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The Impact of Stress on Police Officers' Coordination and De-Escalation Behaviour

Master Thesis

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Abstract

Critical action teams, such as police teams, are faced with unique and everchanging situations that require swift action to control the situation. Police officers use coordination and de-escalation behaviours to achieve this. However, acute stress, which is also inherent to their job, affects individuals' coordination and task performance by impairing their cognitive abilities. However, it remains unclear how stress affects both coordination and de-escalation behaviours in critical action teams over time, as most studies fail to adopt a temporal lens. Novel, wearable technologies open up avenues for this line of research. Therefore, this study uses a multimodal approach, using both video observation and physiological data to gain fine-grained insights into the combination of behaviour and stress.

In a simulated training environment, 22 police officers were divided into 11 dyads and they performed three training scenarios with increasing environmental stressors. During these scenarios, they wore a Zephyr Bioharness collecting their physiological responses (i.e., electrocardiogram [ECG]) and they were video recorded. Afterwards, their ECG was used to determine their heart rate variability (HRV) over time by using the root mean square of successive differences (RMSSD), and the video recordings were used to code their coordination and de-escalation behaviours. The RMSSD values were corrected with the individual's baseline values, and moments of individual stress were identified. To translate stress to the team level, moments of simultaneous (no-)stress between team members were identified. These moments of simultaneous (no-)stress were then related to the coordination and de-escalation behaviours displayed at that time.

First, it was found that the moments of simultaneous stress differed across the three scenarios. In the second (medium stress) scenario, police officers experienced stress only in the last part of the scenario, whereas in the other scenarios it occurred throughout the scenario. Second, during moments of simultaneous stress, police officers displayed more explicit than implicit coordination behaviours compared to moments of simultaneous no-stress. Third, during moments of simultaneous stress, the de-escalation behaviour *listen* was displayed more, whilst during moments of simultaneous no-stress, the de-escalation behaviours *empower* and *honesty* were displayed more.

These findings suggest that stress-induced selective attention first limits police officers' ability to de-escalate and then leads to a loss of team perspective. Furthermore, simulated training environments for police officers were found to be effective in training stress coping, although caution should be exercised in generalising this to novel stressors. This multimodal approach allowed us to gain fine-grained insights into the processes that take place in police teams under stress.

Keywords: heart rate variability (HRV), simultaneous stress, de-escalation behaviour, coordination behaviour, multimodal approach, critical action teams

Contents

Abbreviations

ANS	Autonomic nervous system
EAC	Explicit action coordination
ECG	Electrocardiogram
EIC	Explicit information coordination
HR	Heart rate
HRV	Heart rate variability
HS	High stress
IAC	Implicit action coordination
IBT	Integraal beroepsvaardigheids trainingscentrum
IIC	Implicit information coordination
Kubios	Kubios HRV analysis software
LS	Low stress
MS	Medium stress
RMSE	Rating scale for mental effort
RMSSD	Root mean square of successive differences
SD	Standard deviation
TCD	Team coordination dynamics
VAS	Visual analogue scale
Zephyr	Medtronic Zephyr Bioharness 3.0

Introduction

First responders, such as firefighters, paramedics, and police officers are the first to arrive at the site of an emergency with limited information about what they will encounter, but they nevertheless have to respond adequately, yet cautiously (Ishak & Ballard, 2012; Kolbe et al., 2013). The final nature of emergency events often requires swift action by the team arriving at the scene, because the implications of slow or ineffective response can be disastrous and irreversible, for instance, loss of life or property damage due to fire. The behaviours and actions of these so-called critical action teams can thus have far-reaching implications, which makes them unique (Ishak & Ballard, 2012) and stresses the importance of acting legitimately and efficiently. This entails that their actions need to be in accordance with protocols and law to secure both their own and civilians' safety, whilst being adaptive to constantly changing circumstances. However, until now we have a limited understanding of the actual actions that critical action teams display during emergency events over time (Baldwin et al., 2019; Zechner et al., 2023).

An example showcasing the importance of coordination and de-escalation behaviours is the arrest of George Floyd, where police officers were critically assessed for the amount of force used, eventually resulting in his death. This resulted in vivid discussions about the actions displayed during the event and the lack of coordination between police officers. It drew attention to de-escalation behaviours, which can play a vital role in reducing the level of force necessary to control a situation (National Consensus Policy and Discussion Paper on Use of Force, n.d.). By strategically employing non-verbal and verbal communication techniques, police officers can effectively reduce the use of force, because the civilian(s) involved are calmed down preventing further escalation. Such de-escalation behaviours have been shown to be effective in practice for de-escalating a situation above and beyond the use of force (Engel et al., 2022). However, this requires the police officers at the scene to effectively coordinate their on-site actions. Hence, especially in the action-filled, complex situations that action teams find themselves in, effective coordination is crucial for effectively handling crises (Lemieux-Charles & McGuire, 2006) and thus the outcome of the event.

Continuously coordinating effectively is challenging in critical action teams, because a key characteristic of the situations that police officers often end up in, is that they are unpredictable and thus stressful (Crosswell & Lockwood, 2020; Ishak & Ballard, 2012; Weiss et al., 2017). Stress can hamper individuals' coordination and task performance by affecting their cognitive abilities (Dijkstra et al., 2021; LeBlanc, 2009). For example, stress can impair one's working memory, limiting one's attention to peripheral information, leading to impaired decision-making (Kamphuis et al., 2011). Since teamwork and coordination are crucial in critical action teams, the task performance of the team can therefore greatly suffer from an individual's stress (Dietz et al., 2010; Drach-Zahavy & Freund, 2007).

Thus, it is important to understand the influence of an individual's stress level on coordination within a police context.

However, we currently lack insight into how stress influences coordination in critical action teams because most studies fail to adopt a temporal lens. This limits our understanding of what actually happens under increasing stress levels with coordination behaviours over time (Baldwin et al., 2019). In addition, both stress and coordination have mostly been studied using self-reports that are based on self-perception and that are often filled out at the end of the study as a recall measure (Delice et al., 2019). This does not allow to study behaviour and stress dynamically and can cause response bias (Rosenman et al., 2011). When insights into coordination and de-escalation behaviours over time are obtained, training for first responders can be optimised. Novel methodologies have the potential to overcome the above-mentioned limitations and can accurately capture the temporally varying stress levels and their effect on displayed coordination and de-escalation behaviour (Hałgas et al., 2023).

At the moment, novel, wearable technologies are available that allow for continuous, unobtrusive and objective measurement of stress using one's physiological measures (Dindar et al., 2022; Klonek et al., 2019). Combining this measure with video observation and coding allows for uncovering temporal coordination and de-escalation behaviours and how these are affected by stress (Järvelä et al., 2021; Kozlowski et al., 2013; Malmberg et al., 2019). Taking such a so-called multimodal approach, which combines multiple modalities (i.e., in this case, video observation and physiological measures), allows for studying team dynamics over time. Hence, by taking a multimodal approach the black box of how stress impacts the coordination and de-escalation behaviour of police officers can be unpacked.

This contributes to existing literature in at least two ways. First, it extends the knowledge base of stress and its impact on coordination and de-escalation behaviours, which have been understudied (Engel et al., 2022; Espevik et al., 2021). Previous research in the context of critical action teams and police teams has often used modalities such as video, audio, or stress separately. Second, whilst police teams are constantly encountering stressful situations, also being in contact with civilians, these critical action teams remain understudied. Despite its practical and scientific relevance, other action team contexts, such as aviation (e.g., Grote et al., 2010), and especially the health sector (e.g., Burtscher et al., 2011) received more attention up until now. In this study, we therefore adopt a multimodal approach to study the temporal evolving nature of stress, and coordination and de-escalation behaviours. This will provide insights into how critical action teams keep coordinating under stressful circumstances. In doing so, we contribute to the team coordination dynamics theory, which focuses mainly on the healthcare context (Gorman & Wiltshire, 2024), but then in the context of critical action teams and with the addition of an important aspect (i.e., stress). Moreover, we contribute to a growing body of studies that are focused on action teams, and specifically police teams. If team processes are better understood they can be trained more efficiently, thereby increasing team effectiveness (Magana et al., 2023).

Theoretical Framework

Team Typologies and Functions (of Police Teams)

To effectively execute tasks individuals are often put together in a team, it has been prevalent that a team can achieve more than individuals with fewer resources (Salas et al., 2000). Different types of teams exist, as described by Sundstrom et al. (1990). These different teams are advice/involvement teams, production/service teams, project/development teams, and action/negotiation teams and can be classified based on differentiation (i.e., specialisation and autonomy in relation to other work units), external integration (i.e., degree of external coordination and synchronisation needed), and work cycles (i.e., degree of routine or one-of-a-kind work performed). Police teams are highly differentiated, requiring regular and specialised training in unique training facilities. Additionally, they show high external integration, because they coordinate their actions with the control room and other police teams involved. Moreover, they must perform during short, yet everchanging events. Therefore, police teams will fall under the action/negotiation teams in this typology (Sundstrom et al., 1990).

A more recent paper by Ishak and Ballard (2012) differentiates the action/negotiation teams even further, by splitting them into three different action teams: performing, contending, and critical teams. The great variance within action teams warranted further specification. For instance, an orchestra (performing), a sports team (contending), and a fire crew (critical) are all considered to be action teams by Sundstrom et al. (1990), but they have different tasks, contexts and performance outcomes. For the orchestra (performing) the performance and success thereof depend on sufficient repetitions and the opinion of the audience (Ishak & Ballard, 2012). While for the sports team (contending) the performance and success thereof are not necessarily related, success means a win against an opponent, but this can also be achieved with an imperfect performance. And lastly, for the fire crew (critical) their performance and success are partially dependent on an objective scale (e.g. is the fire extinguished) and partially on a subjective scale (e.g. could the number of casualties have been decreased). In Ishak and Ballard's taxonomy (2012), police teams fall under the critical action team typology. This indicates that their performance events are generally unplanned, they have to consider both their team members and civilians, they at times have to improvise when they encounter an unknown situation, and their performance is usually evaluated on a spectrum (Ishak & Ballard, 2012).

As critical action teams, the police teams have several duties. They make sure that all laws are complied with and take action if that is not the case (*Kerntaken politie*, n.d.). Moreover, they offer help to those in need and protect civilians. Since these situations can occur in a wide variety of settings, the work of police officers is dynamic and unpredictable. Under these difficult circumstances, they need to take the necessary, proportional, and legal actions required (Zaiser et al., 2023).

Coordination in Teamwork

To effectively fulfil the duties of the police, teamwork is required. During teamwork, a team of two or more individuals works adaptively, and interdependently to achieve commonly valued goals (Harris & Harris, 1996; Kozlowski & Ilgen, 2006; Salas et al., 2000). Adaptivity refers to the ability of a team to change and adjust strategies based on the information gathered during an event (Salas et al., 2000). For example, whenever the threats coming from a civilian change from being verbal to being physical a different approach needs to be adopted swiftly by police officers, requiring constant coordination between team members. Interdependence refers to the need for individuals to coordinate their actions in a way that other team members' demands are met (Salas et al., 2000).

Coordination in teamwork can be defined as "orchestrating the sequence and timing of interdependent actions" (Marks et al., 2001, p. 363). In practice, this shows for instance in the form of dividing tasks, or receiving and requesting information (Burtscher et al., 2011; Grote et al., 2010). An important framework of Kolbe et al. (2013) (i.e., Co-ACT) that has been used often, distinguishes between implicit and explicit coordination. Explicit coordination is defined as the process of explicitly and unambiguously communicating plans, responsibilities and courses of action (Rico et al., 2019). On the contrary, implicit coordination is defined as the process of implicit and unspoken knowledge and understanding of task demands or team member's needs (Rico et al., 2019). During implicit coordination, teams rely on concepts such as shared mental models replacing the need for explicit, overhead communication (Entin & Serfaty, 1999).

