are sets of rules that people use to solve a problem or question. In simple heuristics these rules are described as search, stop, and decision rules. Search rules provide a structure to quickly process information, stop rules determine which cue should be met to stop searching for additional information, and decision rules dictate the outcome of the search and stop, the actual choice that is made. Raab (2017) adds execution rules to search, stop and decision rules to expand the concept of heuristics into the concept of motor heuristics. In

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motor heuristics there are not only (relatively) simple rules to decide *what to do* (decision rule), but also *how to act* (execution rule). Raab defines a motor heuristic (referring to the sports domain) as: "a simple rule of thumb that allows an athlete to choose between options (here movements) to satisfy the current needs in a situation" (2017, p. 34). For police officers motor heuristics are thus *simple rules of thumb that enables police officers to choose between behavioral options* (for example use of force behaviors, de-escalating behaviors, running away, etc.) *to satisfy the demands of a situation*.

The concept of motor heuristics can be illustrated by footage of a police officer in one of our experiments. In the experiment, the police officer is instructed to approach a door to a room where a suspect is present. Figure 1 depicts the officer at the door. In this stage of the scenario the officer thoughts and movement coincide, that is he executes the procedure of announcing that he is a police officer and positions himself to the side of the door.

Figure 1. First stage of the scenario, the officer has approached the door and announces his presence in sage position.

As soon as the officer opens the door, the suspect draws a a shock knife (a weapon that has the shape of a knife and gives an electric, taser-like, shock when you are nicked with it) and walks towards the police officer, see figure 2.

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Figure 2. Suspect draws a shock knife when officer opens the door.

The officer now finds himself in a threatening situation and has to act quickly. In this case he eventually draws his gun, tells the suspect to drop the knife, and shoots the suspect in the leg when the suspect does not comply. These actions are the endpoint of motor heuristics and embedded choices (explained in more detail in the next section), meaning that the officer applied rules of thumb using integrated cognitive and sensory information (indicated with red, blue and purple in figure 3). The police officer has knowledge (cognitive input) of judicial use of force, effectiveness of shooting a suspect, and the threat of a knife (red and purple in the figure). The officer also has sensory input, not only perceiving the distance between the suspect and him, but also the speed with which he moves backwards and thus increases the distance (the blue arrow). In addition, his hand was already near his gun (blue circle), he is fit and skillful in shooting (blue stripes), and the perceived threat (purple) will impact his alertness and stress level. The cognitive input and sensory input are used simultaneously and collectively to select the action of eventually shooting the suspect in the leg.

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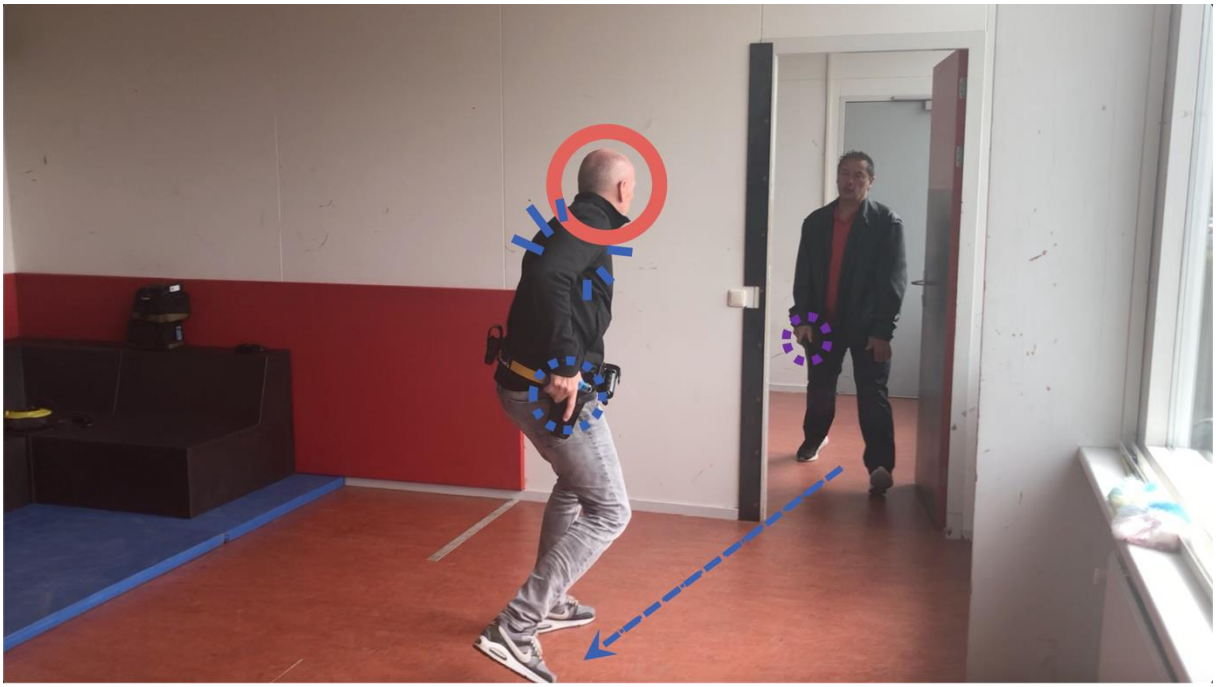

Figure 3. Motor heuristics (and embodied choices, see next section) illustrated.

2.2.4.2 Embodied Choices

The concept of embodied choices finds its origin in the notion of embodiment, which links sensorimotor processes and cognitive processes. Simply put, embodiment describes that the connection between the body (more precisely sensorimotor processes) and the brain (more precisely cognitive processes) is a two-way street. It has long been acknowledged that sensorimotor processes are (partially) under control of cognitive processes. Embodiment, in addition, points out that the reverse also holds; sensorimotor processes partially control cognitive processes.