Especially in the highly complex, dynamic environment that police officers often find themselves in police officers have to excel at adaptive coordination (Espevik et al., 2022). Adaptive coordination refers to the ability to choose different coordination strategies based on what the changing environment demands (Entin & Serfaty, 1999). Research has shown that critical action teams indeed adapt their coordination mechanisms to the situational demands (Grote et al., 2010; Manser et al., 2008; Rico et al., 2011). Additionally, adaptive coordination has been linked to timely responses (Boin & Bynander, 2015), which is key because of the final nature of emergency events. For example, in the healthcare context coordination adaptation during an emergency event, specifically concerning information management, has been related to greater clinical performance (Burtscher et al., 2011).

In unexpected situations that can often cause stress among the team members (Ishak & Ballard, 2012), a shift towards more explicit coordination occurs, especially when the condition does not allow for monitoring of other team members (Williges et al., 1966). Moreover, during non-routine events also more explicit coordination is displayed in higher-performing teams (Faraj & Xiao, 2006; Grote et al., 2010; Rico et al., 2011). This can be explained by the fact that when procedures are not standardised team members do not know what is expected from them and explicit coordination is needed. On the contrary, when procedures are standardised team members can rely on the shared mental models and thus implicit coordination. The study by Manser et al. (2008) on operating room teams indicated that during critical activities not only did explicit coordination slightly increase, but also the monitoring of other team members (i.e., an implicit coordination behaviour) was more prevalent, which is in line with the reasoning mentioned above.

Team coordination dynamics (TCD) serve as an approach to use more objective methods to measure changes in team coordination over time (Gorman & Wiltshire, 2024). This is especially important for critical action teams because they are known for their highly dynamic and unpredictable nature which is otherwise hard to capture objectively. For these complex teams, so-called system III teams in the theory of Gorman & Wiltshire (2024), a multimodal approach is beneficial. A study by Wiltshire et al. (2021) already successfully used multiple modalities on a system III team showing proof of concept. Wiltshire et al. (2021) combined the use of sociometric sensors, and the visualisations of dynamic complexity with identified critical instabilities to understand team dynamics. Finding that this enabled the identification of task- and interaction transitions based on TCD data above and beyond the priorly known task transitions. Allowing to link this to a team member's energy and engagement within the team (Wiltshire et al., 2021). In the light of regular teams, van Eijndhoven et al. (2023) combined both video observations and physiological data as one of the firsts. This resulted in more accurate insights into the studied construct (i.e., coordination breakdowns) than any modality on its own. Therefore, the use of a multimodal approach to further enhance the understanding of team coordination and how it unfolds over time is worthwhile.

De-Escalation Behaviours

Next to coordination between team members, de-escalation behaviours displayed by the team members towards the civilians are also of importance to understand what is needed to get unpredicted situations under control. De-escalation behaviour can be used to lower the amount of force that is needed to get control over a situation, by using communication instead (Engel et al., 2022). In this study, de-escalation behaviour is defined as "the successful slowing down, stopping, and/or reversing of the conflict spiral, as well as avoiding/preventing it in the first place" (Zaiser et al., 2023, p. 271). Thus, this type of behaviour can be used in two different scenarios; either to stop ongoing conflict or to prevent it (Todak, 2017).

Communication with the civilian(s) involved in the emergency event is key when de-escalating a situation. Todak (2017), and Todak and James (2018) outlined eight different behaviours that can be used to de-escalate a civilian encounter by police teams. 1) *Respect.* Using a respectful tone towards the civilian. 2) *Listen.* Listening to the story of the involved civilian and their view on what happened. This helps to empathise with the civilian, as well as to learn more about the context and background of the event. This can also help in determining a suitable solution. 3) *Compromise.* If in line with the law, offer something to the civilian to get something in return. For example, offer a reduction of sentence when the civilian cooperates. In this way, justice is still served, but the situation is also de-escalated. 4) *Honesty.* Being honest with the civilian. Make promises you can keep, present the facts of the case, and tell the consequences of certain actions in light of the legal system. This can also help to structure the thoughts, and increase the understanding, of the civilian with regard to why police officers make certain decisions. This creates empathy between the civilian and police officer, which can result in cooperation. 5) *Empower.* Make the civilians feel that they are in charge of certain decisions. Often, they have different options, by using this behaviour police officers want to encourage civilians to make better decisions for themselves. For instance, a decision to cooperate with police officers can be seen as a move towards a better future. Moreover, police officers can help to prevent civilians from making the same mistakes again. 6) *Calm.* Staying calm as a police officer. Regulate emotions whilst being in a stressful event. 7) *Human.* Talk to the civilian as your equal, thereby avoiding 'cop talk'. This should lower the perceived power difference, which reduces the tension and makes the civilian feel less threatened. 8) *Shoes.* Emphasise with the civilian by placing yourself in the shoes of the civilian.

Although these eight de-escalation behaviours can be used on their own, it is also not unusual that they are used complimentary to each other (Todak & James, 2018). Police officers can for instance offer the involved civilian(s) a *compromise*, whilst staying *calm* and talking *respectfully*. Hence, the behaviours are not mutually exclusive. In fact, according to constitutional law, *respect* is something that should always be present. However, it can be compromised unwillingly, especially in demanding situations.

Todak and James (2018) explored, by systemic social observations (observer-police officer), in what situations what de-escalation behaviours were used and whether they predicted success. This depended on the police officer's demographics, the civilian's demographics, and the nature of the emergency event. For example, police officers with more years of service using the *calm* and *human* behaviours were more likely to de-escalate a situation than their less experienced counterparts. However, police officers used the *honesty* behaviour depending on the situation. Using this behaviour could either help to make things clear for the civilian but could also escalate the civilian thereby endangering the police officers' own safety. For example, when police officers were waiting for backup, sometimes there was strategically chosen not to tell the civilian that he was going to jail until backup arrived to prevent potentially dangerous situations. Therefore, a case-by-case (i.e., *ad hoc*) strategy is used to find a suitable approach for every situation.

Whilst temporal aspects of de-escalation behaviour could give more extensive insights into what behaviours are effective at what point in time, the temporal nature of de-escalation is not yet studied. Current research on de-escalation behaviours did not study temporal aspects and the methodological strategies chosen in these studies also did not allow to do so, because the time and order of events were not noted. Hence, a first required contribution is to understand how coordination and de-escalation behaviours can be effectively displayed over time by critical action teams. Secondly, numerous studies already indicated that stress influences behaviour (e.g., Chajut & Algom, 2003; Dietz et al., 2010; Stephenson et al., 2022), and is therefore another important element to consider. Especially in the case of critical action/police teams, it is crucial to understand how they can keep on coordinating and using the right de-escalation behaviours under (increasing) stressful circumstances. However, current methodological approaches fail to bring these two important elements together, while there are recent technological advancements (i.e., wearables) that enable this work (Hałgas et al., 2023).

Physiological Arousal States as a Proxy for Stress Detection

Stress is a response that occurs in everyday life and is also needed to function properly (Russell & Lightman, 2019). This can be traced back to our primal instincts to times when life and death depended on the stress-induced fight-or-flight response, in which stress resulted in for example increased alertness. A stress response occurs when homeostasis is disrupted (Stephenson et al., 2022) and the demands of a situation exceed one's skills to deal with it (Peifer et al., 2014). Especially in police work short, stressful events (i.e., stressors) causing acute stress are inherent to the job (Crosswell & Lockwood, 2020).

Acute stress causes a non-specific physical response since the body is subconsciously activated to cope with the stressor (Stephenson et al., 2022). The stress (sub)consciously perceived by the individual results in a cascade of responses through the autonomic nervous system (ANS). Within the ANS, the sympathetic branch upregulates in case of stress and this causes an increase in heart rate (HR), blood pressure and skin conductance among other physiological parameters (Arza et al., 2019; Crosswell & Lockwood, 2020; Oken et al., 2015). In this way, psychological stress is reflected in physiological measures, such as heart rate or skin conductance (Dietz et al., 2010; Kim et al., 2018).

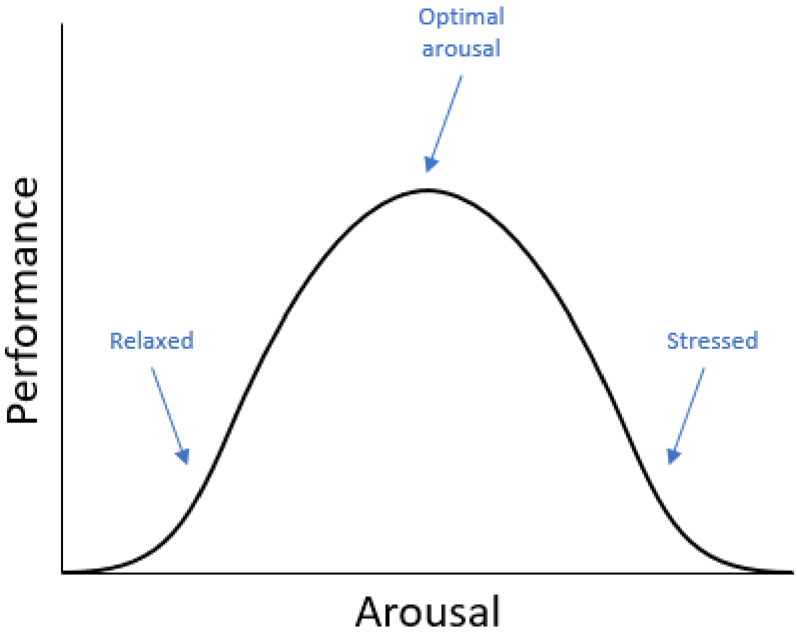
Directly derived from the heart rate is the heart rate variability (HRV), which reflects fluctuations in heart rate over time (Kim et al., 2018; Raz & Lahad, 2022). A low HRV thus shows a monotonously and highly regular heart rate, whereas a high HRV shows an irregular, yet still healthy, heart rate. In fact, this more irregular heart rate reflecting a high HRV has shown to be healthier than a low HRV, since it is associated with improvements in ANS regulatory functions (Kim et al., 2018). Thereby, the ability of the body to cope with stressors is enhanced (Kim et al., 2018). To detect stressful periods the HRV is expected to be lower than the baseline value, since the ANS has difficulties to cope with the stressor (Raz & Lahad, 2022). Where HR is influenced by a variety of parameters, HRV tends to be more affected by psychological stress instead of physical stress (Delliaux et al., 2019; Peabody et al., 2023). Because this research aims to study psychological stress, HRV was chosen accordingly.

The Effects of Stress on Task Performance

Stress responses are physiologically observable (e.g. through lower HRV) and are then referred to as physiological arousal. In turn, physiological arousal is directly related to task performance in the form of an inverted U-curve, as first described by Yerkes and Dodson (1908). According to them three states of arousal can be determined (see Figure 1): low arousal (i.e. relaxed), optimal arousal, and high arousal (i.e. stressed). In the low arousal state, the individual is completely relaxed, for example during sleep or at times of boredom, and task performance is poor, because one experiences attention problems and a lack of intrinsic motivation (Pekrun et al., 2010). Whereas during high arousal states, the individual is stressed, and task performance is also poor because cognitive abilities are affected (Dijkstra et al., 2021). In between the low and high state of arousal, the optimal state of arousal for task performance is located. The exact location of this optimal state depends on the complexity of the task at hand (Healthcare, 2000; Yerkes & Dodson, 1908). The higher the complexity of the task, the further the optimal arousal state is shifted to the left (i.e., to lower levels of arousal) (Healthcare, 2000; Kenny, 2011).

Figure 1

The Yerkes-Dodson Curve Performance Plotted Against Arousal (Yerkes & Dodson, 1908)



Note. The three states of arousal (i.e., relaxed, optimal, stressed) are indicated on the graph.

Stress can hamper task performance mostly by affecting one's cognitive abilities (Dijkstra et al., 2021; LeBlanc, 2009). Individuals tend to exhibit a narrow focus on themselves and task execution, so-called selective attention, by impairing one's working memory (Chajut & Algom, 2003; Dijkstra et al., 2021; LeBlanc, 2009). This limits their attention to the broader team view (Driskell et al., 1999) and peripheral information (Kamphuis et al., 2011). The latter can impair decision-making, since under stress individuals tend to filter out information that seems to be less important to them (Kamphuis et al., 2011; Kelly & Loving, 2004). Therefore, the decisions made by an individual might be based on incomplete information, although the information is available. Especially in police work, the integration of information from several sources is vital to reach accurate and legitimate decisions. Thus, the adverse effects of stress will be more apparent in such complex contexts (Chajut & Algom, 2003). Hence, if the situation creates a too big stress response, then oftentimes it is more challenging for police officers to make correct decisions.

Because the cognitive abilities of an individual are affected by stress this also influences the task performance of the whole team (Dietz et al., 2010; Drach-Zahavy & Freund, 2007). For example, if a civilian displays changes in demeanour and unexpectedly reaches for a gun the police officer should still be able to decide to shoot him before he gets shot himself. Whilst making the decision, the police officer should be able to control his motor performance such that his shooting accuracy (i.e., a higher-order cognitive function) remains sufficient to eliminate the civilian holding the gun without collateral damage. However, shooting accuracy can also be impaired because of stress putting the safety of fellow police officers and civilians at risk (Stephenson et al., 2022).

Simulation Training Police

Because of the unique short work cycles of critical action teams, such as police teams, it is crucial to have sufficient training opportunities to train the skills that are required for effective response in high-risk situations (Ishak & Ballard, 2012). A way in which police officers try to optimise their task performance in the field is by attending simulation training. Simulation training allows to simulate aspects of the real world in an interactive manner (Dijkstra et al., 2024; Ishak & Ballard, 2012). Moreover, it fosters a safe environment in which both theoretical knowledge, and hands-on-skills can be trained (Hunziker et al., 2011).

To increase task performance under stress, training should incorporate preexposure to the high-stress conditions that will be faced by police officers (Arora et al., 2010; Low et al., 2020). This study will provide these high-stress conditions in an isolated training environment, that is therefore not really threatening but still allows practice under stress (McClernon et al., 2011). The police officers can familiarise themselves with the high-risk and unknown events they can encounter, lowering the unwelcome, stressful feeling that comes with the unknown (Ishak & Ballard, 2012). Moreover, the ability to deal with stress trained in the particularly tested situation is generalisable to other types of stressors and tasks (Driskell et al., 2001; McClernon et al., 2011). By doing so, one increases its skills to take on the demands of the situation. Thereby, by definition also decreasing stress, since one's skillset gets enriched and gets closer to that needed to deal with the demands to tackle the problem.

Moreover, simulation training provides a great research environment, because of its controllable and standardisable features (Hunziker et al., 2011). According to Dietz et al. (2012), the most accurate measurements of team stress take place *in situ*, which reflects a natural task performance episode. The measures to determine team stress, such as video, audio, and physiology can all be measured unobtrusively in this simulation environment (Dietz et al., 2012; Zechner et al., 2023).

This research aims to explore the impact of stress on coordination and de-escalation behaviour in police teams. To address this issue, the following sub-questions are posed:

1. When does stress occur for the police officers in the different training scenarios?
2. Are different coordination behaviours displayed during simultaneous stress than during simultaneous no-stress?
3. Are different de-escalation behaviours displayed during simultaneous stress than during simultaneous no-stress?

Before answering these sub-questions, the three different training scenarios used in this study (i.e., the low stress (LS), medium stress (MS), and high stress (HS) scenarios) are compared. Differences in the coordination and de-escalation behaviours, and actions displayed during these scenarios might also affect the sub questions' outcomes.

Method

Design and Participants

This study examines the coordination and de-escalation behaviour of police officers during stressful events in an *in situ* simulation training using a mixed-method design. The study received approval from the ethics committee of the University of Twente (no. 231477).

Police officers regularly have training days to refresh and assess skills (e.g., shooting with a firearm), but also to teach them about new and relevant information on possible threats (e.g., increased risk of terrorism). These training days take place at a so-called *Integraal Beroepsvaardigheids Trainingscentrum* (IBT) located throughout the Netherlands. In this study convenience sampling was used at one of the IBTs, located in the eastern part of the Netherlands. Using a multimodal approach, data from various sources was collected during two of these training days. Eleven teams of two police officers participated in this study (i.e., 22 police officers in total), since police officers usually team up in dyads during their shift (Verhulst & Rutkowski, 2018). The mean age of the police officers is 37.05 years (*SD* = 9.16) with 95.5% of them being male (21 out of 22 participants). Moreover, the mean number of years of service at the police was 13.18 (*SD* = 8.51) and the mean number of years of service in the current function at the police was 6.57 (*SD* = 6.18).

Measures

Stress Measures

Physiological measures were collected, because physiological arousal is a proxy to identify stress (Arora et al., 2010). In the context of police teams, where physical movement is inevitable, the influence of physical movement must be limited as much as possible. Therefore, HRV better reflects psychological stress than HR (Gedam & Paul, 2021) and was chosen as a temporal measure of stress to identify physiological arousal during the scenarios. The police officers were equipped with a Medtronic Zephyr Bioharness™ 3.0 (Zephyr), a wireless chest strap, which has an integrated electrocardiogram (ECG) recorder, recording ECG at 250 Hz. The reliability and validity of the Zephyr heart rate measurements have been proven to be of high quality (Nazari et al., 2018). The ECG recordings were retrieved and visually inspected within Kubios HRV analysis software (Kubios). Kubios allows to pre-process the collected data, which will be elaborated upon in the *data analysis* section. Thereafter, the root mean square of successive differences (RMSSD) is taken as the HRV value, because of its capacity to work with ultrashort time (30s) windows in the time domain (Salahuddin et al., 2007; Sztajzel, 2004). Moreover, the influence of the low-frequency breathing patterns is minimal when taking the RMSSD (Laborde et al., 2017).

After all three scenarios were completed the police officers rated their perceived anxiety, and mental effort on two different visual analogue scales (VAS) *post-hoc*. Both scales were translated into Dutch, the language that was used during the entire study. The perceived anxiety scores ranged from 0 (no anxiety at all) to 10 (very much anxiety) (i.e., anxiety thermometer [Houtman & Bakker, 1989]). According to Fumiko et al. (2012) there is a correlation between stress and anxiety, thus this is a useful way to gain more information regarding the participant's experiences regarding stress after the completion of the scenarios. Additionally, mental effort has been proven to moderate this relationship (Edwards et al., 2015). The perceived mental effort scores ranged from 0 (not effortful) to 150 (extremely effortful) (i.e., Rating Scale for Mental Effort [RSME] [Zijlstra et al., 2012]).

Behaviour Measures

To code the dataset, a deductive approach was used by using a combination of the validated Co-ACT codebook of Kolbe et al. (2013, 2014) to code the coordination behaviour, the eight de-escalation behaviours of Todak & James (2018), and actions for both police officers and civilians to identify possible escalating behaviour. A code for *closed loop behaviour* was added to the original codebook of twelve codes of Kolbe et al. (2013, 2014) for when a message was clearly received and understood by the police officer. The codebooks were combined and adjusted in code definition and examples to better suit the context, see Table 1. The final codebook consisted of 37 codes. There are also codes present for *compromise*, *gun*, and *civilian shock-knife* however these codes were not used, so no example could be provided.

To apply the codebook, it was added to Noldus' Observer XT 14 software together with the video recordings of the scenarios. Thereafter, for each category, the behaviours were coded in this software. After coding, frequencies per minute and mean duration in seconds were calculated for the behaviours. Additionally, to get temporal data, for every second the behaviours that were displayed during that second were given. All measures are listed in Table 2.

Table 1

Extended Codebook (Kolbe et al., 2013, 2014; Todak & James, 2018) With Corresponding Definitions and Examples

Category	Code	Definition	Example
		Coordination (intra-team)	
Explicit action coordination	Give instruction	Includes directives, commands, or assignments of subtasks	"Add the other arm"
	Planning	Includes the verbalisations of non-immediate considerations regarding what should be done and when, also in the form of questions	"On resistance?"
	Speaking up	Questions and direct remarks regarding procedure and further courses of action, also disagreements, and opinions	"So, we are going to handcuff him?"
Implicit action coordination	Action-related talking to the room	Includes comments on performance of own current behaviour not directed to a specific other team member	"I have control"
	Monitoring	Coded when team members observe the actions of fellow team members and anticipate what they are looking for (but not from the environment → gather information)	Police officer watches fellow team member
	Provide assistance	Includes task-relevant action completed without being asked to do so, backing team members up	Police officer helps fellow team member when handcuffing civilian
Explicit information coordination	Information request	Coded if one directly asks another for (task-relevant) information	"Do you have control?"
	Information evaluation	Statements expressing doubt or assurance regarding the accuracy or source of information	"For the dog handler"
	Information upon request	Coded if one answers a (task-relevant) question asked by a team member	"Here is difficult"
Implicit information coordination	Gather information	Coded when a police officer actively gathers information from the environment (but not from team members → monitoring)	Police officer watches the environment
	Information related talking to the room	Coded when team member appeared to address communication not directed to a specific other team member	"This arm has to go to the back"
	Information without request	Providing information to a team member without being asked to do so	"Knife, knife!"
Other	Closed loop behaviour	Includes nodding, or verbally confirming that the message was understood	"Yes, I saw it"

		De-escalation (outside team)	
De-escalation	Respect	Using a respectful tone towards the civilian	Present unless a police officer showed disrespect
	Listen	Actively listen to the story of the civilian and his view on what happened	“Yes … yes”
	Compromise	Making a compromise with the civilian	-
	Honesty	Includes making promises you can keep, presenting the facts of the case, and telling the consequences of certain actions	“Everything you say can be used against you”
	Empower	Give the civilian different options that he can choose from	“You can either cooperate or we have to use violence”
	Calm	Includes that the police officers regulate their emotions and remain calm	Present unless a police officer got frustrated or angry
	Human	Includes talking to the civilian as your equal, avoiding ‘cop talk’	Present unless a police officer used cop talk
	Shoes	Includes emphasising with the civilian by placing yourself in the shoes of the civilian	“I get it”
		Action	
Action from police	Police verbal force	Includes shouting at civilian or bullying	“Drop it! Drop it!”
	Police physical contact	The police officer touches the civilian with no intention to harm or use violence	Police officer physically touches the civilian as preparation towards handcuffing
	Police warning	Includes police officer threatening to use force, and pulling tools	“If you don’t cooperate, we have to use force”
	Handcuffs	Police officer handcuffs civilian	Police officer handcuffs civilian
	Pepper spray	Police officer uses pepper spray on civilian	Police officer uses pepper spray on civilian
	Taser	Police officer uses taser on civilian	Police officer uses taser on civilian
	Gun	Police officer uses gun on civilian	-
	Police entering	Includes police officer opening the door towards a room and/or entering it	Police officer opens the front door
	Police physical force (no tools)	Police officer uses physical force on civilian	Police officer has to use force to control the civilian
Action from civilian	Civilian threatening	Includes civilian threatening to use force, and pulling tools	“I will stab you”
	Civilian throwing objects	Civilian uses objects (e.g. beer can) on police officer	Civilian throws cushion towards police officer