Various experiments have shown an effect of sensorimotor processes on cognitive processes. Typically, in these experiments sensorimotor status of participants is manipulated and the decisions made or cognitive performance under both sensorimotor conditions are then compared (see for examples and overviews e.g., Lakofff, 2012; Shapiro, 2019; Wilson & Foglia, 2011). Overall, these experiments show that changes in sensorimotor processes lead to differences in cognitive processes. Probably the most well-known (albeit by now criticized) example is the facial feedback hypothesis test. In this test people either hold a pen between their teeth or hold the pen by curling their upper lip . By holding the pen between their teeth people are, unknowingly, forming their face into a smile, whereas holding a pen with their upper lip recreates a frown. The facial feedback hypothesis implies that the “smiling” condition yields more positive evaluations (of stories, pictures, events) than the “frowning”

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condition (e.g., Noah, Schul, & Mayo, 2018; Strack, Martin, & Strepper, 1988; Wagenmakers et al., 2016).

To summarize, embodiment points out that not only do thoughts, feelings, decisions and emotions impact our actions, postures, movements, and interactions with the environment, but our actions, movements, and sensory motor experience in general also impact our thoughts, feelings, decisions, and emotions.

Embodiment implies that sensory motor processes may form an additional cue in the heuristics that lead to decisions what to do and how to achieve that. Raab (2017) states that the human body and stored sensory motor experiences have been largely overlooked in problem solving in real life situations. Intuitively we may all be aware that our bodily state plays a big part in our decision-making and acting. We expect that the decision-making and acting of a police officer who is well rested and has excellent fighting skills will be different from a police officer who is tired or injured, and has mediocre fighting skills. Yet, in decision-making and acting models the only role (if any) that is reserved for sensory motor information is in the actual execution of action. Raab (2017) introduces the construct of embodied choices to resolve this caveat. Embodied choices are, similar to motor heuristics, rules of thumb that are useful when police officers have to decide quickly what to do and how, and that rely on sensory motor input. By including embodied choices in the conceptual model we posit (conform Raab, 2017) that sensory motor processes themselves provide cues for choices of what to do and how, further underlining that decision-making and acting cannot be separated, as the acting provides input for the choices to be made. In a similar vein Araújo et al. (2019) state that action should be understood as an expression of embedded and embodied cognition, that decision making is in fact, an emergent behavior (Araújo, Davids, & Hristovski, 2006), and we act to perceive information that we act upon and with (Araújo & Davids, 2015). In more practical terms, and linking back to our example above, the decision making *is* the drawing of the gun while moving backwards and instructing the suspect to drop the knife, and the moving backwards and instructing the suspect is informing us on both action possibilities and collaboration of the suspect, so the actions render input.

To conclude our explanation of motor heuristics and embedded choices we will wrap up the example of the police officers in the experiment. The decision and acting of the officer (eventually shooting the suspect) probably resulted partly from cognitive processes (being engrained with the importance of proportionality, assessment of level of threat, etc.). A number of sensory motor inputs have played a role as well, however. The fact that the officer had immediately started moving backwards enabled him with the time and distance to warn the suspect to drop the knife and be ready to shoot if the suspect failed to comply. The fact

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that his hand was already in vicinity of the gun may have also made the choice/action to shoot more salient. The fact that he was very well trained and therefore fluent in his movement to draw and shoot while walking backwards is a final example of sensory motor input. In this example the embodied choice may be seen as the option to shoot the suspect in the leg which presented itself from his physical movement and position, and his skill automaticity.

As becomes clear from this example, as observers of perceptual-motor behavior we cannot directly see motor heuristics and embodied choices. What we see, and what matters in practice, is the outcome of motor heuristics and embodied choices, not the set of rules leading to the outcome. The concepts of motor heuristics and embodied choices in the model are very important though, because it implies that training needs to equip police officers with these rules of thumb that can be used in stressful circumstances. We therefore argue that motor heuristics and embodied choices are concepts that need to be developed, tested, and applied in VR-training.

There are two routes how developers and LEAs can improve training with the use of the concepts of motor heuristics and embodied choices in VR-training: The first route is to engrain, through (VR) training, motor heuristics that are so simple that they are still salient under stimulus-driven attentional control, meaning that even when officers are stressed and attention turns threat-related, they have simple motor heuristics to reliably, and with little attention fall back on. VR training, if designed in alignment with the conceptual model, provides police officers unique opportunities to discover and engrain proper motor heuristics. In VR training cognitions of officers and sensory input can be deliberately manipulated. Similarly, in (VR) training emphasis can be deliberately placed alternately on the what (the decision-making of action) and the how (the acting of action). The intention is not to address decision-making and acting separately (which the model and evidence base explicitly argues against), but instead to scaffold the learning/development process of developing applicable motor heuristics and embedded choices, useful in stressful situations.

The second route is that police officers train their ability to restore or maintain sufficient goal-directed attentional control to still apply complex motor heuristics and embodied choices in stressful situations. As mentioned earlier in this deliverable, particularly the opportunities that VR training offers in terms of manipulating presence and absence of stimuli makes VR training a promising avenue for training the capacity to apply complex heuristics and embodied choices under goal-directed attentional control.

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3 The Conceptual Model: Input, Throughput, Output

In this deliverable we have outlined the different parts of the conceptual human factors model of police officer's decision-making and acting in stressful, high-risk situations. *Figure 1* shows the conceptual model in full.