	Civilian slamming door	Civilian forcefully closes the door	Civilian forcefully closes the door between the two adjacent rooms
	Civilian shock-knife	Civilian uses shock knives on police officer	-
	Civilian physical force (no tools)	Civilian uses physical force on police officer	Civilian keeps his hands to his chest when police officer attempts to handcuff
	Civilian verbal force	Includes civilian shouting, bullying police officers	"I'm not coming with you!"
	Civilian entering	Includes civilian opening the door towards a room and/or entering it	Civilian opens the door from the second to the first room

Table 2

List of Every Measure, How it is Measured and What Tools are Used

Measure	Measurement	Tool(s)
	Stress	
HRV (RMSSD)	ECG	Zephyr, Kubios
Perceived anxiety	Self-reported VAS	Anxiety thermometer
Perceived mental effort	Self-reported VAS	RSME
	Coordination and de-escalation behaviours	
Behaviours/actions	Video observations	Codebook, Noldus Observer XT 14

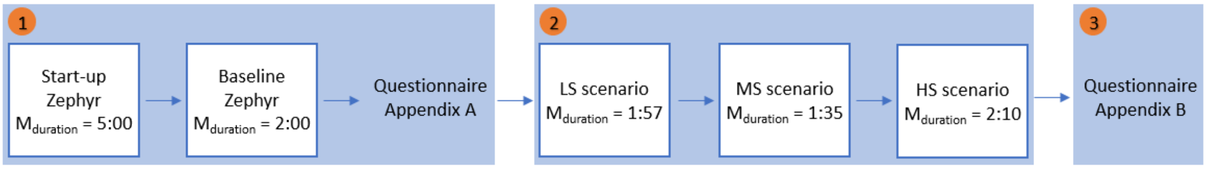
Procedure

The study set-up consisted of three parts, pre-scenario, scenario, and post-scenario. Every part is described in more detail below and an overview can be found in Figure 2. The scenarios were designed in co-creation with the trainers of the IBT because they have experience with designing an ecologically valid scenario that also fulfilled our required conditions. The required conditions for the scenario were the following:

- Needs to be dynamic and interactive (e.g., time for conversation with the civilian),
- Needs teamwork between the two police officers to be successful,
- Needs to evoke stress, ideally with different stressors (e.g., time pressure, and threat),
- Needs to have periods of lower stress and higher stress,
- Needs to stimulate the police officers to use different tactical tools, or at least not clearly one tactical tool,
- Needs to be realistic and ecologically valid.

Figure 2

Overview of the Procedure



Note. The procedure is from the point of equipping until detaching the police officers with the wearables. 1 = pre-scenario, 2 = scenario, and 3 = post-scenario, LS = low stress, MS = medium stress, and HS = high stress.

Pre-Scenario

After signing informed consent, the police officers were equipped with a Medtronic Zephyr Bioharness™ 3.0 (Zephyr). The Zephyr reaches its full functionality after five minutes of wearing it. Therefore, the police officers had to wear the Zephyr five minutes before their baseline values during two minutes, while casually standing, could be established. Moreover, the police officers received a bodycam that collected their individual video and audio footage during the training scenario. Once the police officers were equipped with the data collection sources, they filled out a short questionnaire to collect their demographics. This questionnaire can be found in Appendix A.

Scenario

After equipping the police officers with the bodycam and the Zephyr, they were escorted by one of the researchers to the place where the scenario had to be performed. They were orally instructed that they had an arrest warrant for the male individual present in the building, because he was involved in an incident in which someone was physically abused. Moreover, it was known that the man could act violently under the influence of alcohol. The goal of the scenario was to arrest this man.

The building consisted of two rooms behind each other separated by a closed door. The man was present in the first room with an empty can of beer (visible to the police officers) and his wife was present in the second room (invisible to the police officers). This scenario was performed three times consecutively with increasing stressors present. The first time, LS, the man was only verbally aggressive. The second time, MS, the man was both verbally, and physically aggressive. The third time, HS, the man exhibited both verbal and physical aggression, additionally threatening to use the knife he was holding. During all three scenarios the man his wife interfered, opening the door from the second room towards the first room. The average time it took the police officers to complete the scenarios (i.e., until handcuffing the man) was also written down and can be found in Table 3. Different behaviour was displayed by the civilians during the scenarios, leaving more room for talking in the LS scenario, but requiring more action in the HS scenario. Therefore, the time durations did not differ very much between the three scenarios.

Table 3

Mean Duration of the Three Scenarios and Their Respective Standard Deviation

Scenario	Mean duration (mm:ss)	Standard deviation (mm:ss)
LS	01:57	00:39
MS	01:35	00:25
HS	02:10	00:38

Note. LS = low stress, MS = medium stress, and HS = high stress.

Post-Scenario

After all three scenarios were executed the police officers were escorted back to where they were equipped with the Zephyr and bodycam. They were detached from their equipment and were asked to fill out a questionnaire about their perceived mental effort, and anxiety. This questionnaire can be found in Appendix B. The police officers experienced some stress during the total scenario (LS + MS + HS) on the visual analogue scale for perceived anxiety ranging from 0 to 10 the mean score was 4.86 (SD = 1.86). The mental effort for the total scenario was scored in between somewhat and fairly strenuous on the visual analogue scale for mental effort ranging from 0 to 150 the mean score was 49.95 (SD = 18.19).

Data Analysis

Stress Detection

To translate the Zephyr data to periods of stress a couple of pre-processing steps were taken. First of all, the Zephyr's raw ECG data was uploaded into Kubios and the automatic noise detection was set to 'low', this means that the threshold for noise is relatively high. Additionally, the beat correction was set at a 'medium threshold', because the quality of the data during exercise requires more beat corrections than at rest (Alcantara et al., 2020). Thereafter, for every police officer, three samples were selected. The first was the LS scenario, the second was the MS scenario, and the third was the HS scenario. Once the correct time windows were selected in Kubios, the RMSSD in the time-domain and in the time-varying domain (window width = 30 s, and grid interval = 1 s) were selected and the data was exported as an Excel file. Hereafter, the mean baseline value for every individual was used to correct the individual's RMSSD values over time (1 Hz output) by subtracting the mean baseline RMSSD value from the RMSSD value (Anton et al., 2023). The standard deviation of the baseline period was determined. Values that were more than two standard deviations below the baseline were indicated as stressed, and values that were more than two standard deviations above the baseline were indicated as relaxed (Wiltshire et al., 2021). In this way, for every individual, the moments in time where the individual was either stressed or relaxed were determined.

Simultaneous (No-)Stress Detection

For further inspection of the data, the moments where both police officers were stressed were considered simultaneous stress moments. The moments where neither of the police officers was stressed were considered simultaneous no-stress moments. A comparison of the behaviours displayed during either moments of simultaneous stress or simultaneous no-stress was made to study the effects of stress on police officers' behaviour. Only the teams that had less than 10% of missing RMSSD data during the scenarios were included. Otherwise, too much uncertainty on whether simultaneous (no-)stress was present exists, causing bias in the results.

Coordination and De-Escalation Behaviours

To analyse the behaviours displayed during the scenarios the videos were coded according to the codebook in Table 1 with Noldus' Observer XT 14 software. In the software, the five video recordings of the scenario (i.e., 2x police officer's bodycam video, 2x room video, and 1x male civilian bodycam video) were manually synchronised. Thereafter, the behaviours of the male civilian, female civilian, police officer 1, and police officer 2 were coded with start behaviour and stop behaviour. Therefore, not only frequencies but also durations of the behaviours were obtained. An exception to this is the *closed loop behaviour*, which is coded as a single point in time, because its duration is very short. The Noldus' Observer XT 14 software can give different data output formats for the coded data of which two variants were used and are explained in the next paragraphs. The data was thereafter exported as an Excel file and analysed in either Excel or SPSS.

The first variant is used for the scenario comparison and both the frequency per minute and the mean duration in seconds for every behaviour were calculated per scenario and aggregated for all teams. Thereafter, because of the non-parametric and paired nature of the data, Friedman's test was used to investigate if the LS, MS, and HS scenarios for each behaviour differed. If the Friedman's test had a significant outcome ($p < .05$), a *post-hoc* Sign test with Bonferroni correction ($p < .017$) was performed to investigate the differences between any combination of two scenarios (i.e., LS versus MS, MS versus HS, and LS versus HS).

The second variant is used to study the behaviours of the police officers during moments of simultaneous (no-)stress. Per police officer, an output file containing the behaviours displayed for every scenario in a 1 s time window was taken. Thereafter, for the time windows in which there was either simultaneous stress or simultaneous no-stress the frequencies of the behaviours of both police officers were analysed. The percentages of the time spent on a certain behaviour within the time window were given. Because the coded behaviours were not mutually exclusive, the sum of all behaviour percentages can exceed 100%. The mean percentage (of police officer 1 and police officer 2) spent on a certain behaviour per team during either simultaneous stress or simultaneous no-stress is given for every scenario. Moreover, the sum of those mean percentages per behaviour was taken to point out differences in general de-escalation, and coordination behaviour as well as implicit and explicit coordination. Additionally, this was also done for the four types of coordination behaviours; implicit action coordination (IAC), explicit action coordination (EAC), implicit information coordination (IIC), and explicit information coordination (EIC).

Results

Before diving into the sub-questions, a comparison is made between the LS, MS, and HS scenarios. Thereafter, the first sub-question on the occurrence and timing of stress during the different scenarios will be answered. Finally, sub-questions two and three about the differences in coordination and de-escalation behaviour, respectively, during simultaneous stress and simultaneous (no-)stress are answered.

LS, MS, and HS Scenario Comparison

Behaviour Comparison Between Scenarios

To investigate the behavioural differences displayed in the scenarios the frequency of each behaviour per minute and the mean duration in seconds for every scenario are calculated, see Table 4. Thereafter, with Friedman's test, it is investigated if the LS, MS, and HS scenarios for each behaviour differed. If Friedman's test had a significant outcome, a *post-hoc* Sign test with Bonferroni correction was performed to investigate the differences between any combination of two scenarios (i.e., LS versus MS, MS versus HS, and LS versus HS). For the coded coordination behaviours, the frequency of *give instruction* ($X^2(2, N = 11) = 9.46$, $p = .009$) and *provide assistance* ($X^2(2, N = 11) = 9.46$, $p = .009$) significantly differed between the three scenarios. *Post-hoc* analysis showed that the frequency for *give instruction* was significantly higher in the HS scenario compared to the LS scenario ($p = .012$). For *provide assistance* the frequency was significantly higher in the MS scenario compared to the LS scenario ($p = .012$).

Table 4

Frequency per Minute and Mean Duration of the Coded Behaviours for the Scenarios

Behaviour	Frequency per minute				Mean duration (s)			
	LS	MS	HS		LS	MS	HS	
Coordination (intra-team)								
Give instruction	1.13	2.38	2.39	*	1.72	0.97	1.13	
Planning	0.34	0.00	0.62		1.28	0.00	1.13	
Speaking up	0.69	0.64	1.06		1.12	0.95	1.14	
Action-related talking to the room	0.91	0.80	0.99		1.08	0.95	1.05	
Monitoring	0.88	1.21	1.17		2.06	1.40	1.38	
Provide assistance	1.26	2.02	2.35	**	2.99	2.46	2.44	
Information request	0.95	1.08	1.10		1.02	0.57	0.85	
Information evaluation	0.00	0.00	0.32		0.00	0.00	3.71	
Information upon request	0.86	0.97	0.66		1.00	0.34	0.72	
Gather information	3.54	4.34	3.50		3.87	3.49	3.07	
Information related talking to the room	0.31	0.00	0.60		1.60	0.00	0.27	
Information without request	1.09	1.07	1.88		1.37	1.37	1.41	
Closed loop behaviour[a]	1.01	1.45	1.34		N/A	N/A	N/A	
De-escalation (outside team)								
Respect	1.15	1.36	0.99		117.44	94.66	130.54	
Listen	1.82	1.71	1.57	**	3.23	2.54	2.85	##
Honesty	3.53	2.31	1.66	*	3.47	3.27	3.22	
Empower	0.43	0.81	0.00		3.86	0.98	0.00	#
Calm	1.15	1.36	0.99		117.44	94.66	130.54	
Human	1.15	1.36	0.99		117.44	94.66	130.54	
Shoes	0.44	0.00	0.00		1.70	0.00	0.00	
Actions								
Police verbal force	2.74	3.69	3.48	**	1.77	2.69	3.16	###
Police physical contact	1.34	1.92	1.27	*	47.88	34.74	41.54	#
Police warning	0.98	1.15	0.88		3.00	1.82	1.31	
Handcuffs	0.58	0.68	0.45	*	13.75	14.95	13.39	
Pepper spray	0.00	0.00	0.94	*	0.00	0.00	0.80	#
Taser	0.00	1.65	1.36	***	0.00	5.04	4.56	##
Police entering	0.73	0.73	0.83		2.23	2.18	1.70	
Police physical force (no tools)	0.76	1.36	0.75	**	39.98	10.17	35.41	
Civilian threatening	0.00	0.00	0.79	***	0.00	0.00	3.34	###
Civilian throwing objects	0.00	0.71	0.66	**	0.00	1.39	1.13	##
Civilian slamming door	2.36	0.69	0.67		1.20	1.11	1.17	
Civilian physical force (no tools)	0.38	0.80	0.57	**	22.15	6.35	29.89	
Civilian verbal force	6.43	6.25	5.81		4.38	5.05	5.12	##
Civilian entering	0.83	1.06	0.86		3.04	2.00	2.05	#

Note. The codes *compromise*, *gun*, and *civilian shock-knife* were not used and are thus not displayed in the table. Significance for frequency per minute is indicated with * = $p < .05$, ** = $p < .01$, *** = $p < .001$. Significance for the mean duration (s) is indicated with # = $p < .05$, ## = $p < .01$, ### = $p < .001$.

[a] coded as a point behaviour, so there were no duration calculations possible (N/A)

For the coded de-escalation behaviours, the frequency of *listen* ($X^2(2, N = 11) = 14.25, p = .001$) and *honesty* ($X^2(2, N = 11) = 8.91, p = .012$) significantly differed between the three scenarios. *Post-hoc* analysis showed that the frequency for both *listen,* and *honesty* was greater in the LS scenario than in the HS scenario, $p = .004$ and $p = .012$, respectively**.** Additionally, the duration of *listen* ($X^2(2, N = 11) = 9.75, p = .008$) and *empower* ($X^2(2, N = 11) = 7.54, p = .023$) significantly differed between the three scenarios. However, *post-hoc* analysis did not show any significant differences between any combination of two scenarios.

For the coded actions the frequency of *police verbal force* ($X^2(2, N = 11) = 9.39, p = .009$), *police physical contact* ($X^2(2, N = 11) = 6.73, p = .035$), *handcuffs* ($X^2(2, N = 11) = 7.43, p = .024$), *pepper spray* ($X^2(2, N = 11) = 8.00, p = .018$), *taser* ($X^2(2, N = 11) = 17.57, p < .001$)*, police physical force (no tools)* ($X^2(2, N = 11) = 9.92, p = .007$), *civilian threatening* ($X^2(2, N = 11) = 22.00, p < .001$), *civilian throwing objects* ($X^2(2, N = 11) = 11.56, p = .003$), and *civilian physical force (no tools)* ($X^2(2, N = 11) = 12.84, p = .002$) significantly differed between the three scenarios. *Post-hoc* analysis showed that the frequency of *police verbal force* was greater in the HS scenario compared to the LS scenario ($p = .012$). For *taser,* the frequency was higher in the HS scenario compared to the MS scenario ($p < .001$), and also in the HS scenario compared to the LS scenario ($p = .012$). For *police physical force (no tools)* the frequency was higher in the MS scenario than in the LS scenario ($p = .016$). For *civilian threatening* the frequency was higher in the HS scenario compared to both the LS and MS scenarios (both $p < .001$). For *civilian throwing objects* the frequency of both the MS and HS scenarios was higher compared to the LS scenario (both $p = .008$). For *civilian physical force (no tools)* the frequency of the MS scenario was higher compared to the LS scenario ($p = .008$). For *police physical contact*, *handcuffs* and *pepper spray* the *post-hoc* analysis showed no significant differences between any combination of two scenarios. Additionally, the duration of *police verbal force* ($X^2(2, N = 11) = 10.82, p = .004$), *police physical contact* ($X^2(2, N = 11) = 6.73, p = .035$), *pepper spray* ($X^2(2, N = 11) = 8.00, p = .018$), *taser* ($X^2(2, N = 11) = 15.08, p = .001$)*, civilian threatening* ($X^2(2, N = 11) = 22.00, p < .001$), *civilian throwing objects* ($X^2(2, N = 11) = 11.56, p = .003$), *civilian verbal force* ($X^2(2, N = 11) = 14.56, p < .001$), and c*ivilian entering* ($X^2(2, N = 11) = 6.73, p = .035$) significantly differed between the three scenarios. *Post-hoc* analysis showed that the duration of *police verbal force* was longer in the HS scenario compared to the LS scenario ($p = .012$). For *taser,* the duration in the HS scenario was longer than that in the LS scenario ($p < .001$). For *civilian threatening* the duration was greater in the HS scenario compared to both the LS and MS scenarios (both $p < .001$). For *civilian throwing objects* the duration of both the MS and HS scenarios was higher compared to the LS scenario (both $p = .008$). For *civilian verbal force,* the duration during the HS scenario was higher compared to the LS scenario ($p < .001$). For *police physical contact, pepper spray,* and *civilian entering* the *post-hoc* analysis showed no significant differences between any combination of two scenarios.

Stress Response Comparison Between Scenarios

To assess when police officers experience physiological stress in the different scenarios the baseline corrected mean RMSSD values for LS, MS, and HS were compared with Friedman's test. The mean and standard deviation of all police officers are displayed in Table 5. There was no significant difference found between these scenarios in terms of mean RMSSD. Moreover, the differences between the three scenarios and the percentage of stress during the scenario per police officer for LS, MS, and HS scenarios were compared with Friedman's test. The percentage and the standard deviation are displayed in Table 5. There were no significant differences found between these scenarios in terms of the percentage of physiological stress experienced during the scenarios. Thus, some of the behaviours differed significantly across the scenarios, however, the physiological stress responses did not.

Table 5

Differences per Scenario for Different Physiological Variables

Physiological stress variable	LS	MS	HS
Baseline corrected mean RMSSD (SD)	1 (17)	2 (17)	-1 (15)
Percentage stress during scenario (SD)	32 (31)	27 (29)	37 (33)

Note. RMSSD = root mean square of successive differences, LS = low stress, MS = medium stress, and HS = high stress.

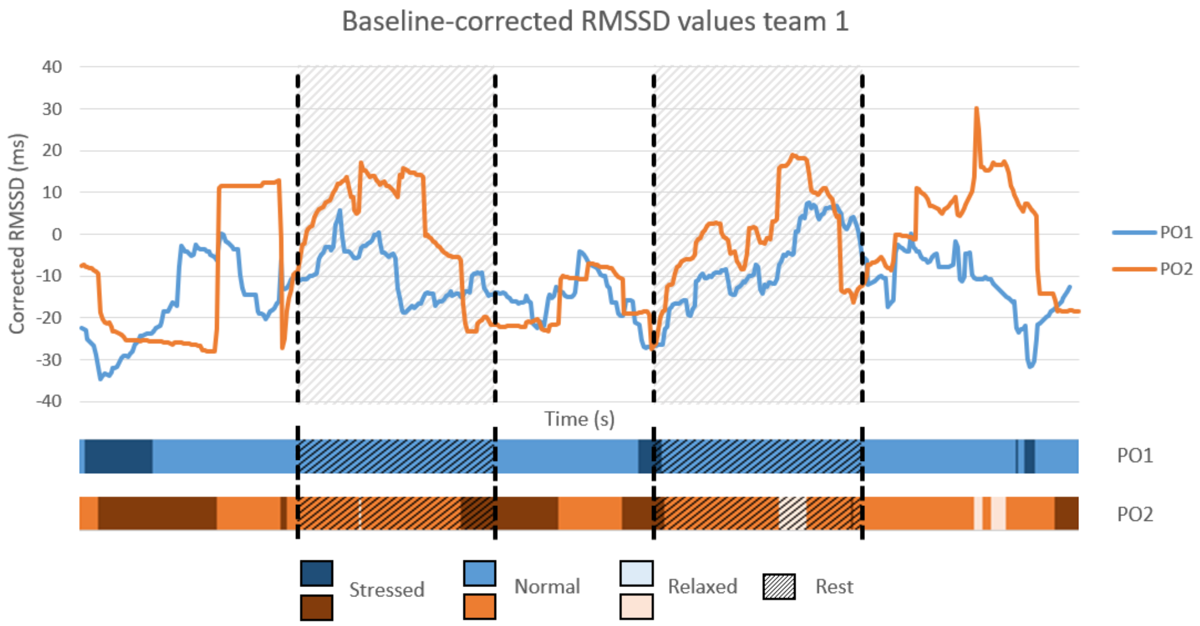
Moments of Stress Occurrence per Police Officer per Team

Because of the great differences (i.e., high standard deviations) in the aggregated physiological stress responses shown in Table 5, the police officers' individual stress responses were studied more closely. The stress levels of the police officers over the scenarios from teams with less than 10% missing RMSSD data (n = 8) were studied, such that patterns could be recognised. The stress levels of the three remaining teams (i.e., teams with more than 10% missing RMSSD data) can be found in Appendix C. In general, it can be seen from Figure 3 until Figure 10 that although the police officers are in the same team and thus in the exact same scenarios, their individual stress responses differ in terms of minimum and maximum corrected RMSSD values. Although the corrected RMSSD values are not identical, the pattern of the corrected RMSSD values within the teams shows a lot of similarities. When the corrected RMSSD values for one police officer in the team rise, the corrected RMSSD values for the other police officer in the team often rise too and the other way around. The most striking exception is found in team 4, see Figure 6. Where when for one police officer the corrected RMSSD values rise, for the other police officer its corrected RMSSD values drop.

Moreover, out of the sixteen included police officers nine reached both stressed and relaxed moments during the scenarios, four only reached stressed moments, and three only reached relaxed moments. There is also a big difference in the corrected RMSSD values the police officers enter the first, LS, scenario with. For example, in team 1 (Figure 3) both police officers enter the LS scenario with a lower RMSSD value than their baseline value, indicating more stress. This is also expected, because they do not exactly know what to expect and what they will encounter. Interestingly, there are also a few police officers, for example in team 11 (Figure 10) that enter the first scenario with a higher corrected RMSSD value, indicating less stress.