The model can be characterized as an input-throughput-output model. The inputs of the model are the human factors that determine whether a situation is potentially stressful and high risk. The throughput of the model are the responses to the potentially stressful situation, specifically the scenario in which a stress response indeed occurs, the mental effort invested, and potential changes in attentional control as a result of the stress response and the mental effort combined. The changes in attentional control determine changes in the output: decision-making and acting, in the model specified as motor heuristics and embodied choices. As outlined throughout the deliverable, the input, throughput, and output inform VR training and research. For example, the contextual human factors (input) enable the design of stress-evolving scenarios, and require assessment of personal human factors (input) in research. The throughput dictates that in VR training attentional control is required to execute the scenario successfully, and in research stress and mental effort need to be measured, as well as proxies of attentional control, such as gaze behavior or field of view. The output of action requires for both training and research that ecologically valid cognitive and sensory inputs are present, as these dictate eventual actions. A particularly important implication of the model is that in debriefing the emphasis should be on the action as a whole (the what and the how of the action, and action possibilities) instead of a reiteration of the cognitive decision-making only, or a separate evaluation of physical/technical skill acquisition. VR seems a useful instrument for such holistic debriefing, as it makes language (and thus cognition) partly redundant and it is likely to provide opportunities for multiple repetitions (instead of extensive cognitive debriefing, go through the holistic experience with cognitive and sensory input again, or try and experience alternative actions).

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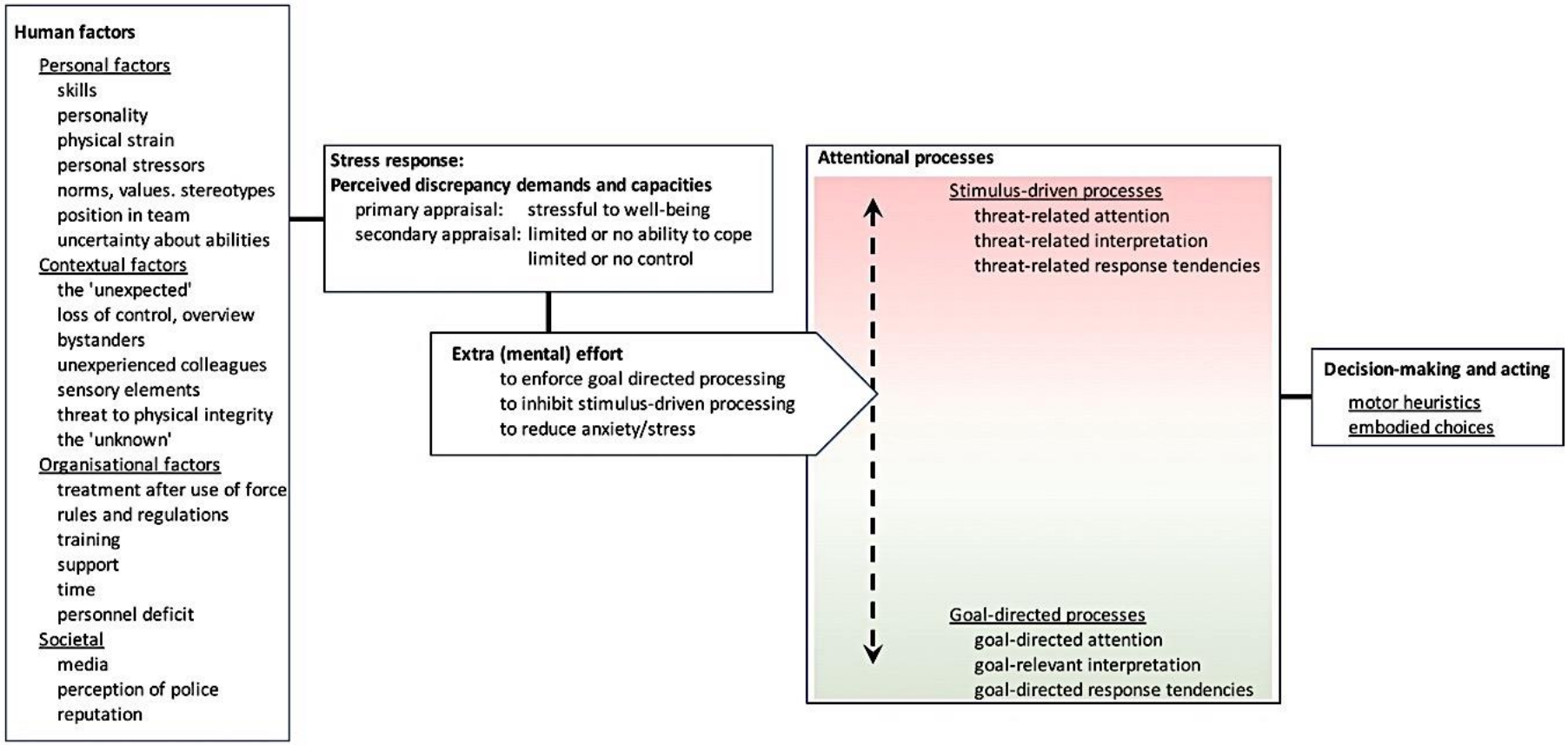

Figure 4: *Conceptual Human Factors Model of Police Officer's Decision-making and Acting in Stressful, High-Risk Situations.*

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The Conceptual Model, in Brief, including a summary of implications:

- Stress is the response to a perceived discrepancy between demands of an event and capacities to deal with these demands. This discrepancy threatens physical or mental well-being and control is uncertain.
- The occurrence of stress is related to personal, contextual, organizational, and societal human factors, as these factors determine the (perceived) demands of a situation, the (perceived) capacities to deal with the demands, and the appraisal of discrepancies between demands and capacities as stressful for well-being and under limited or no control. In VR training all components of the stress response can possibly be manipulated to suit training needs, and the definition of stress provides a univocal language and understanding of stress which omits noise from the collaboration between LEAs, developers, and researchers.
- Stress leads to a shift from goal-directed attentional control towards more stimulus-driven control. This dictates that, to train for optimal (I.e. goal-directed) attentional control in stressful situation stress , should be evoked in VR training, and stimuli related to both types of attentional control present. Naturally these should be scaffolded in a proper didactical way for officers to become skillful in maintaining or restoring goal-directed control in the presence of high risks.
- Stress also leads to extra (mental) effort to maintain or shift attentional control back to goal-directed control, particularly through the attentional strategies of enforcing goal-directed processing, inhibiting stimulus-driven processing, and reducing the stress response.The result of stress plus mental effort determines attentional control, ranging fromstimulus-driven to goal-directed control. Implications are the same as for the previous bulletpoint.
- Attentional control, through the operational levels of attention, interpretation, and response formation, directs decision-making and acting.
- Decision-making and acting are not sequential stages in action but are integrated processes, and become apparent as motor heuristics and embodied choices. This implies that decision-making and acting should be trained, evaluated/debriefed and researched as integrated, emergent actions. Moreover, it dictates that both cognitive and sensory input should be carefully considered in development and training. By this we mean that the technology used in training needs to afford the trained individual with natural ways of perceiving, moving and processing information. Moreover that, depending on training objectives and didactics, advantage can be taken of unique