Figure 3

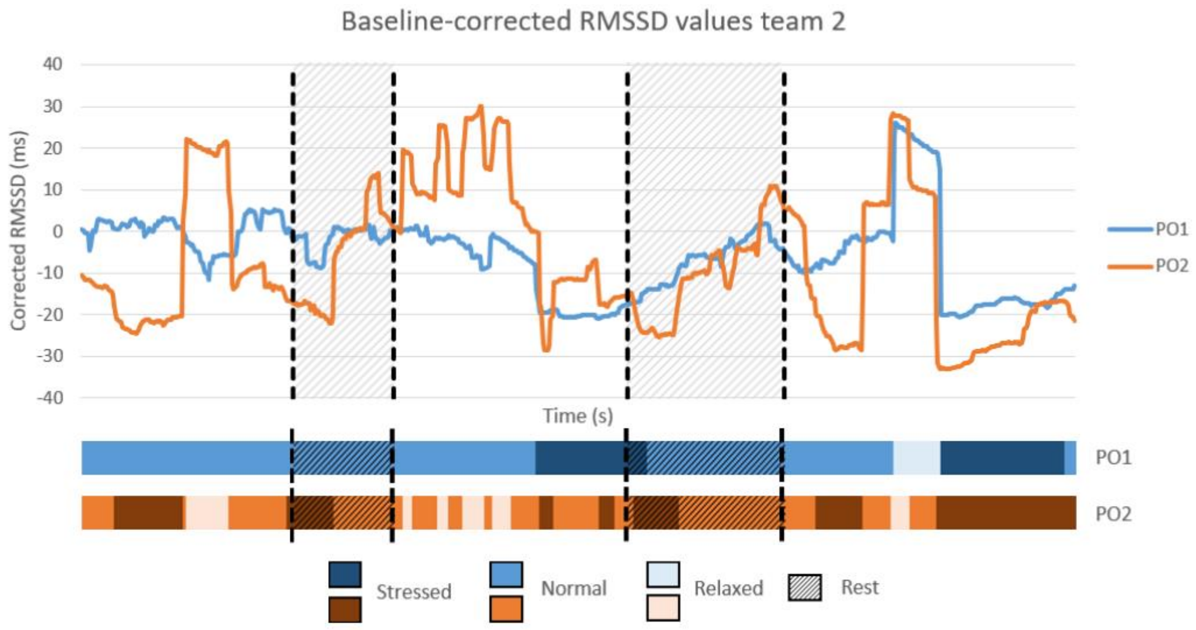
Baseline-Corrected RMSSD Values of Team 1 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

Figure 4

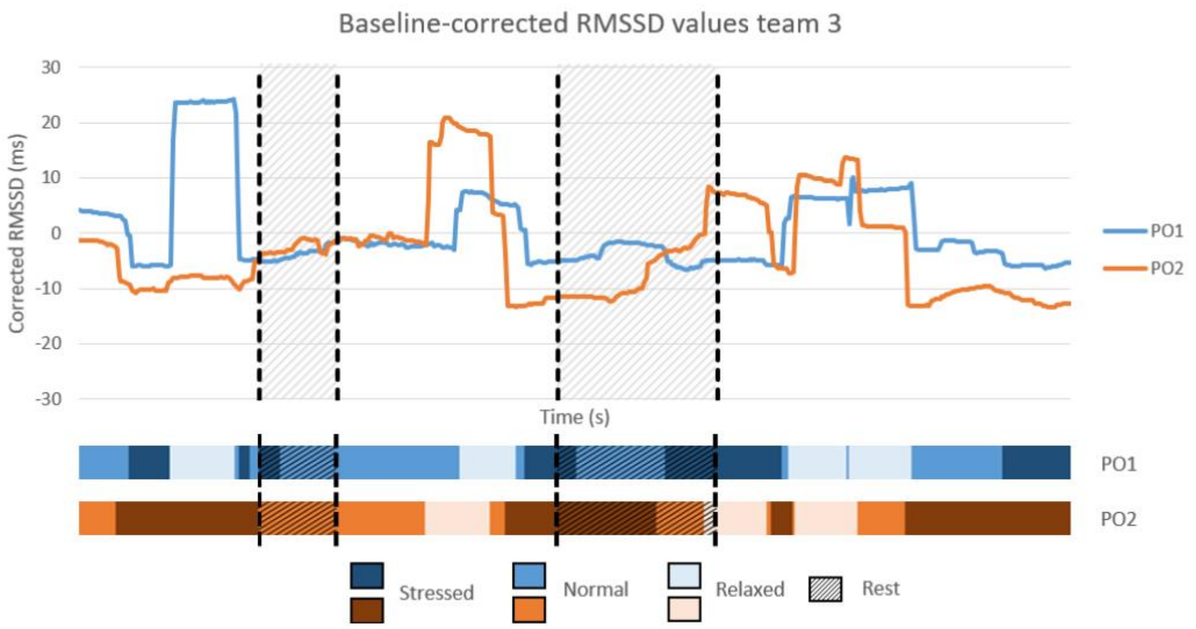
Baseline-Corrected RMSSD Values of Team 2 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

Figure 5

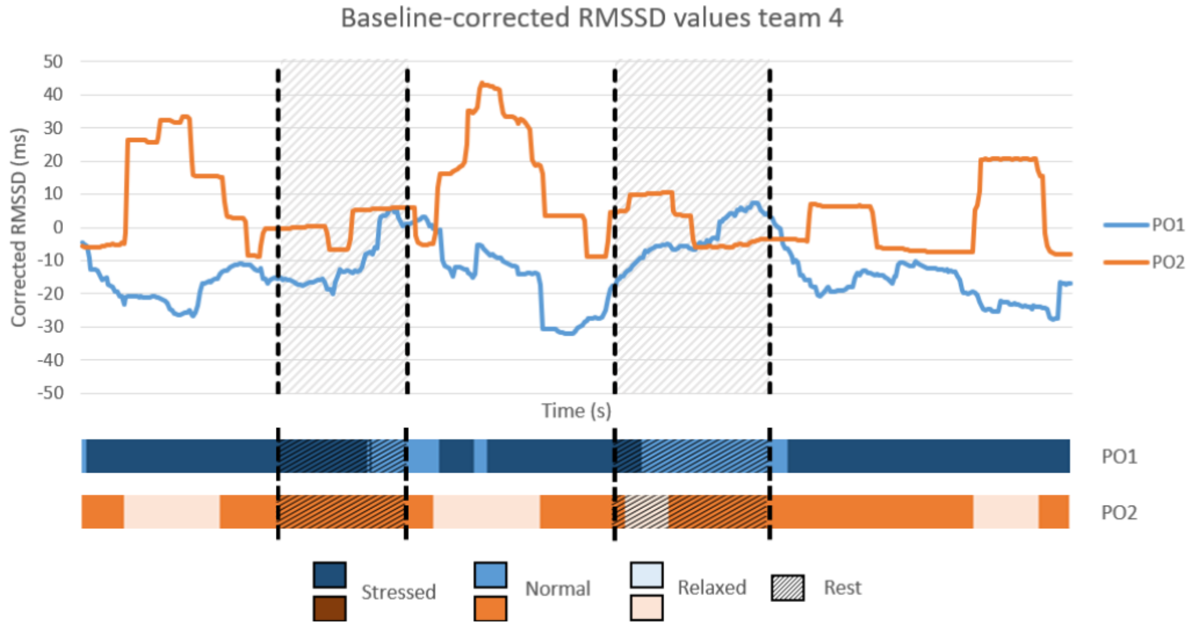
Baseline-Corrected RMSSD Values of Team 3 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

Figure 6

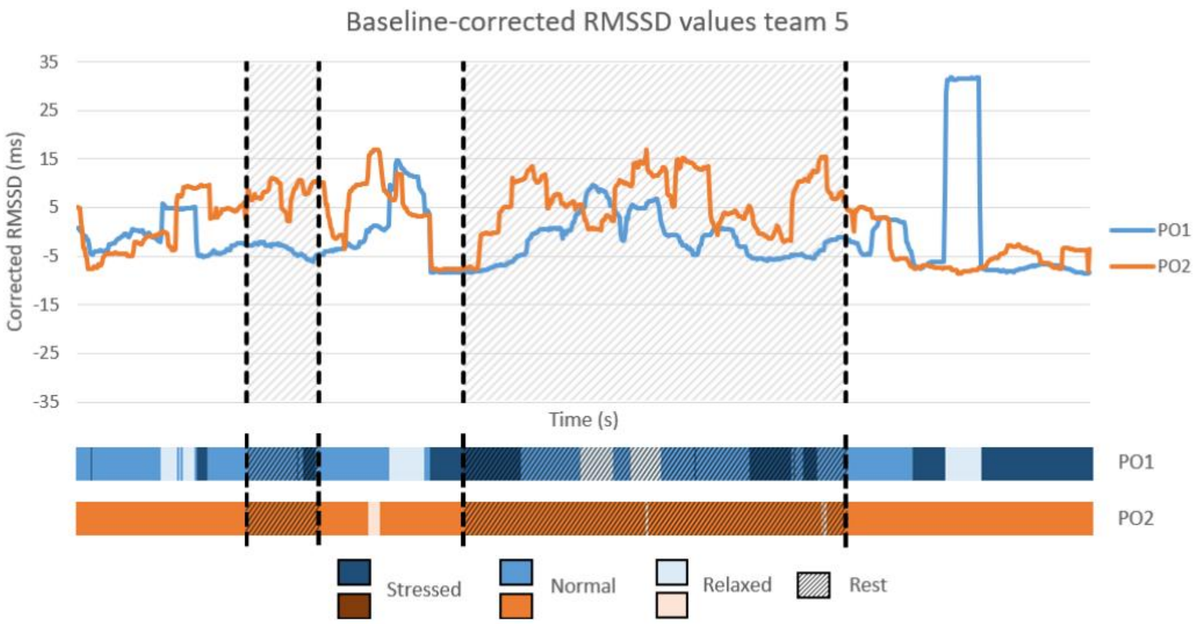
Baseline-Corrected RMSSD Values of Team 4 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

Figure 7

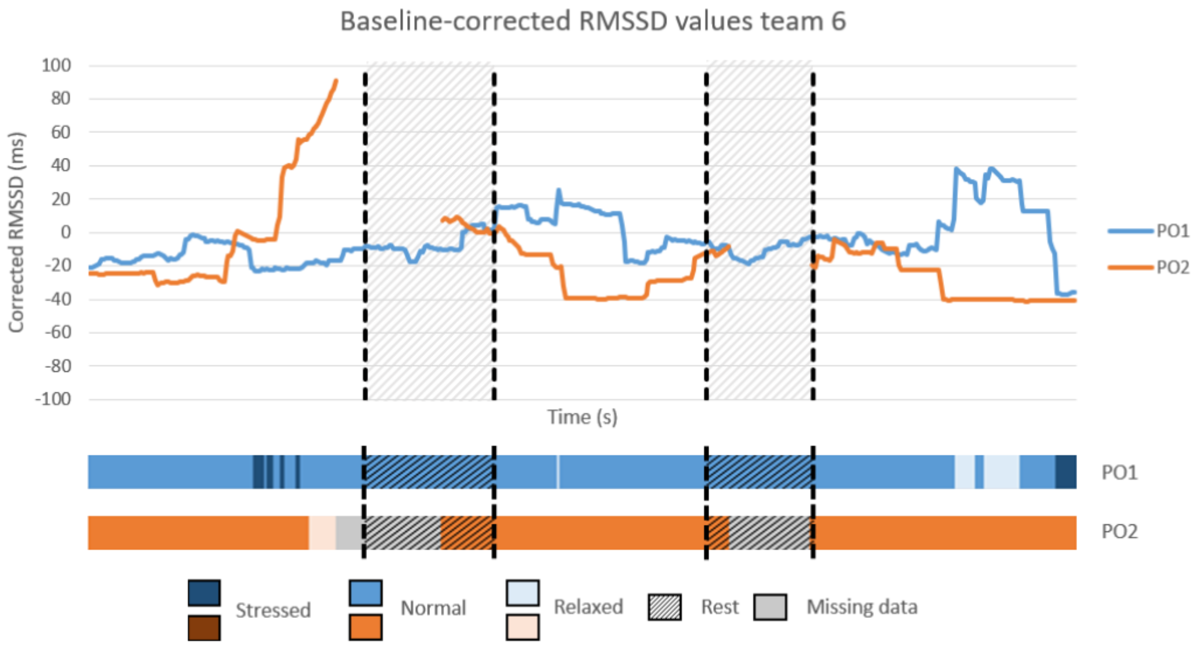
Baseline-Corrected RMSSD Values of Team 5 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

Figure 8

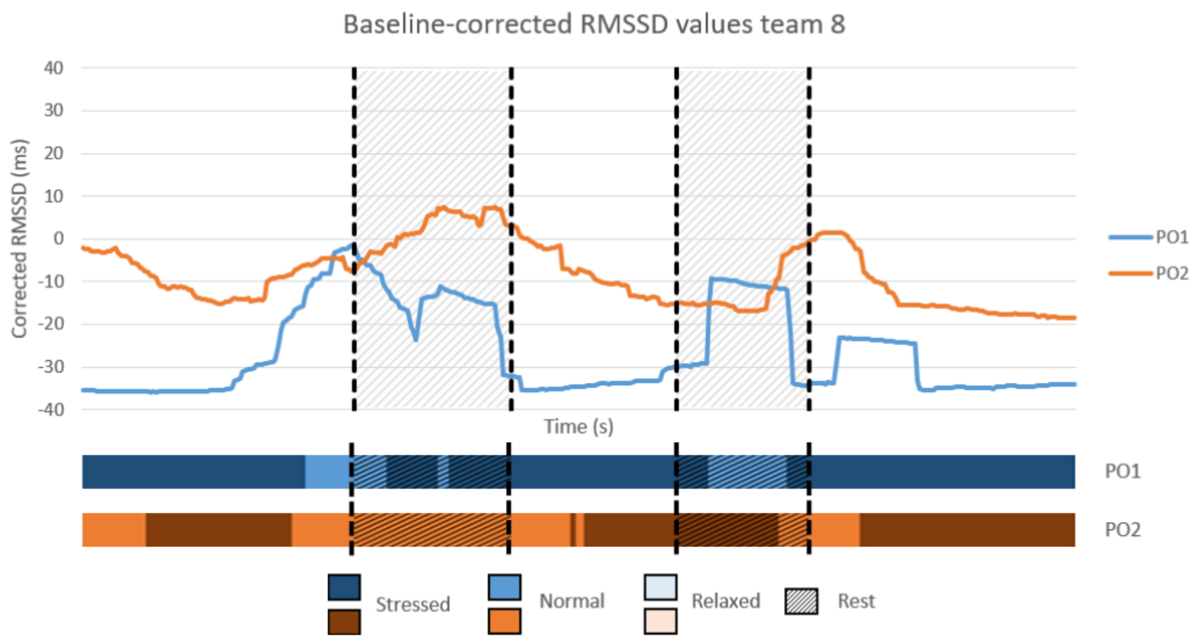
Baseline-Corrected RMSSD Values of Team 6 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

Figure 9

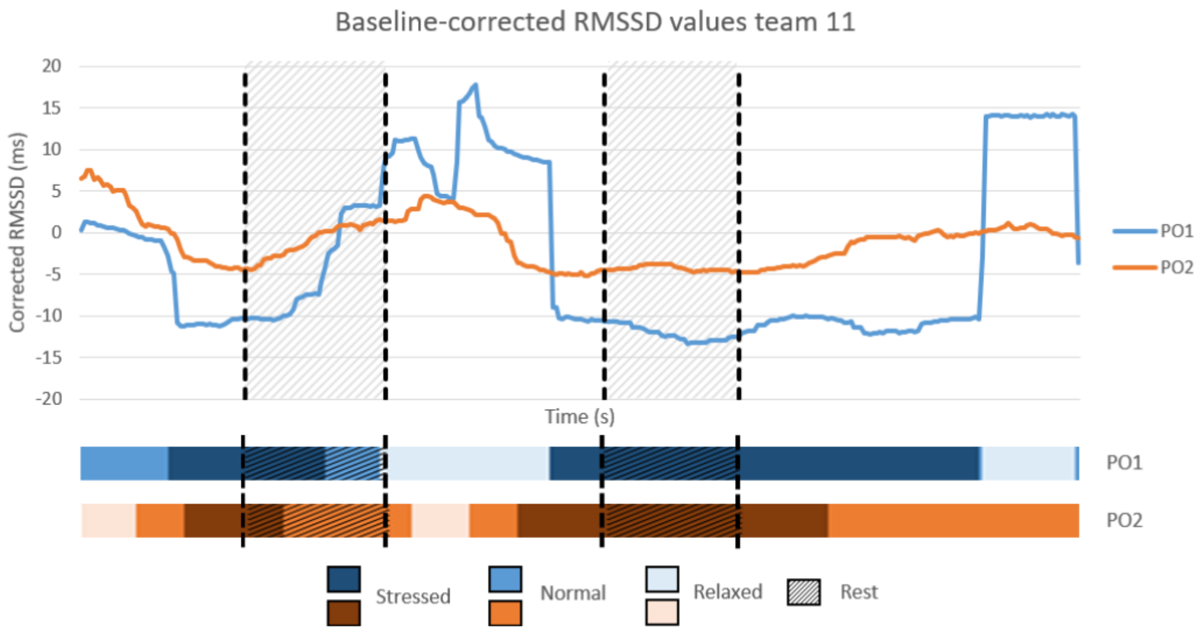
Baseline-Corrected RMSSD Values of Team 8 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

Figure 10

Baseline-Corrected RMSSD Values of Team 11 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

On the individual stress level, it becomes apparent that, although police officers within a team often show similar stress level patterns, a general trend across all teams is not visible. Hence, moments of simultaneous (no-)stress are compared to investigate if a general trend across the teams can be detected.

Moments of Simultaneous (No-)Stress Occurrence per Team

The individual stress levels of the police officers show high across-team variety. But if it is taken to the team level, the moments that both police officers experience stress (i.e., simultaneous stress) and the moments where both police officers do not experience stress (i.e., simultaneous no-stress) are relevant, because they give insight into the behavioural changes due to stress of the team as a whole. In five out of the eight teams, i.e., teams 1, 2, 3, 8, and 11 (Figures 3, 4, 5, 10, and 11) both individuals experienced simultaneously stress during at least one of the scenarios. For both the LS and the HS scenarios, this simultaneous stress occurred during the beginning, the middle, or the end of the scenario (or a combination thereof). The MS scenario had an occurrence of simultaneous stress only at the end of the scenario.

In all eight teams, there were moments where neither of the individuals in the teams experienced stress during at least one of the scenarios, simultaneous no-stress. For the LS scenario, the simultaneous no-stress occurred during the beginning, the middle, or the end of the scenario (or a combination thereof). For the MS scenario, the simultaneous no-stress occurred usually at the beginning of the scenario, sometimes in combination with the middle of the scenario. For the HS scenario, the simultaneous no-stress occurred mostly in both the beginning and the middle of the scenario. Thereby the first sub-question about when stress occurs and whether this differs per scenario is answered.

Coordination Behaviour During Simultaneous (No-)Stress

Now that the simultaneous (no-)stress on the team level is mapped, the coordination behaviours that correspond with either simultaneous stress or simultaneous no-stress are compared, answering the second sub-question. The LS, MS, and HS scenarios are subdivided, because it became clear from Table 4 that these scenarios significantly differ. Especially concerning the actions displayed by the male and female civilians, which can therefore require other coordination behaviours.

The percentage of the time spent on coordination behaviour during simultaneous (no-)stress is given in Appendix D. This percentage is constructed out of the coded behaviours from the codebook of Table 1. As these behaviours are divided into categories (i.e., explicit action coordination [EAC], implicit action coordination [IAC], explicit information coordination [EIC], and implicit information coordination [IIC]) it is of interest to see which of these categories contribute to the total percentage of coordination behaviour and in what way. Adding the percentages of EAC, IAC, EIC, and IIC will not exactly reach 100% combined, because closed loop behaviour also contributes, but does not fall within one of the categories.

In Table 6 an overview of the percentage of the coordination that the different coordination categories contribute to is given. It is important to note the difference between a 0.00 per cent value and N/A. The N/A value is given when there were no moments of simultaneous (no-)stress present, and therefore there is no chance of any behaviours being displayed. Whereas, for the 0.00 per cent value, there was a chance for the behaviour to occur, but it did not. For every coordination category, the results are separately discussed below.

Under EAC fall the behaviours: *give instruction*, *planning*, and *speaking up*. It is striking that, looking at the average, for both the simultaneous stress and simultaneous no-stress situation in the HS scenario relatively much time is spent on EAC, 13.26% and 18.35%, respectively. The average values for both the LS and MS scenarios are close to each other for the simultaneous stress and no-stress situations ranging from 7.66% to 9.67%. The differences in the EAC percentage are more apparent between the scenarios than between the simultaneous stress versus simultaneous no-stress.

Table 6

The Percentage of the Coordination Behaviour During Simultaneous Stress or Simultaneous No-Stress Spent on the Coordination Categories per Scenario Per Team

Team #	Simultaneous stress			Simultaneous no-stress		
	LS	MS	HS	LS	MS	HS
			Explicit action coordination (EAC)			
1	0.00	0.00	N/A	25.00	0.00	7.32
2	N/A	0.00	16.36	2.90	4.94	6.06
3	0.00	0.00	3.17	0.00	3.85	16.67
4	N/A	N/A	N/A	N/A	0.00	0.00
5	N/A	N/A	N/A	2.44	4.41	11.76
6	N/A	N/A	N/A	16.36	29.41	20.00
8	0.00	15.00	16.13	0.00	N/A	N/A
11	37.50	33.33	17.39	6.90	11.43	66.67
Average	9.38	9.67	13.26	7.66	7.72	18.35
			Implicit action coordination (IAC)			
1	0.00	0.00	N/A	0.00	6.67	24.39
2	N/A	0.00	7.27	17.39	8.64	42.42
3	14.29	38.46	26.98	0.00	28.85	26.19
4	N/A	N/A	N/A	N/A	20.00	28.57
5	N/A	N/A	N/A	23.17	14.71	10.29
6	N/A	N/A	N/A	5.45	26.47	26.67
8	52.27	5.00	25.81	100.00	N/A	N/A
11	0.00	0.00	4.35	51.72	40.00	33.33
Average	16.64	8.69	16.10	28.25	20.76	27.41
			Explicit information coordination (EIC)			
1	0.00	0.00	N/A	0.00	20.00	2.44
2	N/A	0.00	34.55	5.80	2.47	0.00
3	0.00	0.00	0.00	0.00	0.00	4.76
4	N/A	N/A	N/A	N/A	0.00	0.00
5	N/A	N/A	N/A	6.10	0.00	5.88
6	N/A	N/A	N/A	18.18	8.82	10.67
8	22.73	15.00	3.23	0.00	N/A	N/A
11	0.00	0.00	17.39	10.34	0.00	0.00
Average	5.68	3.00	13.79	5.77	4.47	3.39
			Implicit information coordination (IIC)			
1	87.50	0.00	N/A	75.00	73.33	51.22
2	N/A	75.00	27.27	68.12	64.20	39.39
3	57.14	61.54	63.49	100.00	67.31	42.86
4	N/A	N/A	N/A	N/A	80.00	71.43
5	N/A	N/A	N/A	58.54	75.00	72.06
6	N/A	N/A	N/A	30.91	23.53	37.33
8	25.00	25.00	35.48	0.00	N/A	N/A
11	62.50	13.33	43.48	31.03	37.14	0.00
Average	58.04	34.97	42.43	51.94	60.07	44.90

Note. N/A differs from 0.00. For N/A there were no moments of simultaneous (no-)stress present. For 0.00 there were moments of simultaneous (no-)stress present, but they did not occur in the category.