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possibilities of VR to systematically steer perception, movement and information processing to help police officers develop applicable motor heurstics and embedded choices.

- All the implications for VR training drawn in these bulletpoints were cross-checked with the recommendations for training and VR training in D3.1 and found to align very well.

4 Existing Evidence for the Proposed Links in the Model, from Studies with Police Officers

In chapters 2 and 3 we have outlined the conceptual human factors model of decision-making and acting under stress and in high-risk situation that we developed in WP3. We drew, in those chapters, several implications from the model for VR training, and the research and development to be done in SHOTPROS. The useability and credibility of these implications stand or fall on the strength of the model. Although the model is conceptual, it rests upon a compelling body of evidence on human behavior in general, but also on police actions specifically. In this chapter we aim to demonstrate the strength of the model itself (not the suggested implications that are the backbone of the research and development to be done in the project) by summarizing the exisiting evidence that support (separate parts of) the model.

4.1 Human Factors - Stress Response

The human factors in the model have been derived from deliverable D2.1. Planning, Setup and Methodology for Collection of User Requirements, Needs, and Expertise. In the work package that led to that deliverable, the human factors were elicited through content analysis of qualitative data from focus groups and interviews with different law enforcement agencies. For details about methodology and outcomes see the **report of D2.1**.

Based on D2.1, four types of human factors are distinguished in the conceptual model; personal, contextual, organizational, and societal. In the police sciences literature the most common distinction in types of stress is between operational stress and organizational stress (e.g., McCreary & Thompson, 2006; McCreary, Fong, &, Groll, 2017). For the conceptual model, we are most interested in the stress response that occurs in the operation (i.e., operational stressors). It is clear, however, that organizational stressors are prevalent in police work; in fact it has been claimed that organizational factors may be the largest contributors to stress in police officers (e.g., McCraty & Atkinson, 2012; Shane, 2010). Moreover, it is clear

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that general, persistent stressors have an impact on stress responses, and thus performance, in situations on duty (Shane, 2010).

The human factors that were formulated in **deliverable D2.1** and included in the conceptual model generally fit well with various frameworks of stressors in police work. Abdollahi (2002) for example outlined intra-interpersonal, occupational, and organizational stressors that are commonly studied in police populations. Her overview lends support for the inclusion of a large number of the contextual, organizational, and societal human factors in the model. Examples are media and perception of the police, the unexpected and the unknown, and rules and regulations. In addition, Abdollahi's findings on intra-interpersonal stressors partly support the inclusion of personal human factors like personality and uncertainty about abilities. This in in line with the results of **WP2** of the SHOTPROS project, which identified that personality is a relevant human factor, that should be included in the conceptual model. The relationships between personality traits like optimism/pessimism, neuroticism, extraversion/introversion, and authoritarian personality and stress have been studied. Research is however not as conclusive as one might expect (no relation, as well as contradictory findings have been reported), therefore this human factor of the conceptual model should be considered with caution. As an example, Landman, Nieuwenhuys, and Oudejans (2016a) found that although personality factors may diminish the negative impact of stress on police performance, this factor is only minor compared to the role that experience plays.

Similar to the fit with the framework of Abdollahi (2002), the included human factors fit well with the questionnaires that are most commonly used to assess stress in police officers, the Police Stress Questionnaire (PSQ, McCreary & Thompson, 2006) and the Police Stress Survey (PSS, Spielberger, Westberry, Grier, & Greenfield, 1981). These questionnaires are based on prevalent and relevant stressors as perceived by police officers, and have been widely used. As such, items of the questionnaires describe salient police specific stressors, and a clear link between the items in these questionnaires and the human factors in the conceptual model further justifies the inclusion of the human factors in the model. In Table 1 we provide examples of items from the questionnaires that are similar to specific human factors in the conceptual model.

Conceptual model	PSQ, McCreary & Thompson (2006)	PSS, Spielberger et al. (1981)
Physical strain	Fatigue (e.g., shift work, overtime), Eating healthy at work, Occupation-related health issues (e.g., back pain)	
Personal stressors	Managing your social life outside of work, Not enough	Family demands

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	time available to spend with friends and family, Lack of understanding from family and friends about your work	
Norms, values. stereotypes	Upholding a "higher image" in public, Feeling like you are always on the job	Demand for high morality
Position in team	The feeling that different rules apply to different people, Feeling like you always have to prove yourself to the organization	
The unexpected	Inadequate equipment	Inadequate or poor quality equipment, Aggressive crowds
Unexperienced colleagues	Dealing with coworkers, Unequal sharing of work responsibilities	Fellow officers not doing their job, Incompatible partner
Threat to physical integrity	Risk of being injured on the job	
The 'unknown'		Making critical on-the-spot decisions, Quick decision-making
Treatment after use of force	Bureaucratic red tape, Internal investigations	Mistreated in court
Rules and regulations	Constant changes in policy/legislation	Job conflict with rules, Disagreeable regulations
Training	Lack of training on new equipment, Finding time to stay in good physical condition	
Support	Leaders overemphasize the negatives (e.g., supervisor evaluations, public complaints), Inconsistent leadership style, If you are sick or injured your coworkers seem to look down on you, Feeling like you always have to prove yourself to the organization	Political pressure from within the department, Inadequate support by department
Time	Overtime demands	
Personnel deficit	Staff shortages	Insufficient manpower to adequately handle a job, Insufficient personnel

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Media		Negative press coverage
Perception of police	Negative comments from the public	Experiencing negative attitudes toward police officers, Personal insult from citizens
Reputation	Upholding a 'higher image' in public	Public criticism of police, Negative public image

Table 1. Examples of the Fit Between Human Factors in the Conceptual Model and Items in Frequently Used Questionnaires to Assess Stressors for Police Officers (i.e., PSQ and PSS)

Last, support for inclusion of specific human factors in the conceptual model can be found in separate studies. For example, the personal human factor "sensory elements" aligns well with the finding that dirty and physically demanding circumstances at the crime scene can be very stressful (Sollie, Kop & Euwema, 2017), or the contextual factor "bystanders" relates to the stress police-officers experience by encountering victims, particularly the vulnerable (e.g., children; Abdollahi, 2002). As a last example, it was found that experience (which relates to skills in the conceptual model) can secure effective performance in high pressure situations (Landman et al., 2016a)

All in all, we conclude that the human factors that were established in **WP2 and D2.1.** Planning, Setup and Methodology for Collection of User Requirements, Needs, and Expertise align well with common findings on sources of stress of police officers. Thus, there is scientific support for inclusion of these human factors in the conceptual model of police officer's decision-making and acting in stressful, high-risk situations.

4.2 Changes in Attentional Processes Caused by the Combination of the Stress-Response and Investment of Mental Effort

The conceptual model is based on the integrated model of anxiety and perceptual-motor performance (Nieuwenhuys & Oudejans 2012; 2017). Nieuwenhuys and Oudejans based their model partially on studies with police officers, and propositions of the model have been tested by them in the police context as well.

The conceptual model posits that the stress response in combination with mental effort results in attentional processes that lie on a continuum from stimulus-driven processes to goal-directed processes. Stimulus-driven processes are characterized by threat related attention, threat related interpretation, and threat related response tendencies. Nieuwenhuys and Oudejans (2011) found that gaze behavior of police officers changes under stressful circumstances. When officers where more anxious, their gaze was more and longer fixated at threat-related sources of information (the head and the gun of the opponent) than

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when they were not anxious. Earlier, the authors had shown that anxious police officers turn away from the aggressors when they are reloading their gun, also pointing to changes in attention as a result of stress (Nieuwenhuys & Oudejans, 2010). Moreover, the timing of incorrect shooting decisions under stressful circumstances also points to changes in attentional control. In incorrect shooting decisions (that is, shoot at an unarmed suspect) police officers responded directly to the suspect appearing, and did not wait to detect the visual information whether the suspect was armed or not (Nieuwenhuys, Savelsbergh & Oudejans, 2012). The authors hypothesize that this faster response is also the result of threat-related interpretation. They argue that the officers were more inclined to decide on the basis of threat-related inferences and expectations, rather than on the task-relevant information about gun possession. This is in line with studies that required officers to identify whether suspects had a gun or not, and that have shown that under time pressure officers report the presence of guns more often than without the time stressor (e.g., Correll, Park, Judd, & Wittenbrink, 2002; Payne, 2001).

Various studies have demonstrated changes in response tendencies of police officers in stressful situations. Generally, these studies point to avoidance tendencies in their behavior and movement under pressure. For example, Renden and colleagues (Renden, Landman, Savelsbergh, & Oudejans, 2015) found that when police officers were more anxious, they had faster reactions, were leaning further backward when they kicked an aggressor back, and ducked down when blocking an aggressor, all signs of avoidance tendencies in the movement patterns of police officers. Nieuwenhuys and Oudejans (2010) reported that under stressful conditions police officers ducked down (in order to decrease the chance of getting hit) and turned away from the opponent (the target) during reloading, again pointing to avoidance tendencies in behavior under stress.

From these series of studies we infer that the threat-related attention, interpretation, and response tendencies that characterize stimulus-driven attention do occur in police officers, when they are stressed. There is thus initial supportive evidence for this part of the conceptual model.

4.3 Mitigating the Stress-Response by Investment of Mental Effort

The conceptual model outlines that the stress-response, and its concurring effects, can be mitigated by investing mental effort. Three mechanisms of mitigation are proposed; Police officers can enforce their goal-directed processing, they can inhibit stimulus driven processing, and/or reduce their anxiety or stress levels.

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Initial support for the mental effort strategies proposed in the model stems from intervention studies aimed at increasing resilience and mental preparedness of police officers. Although such studies are relatively scarce (Andersen, Papazoglou, Nyman, Koskelainen & Gustafsberg, 2015), they generally point to positive effects of interventions, indicating that it is useful to equip police officers with mental preparation strategies. A small word of warning before we discuss the results of intervention studies; not all studies considered job performance, or more specifically decision-making and acting, as primary outcome. In some cases measures such as quality of sleep, anger management, empathy, fatigue, etcetera were the outcome of interest. Moreover, authors have pointed to the lack of control groups and lack of consideration of long-term effects as methodological weaknesses in these studies (Arnetz, Arble, Backman, Lynch, & Lublin, 2013; Romosiou, Brouzos, & Vassilopoulos, 2018).

Frequent components of the studied interventions to enhance resilience are:

- Breathing/Relaxation techniques (Andersen et al., 2015; Andersen & Gustafsberg, 2016; Arnetz, Nevedal, Lumley, Backman, & Lublin, 2009; Arnetz et al., 2013; McCraty & Atkinson, 2012; Page, Asken, Zwemer, & Guido, 2015)
- Imagery/Visualization (Andersen et al., 2015; Andersen & Gustafsberg, 2016; Colin, Nieuwenhuys, Visser, & Oudejans, 2014; Page, et al., 2015; Shipley & Baranski, 2002)
- Attention focus exercises (Andersen et al., 2015; Andersen & Gustafsberg, 2016; Page, et al., 2015
- Mindfulness (Chopko & Schwartz, 2013; Christopher et al., 2015; Palmer, 2019)

Although the specific pathways through which these techniques are thought to impact resilience are usually not discussed, we can align the techniques with the three mechanisms of mitigation proposed in the conceptual model.

Perhaps the most obvious and direct link is seen between attention focus exercises in resilience training and attentional processing. In the intervention studies police officers performed exercises to learn to control their attention, oftentimes through slow-motion tactical training (e.g., Andersen, Papazoglou, Koskelainen, et al., 2015; Andersen & Gustafsberg, 2016). These exercises were meant to train officers to keep their focus on the essentials in critical incidents, thus aligning well with enforcing goal-directed processing, and inhibiting stimulus driven processing.

Similarly, visual and auditory imagery of on-duty incidents, and the officers' responses to these visualized incidents may lead to improved attentional processing in actual incidents. Through imagery, police officers can become aware of task-relevant and task-irrelevant information, of their interpretation of this information, and of successful attention strategies

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in these incidents. In this vein, imagery can be seen as a way of learning to direct your attentional processes in a goal-directed way. Indeed, Colin et al. (2014) reported that through imagery of successful shot execution police officers were able to maintain their shot accuracy under pressure. An additional function of imagery could be to reduce anxiety or stress. By visualizing calming images stress levels may be lowered. This additional way of using imagery was, as far as we know, not an explicit part of the resilience interventions studied.

The breathing/relaxation techniques incorporated in the studies do aim to directly affect the stress level of police officers. In the studies of Arnetz and colleagues (2009; 2013) and Andersen and colleagues (2015; 2016) police officers were trained to use relaxation techniques during critical incidences. They had police officers practice relaxation techniques in combination with the imagery of incidents, thus incorporating the relaxation techniques in the timeline/process of critical incidents. Results indicate that relaxation techniques are effective in controlling physiological arousal, and can thus help officers to maintain adequate levels of decision-making and acting in stressful situations. There may be downsides to such stress-reduction attempts, however. Suppressing stress responses can lead to additional stress in the longer run, and may activate coping processes that place additional stressor loads on police officers (e.g., Crum, Salovey, & Achor, 2013). This points to the fact that the mechanisms to mitigate the stress response come with a cost, which is the expenditure of mental effort, potentially resulting in additional or more chronic stress levels and fatigue.

The last component that has received increasing attention in the police sciences literature is mindfulness. We may align some of the core tenets of mindfulness to the mechanisms proposed in the conceptual model. The aim of mindfulness is to be present in, and accepting of, the moment. One might argue that being present in the moment and attentive to how things evolve enables goal-directed processes and lowers stress levels. It may particularly be the acceptance component of mindfulness that aligns with the propositions of the model. If officers notice and accept their stress levels and then proceed to direct their attentional processes in a goal directed manner, then performance is facilitated in stressful, high-risk circumstances.

From the intervention studies discussed we infer two conclusions that support the proposed conceptual model. First of all, the ability to decide and act adequately in stressful circumstances is malleable, police officers can be trained to cope better with stressful circumstances and maintain performance. Second, the interventions that have been reported to help with this ability align well with the mechanism the conceptual model proposes for mitigation of the stress response and its consequences.

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Additional support for the investment of mental effort to steer attentional processes comes from studies on self-control of police officers (e.g., Landman, Nieuwenhuys, & Oudejans, 2016b; Giessing et al., 2019). Self-control is the capacity to go against dominant response tendencies and to regulate, behavior, thoughts, and emotions. Landman et al. (2016) and Giessing et al. (2019) point to self-control as playing a role in performance of police officers, but it seems that only if self-control is directed at goal-directed processing, and not on lowering anxiety, is helps shooting performance under stressful circumstances.

Overall, the research findings described support the idea that investing mental effort may help in retaining the proper attentional processes and subsequent performance of police officers under stress. It is important to realize that under increased levels of stress, police officers often or always experience investing more mental effort in task execution (Giessing et al., 2019; Nieuwenhuys, Caljouw, Leijsen, Schmeits, & Oudejans, 2009; Nieuwenhuys et al., 2012; Nieuwenhuys & Oudejans, 2010, 2011; Renden et al., 2015). Often this investment of mental effort is not immediately effective, however, in preventing the negative effects of stress, as performance levels still decrease. Yet, after a specific training intervention (e.g., training under stress, imagery) similar high levels of mental effort are reported, which now apparently is more effective in controlling attentional processes and maintaining performance, that is, effective in preventing the negative effects of stress (Colin et al., 2014; Nieuwenhuys & Oudejans, 2011; Renden et al., 2017).

4.4 Attentional Processes and Decision-Making and Acting

In this fourth part of empirical support basically all previous points come together, but now with an eye for apparent effects on attentional processes and eventual performance (decision-making and acting). It is known that stress may have a negative effect on police officers' performance on duty (Conrad & Kellar-Guenther, 2006; Norvell et al., 1998; Wright & Saylor, 1991; as cited in Andersen et al., 2015). Still, research on actual, on duty performance of police officers is scarce. Relatively more experimental or simulation studies are available. For instance, Covey and colleagues (Covey, Shucard, Violanti, Lee, & Shucard, 2013) found that police officers with symptoms of stress-related anxiety were more likely to shoot inappropriately in simulated critical events.

Furthermore, several studies have investigated effects of threat on actual performance in handgun shooting (Nieuwenhuys & Oudejans, 2010, 2011) and decisions to shoot (Nieuwenhuys, Canal-Bruland, & Oudejans, 2012; Nieuwenhuys, Savelsbergh, & Oudejans, 2012; Nieuwenhuys et al., 2015), as well as in arrest and self-defense skills (Renden, Landman, et al., 2017; Renden, Savelsbergh, & Oudejans, 2017). In all studies the level of threat under

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which police officers had to (decide and) act was manipulated, creating low-threat and high-threat conditions. Some studies found direct negative effects of threat on visual attention (Nieuwenhuys & Oudejans, 2010, 2011) leading to worse shooting accuracy, in line with the conceptual model. In other studies it appeared that the more threat-related interpretation of the available information led to negative effects on the decision to shoot or not to shoot, and on the eventual shooting action (Nieuwenhuys, Savelsbergh, & Oudejans, 2012; Nieuwenhuys, Canal-Bruland, & Oudejans, 2012). Both direct effects of perceived threat on attention and changes in the interpretation of the situation due to threat are in line with the conceptual model that a stress response may impact performance via different routes.

The work of Renden and colleagues (e.g., Renden, Landman, et al., 2017; Renden, Savelsbergh, & Oudejans, 2017) confirms that what has been found for shooting also holds for more complex constellations of arrest and self-defense skills. Both studies used realistic scenarios and showed that higher levels of anxiety led to changes in perceptual strategies (scanning, alertness), decision making (taking position, communication, skills used) and action execution (controlling the suspect, handcuffing, overall quality of skill execution), all in line with the conceptual model and the elements included.

It is important to realize that the approach of a potential suspect and eventually having to take actions varying from controlling, handcuffing, or shooting the suspect (depending on how the situation evolves), involves numerous decisions regarding how to approach the suspect, where to position yourself, how to communicate etc. As such, the results of Renden and colleagues (Renden, Landman, et al., 2017; Renden, Savelsbergh, & Oudejans, 2017) underline that stress does indeed affect the entire action package of perceiving the situation, deciding what to do, and doing that. Moreover, just as training under stress has been found to positively affect shooting accuracy by police officers under pressure, Renden, Savelsbergh and Oudejans (2017) demonstrated that with specific training (already with one training session) it is possible to improve arrest and self-defense skills under stress by (a) focusing attention on recognizing signals (perception and attentional processes) of imminent threat in the phase prior to physical contact with an assailant, and (b) continuing actions despite primary reflexes to a threat (the flinch response).

In short, empirical data show that, in line with the conceptual model, threat may affect (a) attentional processes affecting perception and interpretation of the situation in question, and hereby (b) decisions made with respect to actions taken, and (c) eventual quality of execution of these actions and hence, overall performance. Furthermore, the research shows that with proper training police officers can be trained to be better prepared for high-stress situations (see also Anderson, Di Nota, Metz, & Andersen, 2019). The challenge of the SHOTPROS project

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is to design and explore possibilities to use and implement virtual reality in training programs to better prepare police officers in Europe to make decisions and act appropriately in high-stress situations. The conceptual model dictates a number of implications for VR training, as outlined in chapters 2 and 3 of this deliverable D3.2, In this chapter (4) we provide evidence for the components of the conceptual model, thus strengthening the foundation of the implications for training based on the model.

5 Research Agenda Based on the Model

The conceptual model provides a framework for developing (VR) training for decision-making and acting of police-officers in stressful situations. As described in chapter 4, large parts of the model have already been validated in the scientific literature. The model is genuinely evidence-based. Still, within SHOTPROS several elements of the model should be further investigated to provide input for VR development and VR training, and to test the efficacy of the proposed implications of the model for VR training. Therefore, we have created **9 concrete research questions:**

1. How can human factors proposed in the model be used to create realistic VR- training with proper levels of stress?
2. How can the human factors proposed in the model be used to create VR-training in which adequate mental effort strategies are provoked?
3. Does VR provide opportunities to train with a wider range or much quicker alteration of human factors that create stressful circumstances than exisiting real-world training approaches?
4. Is VR-training helpful in making police-officers aware of changes in their attention, interpretation, and response tendencies in stressful situations (through after-action review (AAR) for example, potentially with layered feedback)?
5. Is VR-training helpful in making police-officers discover effective strategies to mitigate changes in their attention, interpretation, and response tendencies in stressful situations (through cues, stressors and repetitions, online layered feedback, through deliberate practice in VR)?
6. Does VR offer training ground for (implicit) development of effective motor heuristics and embodied choices (effective DMA) that are useful and salient in stressful, high-risk situations on actual duty?
7. Which features of VR provide particularly useful feedback for police officers?
8. What is the required or optimal frequency and duration of VR training?
9. How realistic is realistic enough in VR-training?

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5.1 Plan of action

To answer these questions several studies have been either executed or planned within SHOTPROS. These studies are specified here in this plan of action. This plan closely aligns with the **D6.1 Human Factors study plan** that supports the preparation and execution of the human factor experiments and studies that have to be carried out according to the research questions addressed in **WP2-4**, and for details we refer the reader to deliverable D6.1. This action plan focuses on and presents the completed, ongoing, and planned studies and their specific contribution to the research questions based on the SHOTPROS conceptual model created in **WP3**. An overview of how the different studies contribute to the nine research questions is provided in Table 2. Below Table 2 we briefly explain how each study contributes to answering the research questions it is linked to. To avoid redundancies, we refer to the **D6.1 Human Factors study plan** for a more detailed description of each study.

	User_Req	TrainPrac	Case Study	Paintballstudy	EnschVR	ZüriVR	DEC-TREE	RottVR	SHOT-COVID	RAT_study1 & 2	HFWeek 1	HFWeek2	HFWeek 3	Train Compar
Research Question 1	RQ 1		RQ 1	RQ 1	RQ 1	RQ 1			RQ 1	RQ 1	RQ 1		RQ 1	
Research Question 2	RQ 2		RQ 2		RQ 2	RQ 2			RQ 2	RQ 2	RQ 2		RQ 2	
Research Question 3							RQ 3				RQ 3		RQ 3	
Research Question 4				RQ 4		RQ 4		RQ 4				RQ 4		
Research Question 5				RQ 5		RQ 5		RQ 5				RQ 5		
Research Question 6												RQ 6		
Research Question 7		RQ 7				RQ 7								RQ 7
Research Question 8		RQ 8												RQ 8
Research Question 9					RQ 9							RQ 9		

Table 2. Overview of the studies that serve to answer each research question.

User Req: User requirements analysis *(study & evaluation completed).* This study contributes to research questions **1 and 2,** as it fed into the selection of human factors identified by end-

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users that can be further empirically tested on their ability to induce stress and investment of mental effort.

TrainPrac: Analytics and Validation of Current Training Practices of European LEAs *(study completed & ongoing).* This study contributes to research questions **7 and 8**, as it feeds into VR training possibilities in combination with existing training curricula. Furthermore, the study reflects on LEA's training objectives and how they are related to VR training possibilities.

Case Study: Police Officer's Psychophysiological Stress Reactivity on Duty *(study & evaluation completed).* This study contributes to research questions **1 and 2,** as it addressed the psychobiological stress reactivity that can be expected from police officers in real-life high-stress situations. As such, the study feeds into the requirement that VR-training should elicit sufficient stress to identify threat-related attention, interpretation, and response tendencies that characterize stimulus-driven attention in police officers when they are stressed.

Paintballstudy: Performance under Physical and Psychological Stress *(study & evaluation completed).* This study contributes to research questions **1,** as it addressed the validation of influencing human factors for the conceptual model. The study contributes to research questions **4 and 5**, as it explored eye-tracking feasibility as a measure for visual attention. As such, it provides information about measurement instrument selection regarding indications and awareness of attentional processes.

EnschVR: Comparison between reality-based scenario training and VR scenario training *(study completed, evaluation ongoing)*. This study contributes to research questions **1, 2,** as it showed that higher levels of sense of presence in VR increased the level of perceived stress and investment of mental effort. The study contributes to research question **9**, as it will provide insights into physiological responses that VR training can elicit compared to reality-based training.

ZüriVR: The effect of different feedback options and the addition of a pain stimulus on the (learning) experience of Swiss police officers in VR training *(study completed, evaluation ongoing)*. This study contributes to research questions **1, 2,** as it identified that adding a pain stimulus increased the level of perceived stress. The study contributes to research questions **4, 5, and 7,** as it identified which feedback features of the after-action review (AAR) were most relevant for the quality of learning.

DEC-TREE: Development of operational VR scenario (1st phase) for DMA-SR training *(study& evaluation completed)*. This study contributes to research question **3**, as it created scenario contexts with various stressors and decision-points. As such, the study provides a basis for

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further scenario development that provides the opportunity to train with a wide range of human factors that create stressful circumstances.

RottVR: The impact of the type of instruction and level of experience on learning and VR training experience *(study & evaluation completed).* This study contributes to research questions **4 and 5,** as it indicates the effects of the level of experience and type of training instruction on the learning experience of VR training.

SHOT-COVID: Police officers officers' work demands, stressors, and coping strategies during COVID19 crisis *(study & evaluation completed).* This study contributes to research questions **1 and 2,** as it delivered insight into human and contextual factors that contribute to increased stress levels in pandemic duty conditions.

RAT study1 & RAT study2: Development of the Risk Assessment Tool *(ongoing/planned).* These studies will contribute to research question **1 and 2,** as it provides a categorization of HF that influence DMA-SR, and provides information into which human factors and stressors to include in the VR- environment.

HFWeek 1: Initial Stressors + Stressors in Training Scenarios *(planned).* This study will contribute to research questions **1, 2, and 3**, as it will integrate stressors into comprehensive police training scenarios and investigate the potential interrelation between different stressors present in the scenarios and activities demanded from the police officers in these scenarios.

HFWeek2: Efficacy of VR training *(planned).* This study will contribute to research questions **4, 5, 6, and 9**, as it will compare four training interventions (scenario-based based training vs. VR training vs. combined scenario-based and VR training vs. passive control group) on learning and performance outcomes (e.g., self-efficacy, stress, decision-making).

HFWeek 3: Assessment of stress responses in real-world training compared to VR training *(planned)*. This study will contribute to research questions **1, 2, and 3,** as it will investigate both real-world and VR training psychological and physiological stress responses to identify stress and cues that can be implemented in future VR scenarios.

TrainCompar: Direct comparison of realistic training and VR training *(planned).* This study will contribute to research question **7 and 8**, as it will conduct a direct comparison of realistic training and VR training regarding how much actual training is done in a specific time, how many repetitions are executed, how many variations (of scenario) are executed, how much and what type of feedback is provided (on top of measurements of stress levels and [learning] experience with VR).

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6 Proceedings for Site Visit Results

In deliverable 3.1 “Comparison and Analytics of Existing Training Curricula”, we announced that the findings of the desk research described in D3.1 would be enriched and cross-checked with site-visits at the location of the LEAs and that the subsequential results would be reported in deliverable 3.2. In cooperation with the SHOTPROS LEAs, the site-visits have been conducted in the timeframe from December 2019 to March 2020 with the aim to observe training and assessment methods, as well as to conduct interviews with police instructors. Upon initial analysis of the site-visit results and conceptualizing the human factors model, we have decided to exclude the site-visit findings from the reporting of the conceptual model in D3.2. The reason for this exclusion is the lack of coherence between the site-visit results and the elaboration of the HF-DMA model. Instead, the results from the site-visits will be reported in deliverable 3.3, “European Framework for Training and Assessment”, where a connection to the reported content (i.e. proposed training concepts, training methods, and training modules) can be established more congruously.

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