Under IAC fall the behaviours: *action-related talking to the room*, *monitoring*, and *provide assistance*. The average percentage of all simultaneous no-stress scenarios is higher than the average percentage of the simultaneous stress scenarios. This indicates that during moments of simultaneous stress, less implicit action coordination is used regardless of the scenario's demands. Furthermore, it was observed that the average percentages of the LS and HS scenarios are similar in both conditions. During the simultaneous stress conditions, these were 16.64% for the LS scenario and 16.10% for the HS scenario. During the simultaneous no-stress conditions, these were 28.25% for the LS scenario and 27.41% for the HS scenario. For the MS scenario, the average percentages for IAC were lower compared to the LS, and HS scenarios, being 8.69% and 20.76% for simultaneous stress and simultaneous no-stress, respectively. This shows that the conditions for the MS scenario did not encourage the police officers to display IAC behaviour.

Under EIC fall the behaviours: *information request*, *information evaluation*, and *information upon request*. The average percentage of EIC was similar for simultaneous stress, and simultaneous no-stress for almost all scenarios, ranging from 3.00% to 5.77%. The exception was the simultaneous stress condition for the HS scenario. With 13.79% the amount of EIC was about three times as high as for all other conditions. The HS scenario thus elicited an increase in explicit information coordination during simultaneous stress.

Under IIC fall the behaviours: *gather information*, *information related talking to the room*, and *information without request*. It becomes apparent that out of all coordination behaviour categories, the IIC category is responsible for most of it with average percentages ranging from 34.97% to 60.07%. The differences between the simultaneous stress and simultaneous no-stress conditions are small for the LS and HS scenarios. In contrast, the differences between the simultaneous stress and simultaneous no-stress conditions are great for the MS scenario. During simultaneous no-stress about twice the amount of IIC is displayed compared to the simultaneous stress condition (i.e., 60.07% versus 34.97%).

Research showed that adaptive coordination is important (Faraj & Xiao, 2006; Grote et al., 2010; Manser et al., 2008; Rico et al., 2011; Williges et al., 1966), hence the ratio between implicit and explicit coordination during stress is relevant. More adaptive teams, that thus know when to use which coordination strategy, are also more effective (Rico et al., 2019). The ratio was calculated by dividing the explicit coordination behaviour by the implicit coordination behaviours. For this, the difference between action and information coordination was not taken into consideration. Moreover, closed loop behaviour was not taken into account, since this can be both implicit (e.g., nodding) or explicit (e.g., verbal acknowledgement).

In Table 7, the percentage of coordination behaviour that is either implicit or explicit is given. Under implicit fall the categories IAC, and IIC. Under explicit fall the categories EAC, and EIC. Moreover, the ratio between implicit and explicit coordination is given. A ratio higher than 1 indicates that there is more explicit coordination displayed than implicit coordination. It can be noticed that for all scenarios, the E/I ratio is higher during the simultaneous stress condition than during the simultaneous no-stress condition. The only condition that elicited a higher use of explicit coordination than implicit coordination is the MS scenario during simultaneous stress, with a ratio of 1.08.

Table 7

The Percentage of the Coordination Behaviour Spent on Implicit or Explicit Coordination and Their Ratio During Simultaneous (No-)Stress per Scenario.

Variable	Simultaneous stress			Simultaneous no-stress		
	LS	MS	HS	LS	MS	HS
Implicit (I)	22.32	11.69	29.89	34.02	25.23	30.80
Explicit (E)	15.06	12.67	27.06	13.43	12.19	21.75
Ratio (E/I)	0.67	1.08	0.91	0.39	0.48	0.71

Note. Implicit and explicit coordination behaviour percentages are used to calculate a ratio in which the explicit coordination behaviours are divided by the implicit coordination behaviours.

De-Escalation Behaviour During Simultaneous (No-)Stress

With the mapping of simultaneous (no-)stress on the team level, additionally, the de-escalation behaviours that correspond with either simultaneous stress or simultaneous no-stress are compared to answer the third sub-question. The LS, MS, and HS scenarios are subdivided, because it became clear from Table 4 that these scenarios significantly differ. Especially with regard to the actions displayed by the male and female civilians, which can therefore require other de-escalation behaviours. For the results, the de-escalation behaviours that did not deviate over time were left out. These were the de-escalation behaviours that were consistently present: *calm*, *human*, and *respect*. And the de-escalation behaviours that were not present at all: *shoes*, and *compromise*. This means that only the de-escalation behaviours *empower*, *honesty*, and *listen* are left to be analysed.

The percentage of the time spent on de-escalation behaviour during simultaneous (no-)stress is given in Appendix E. This percentage is constructed out of the coded behaviours from the codebook of Table 1. The de-escalation behaviour percentage is built up out of the de-escalation behaviours *empower*, *honesty, and listen*. It is interesting to see which of these behaviours contribute to the total percentage of de-escalation behaviour and in what way.

In Table 8 an overview of the percentage of the de-escalation that the different de-escalation behaviours contribute to is given. It is important to note the difference between a 0.00 per cent value and N/A. The N/A value is given when there were no moments of simultaneous (no-)stress present, and therefore there is no chance of any behaviours being displayed. Whereas, for the 0.00 per cent value, there was a chance for the behaviour to occur, but it did not. For every de-escalation behaviour, the results are separately discussed below.

Table 8

The Percentage of De-Escalation Behaviours During Simultaneous (No-)Stress per Scenario Per Team

Team #	Simultaneous stress			Simultaneous no-stress		
	LS	MS	HS	LS	MS	HS
			Empower			
1	0.00	0.00	N/A	0.00	0.00	0.00
2	N/A	0.00	0.00	8.00	8.47	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00
4	N/A	N/A	N/A	N/A	0.00	0.00
5	N/A	N/A	N/A	6.85	0.00	0.00
6	N/A	N/A	N/A	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	N/A	N/A
11	0.00	0.00	0.00	0.00	0.00	0.00
Average	0.00	0.00	0.00	2.12	1.21	0.00
			Honesty			
1	69.23	0.00	N/A	83.33	0.00	55.56
2	N/A	0.00	63.16	62.00	59.32	77.27
3	33.33	0.00	100.00	100.00	87.50	0.00
4	N/A	N/A	N/A	N/A	100.00	0.00
5	N/A	N/A	N/A	65.75	100.00	100.00
6	N/A	N/A	N/A	88.89	100.00	100.00
8	81.82	100.00	0.00	100.00	N/A	N/A
11	0.00	0.00	0.00	100.00	100.00	100.00
Average	46.10	20.00	40.79	85.71	78.12	61.83
			Listen			
1	30.77	100.00	N/A	16.67	0.00	44.44
2	N/A	100.00	36.84	30.00	32.20	22.73
3	66.67	0.00	0.00	0.00	12.50	0.00
4	N/A	N/A	N/A	N/A	0.00	0.00
5	N/A	N/A	N/A	27.40	0.00	0.00
6	N/A	N/A	N/A	11.11	0.00	0.00
8	18.18	0.00	0.00	0.00	N/A	N/A
11	0.00	0.00	0.00	0.00	0.00	0.00
Average	28.90	40.00	9.21	12.17	6.39	9.60

Note. N/A differs from 0.00. For N/A there were no moments of simultaneous (no-)stress present. For 0.00 there were moments of simultaneous (no-)stress present, but they did not occur in the category.

In Table 8, the percentage of de-escalation behaviour that *empower* contributes to is given. It was found that the *empower* behaviour was not used in the scenarios during simultaneous stress. Moreover, the *empower* behaviour was only used in three cases during simultaneous no-stress, being in team 2 during the LS and HS scenarios, and in team 5 during the LS scenario. Therefore, the average percentage of *empower* use was the highest during simultaneous no-stress being 2.12% for the LS scenario and 1.21% for the MS scenario, which is both still very low.

Moreover, the percentage of de-escalation behaviour that *honesty* contributes to is given in Table 8. A great part of the time spent on de-escalation behaviour is on the *honesty* behaviour. The average percentage of *honesty* behaviour displayed is greater in all scenarios during the simultaneous no-stress condition than during the simultaneous stress condition. Indicating that stress in police officers does hamper the use of the *honesty* behaviour. Additionally, the average percentage during simultaneous no-stress decreases over the scenarios. It goes from 85.71% during the LS scenario to 61.83% during the HS scenario. Moreover, it is noteworthy to mention that during the MS scenario in the simultaneous stress condition, only team 8 displayed the *honesty* behaviour. They did this the entire time in the simultaneous stress condition.

Lastly, the percentage of de-escalation behaviour that *listen* contributes to is given in Table 8. Interestingly, the *listen* behaviour is relatively more shown during the simultaneous stress condition than during the simultaneous no-stress condition, except for the HS scenario.

Discussion

This exploratory study aimed to determine the impact of stress on coordination and de-escalation behaviour in police teams. We used a novel, multimodal approach combining physiological data, and video observations to capture and map these dynamics over time during three distinct training scenarios with increasing stress levels. The findings show: 1) that simultaneous (no-)stress is present at different moments across the different training scenarios; and 2) that coordination and de-escalation behaviours were both displayed differently during moments of simultaneous stress than during moments of simultaneous no-stress. The stress responses of the police officers indicated that, especially during the MS scenario, the police officers learned to better cope with the stress generated by the scenario's stressors. Moreover, we showed how simultaneous stress, in the form of co-occurring decreased RMSSD values, may impact coordination behaviour categories and three de-escalation behaviours. Specifically, although the ratio of implicit coordination behaviours was greater in all but the MS scenario during simultaneous no-stress, a shift towards explicit coordination behaviours was found during simultaneous stress. In contrast, displayed in the de-escalation behaviours, the *listen* behaviour (i.e., implicit) is relatively more displayed than the *honesty* behaviour (i.e., explicit) during simultaneous stress. Below, we will discuss these results in more detail, including their theoretical and practical implications, limitations, and directions for future research.

Discussion of Findings

Different Scenarios Elicit Different Stress Responses and are Highly Individual

The first goal was to assess when stress occurred for the police officers in the different training scenarios. Therefore, the differences between the LS, MS, and HS scenarios were first established. With frequency and duration analyses of all coded behaviours, significant changes were mostly found in the behavioural actions displayed by both the civilians (e.g., *civilian threatening*) and police officers (e.g., *pepper spray*). Moreover, the coordinative behaviours changed significantly in the explicit action coordination *give instruction*, and the implicit action coordination *provide assistance*. Assistance is more often provided during the MS scenario than the LS scenario and instructions are more often given in the HS scenario than the LS scenario. Additionally, the *honesty*, and *listen* de-escalation behaviours significantly changed, both occur more often in the HS scenario than in the LS scenario. With their actions, the priorly instructed civilians were thus able to elicit different behaviours in the police officers. This is in line with the observations by Todak & James (2018) that the reaction of police officers is highly dependent on the actions of the civilians and calls for a case-by-case de-escalation approach.

Thereafter, looking at the overall stress in the scenarios, based on mean RMSSD values and mean percentage of stress, a pattern was observed, although the differences were not significant. Interestingly, the order of increasing overall stress was first the MS scenario, then the LS scenario, and thereafter the HS scenario. This could be explained by the fact that the police officers were instructed that they would perform a scenario three times. The first time, all was unknown, and this could increase one's stress levels (Dietz et al., 2017; Ishak & Ballard, 2012). The second time, they knew what they could expect, and they already had experienced it once, so they might have been less overwhelmed than the first time. Both the LS, and MS scenarios were based on verbal resistance or verbal force, therefore they might not have been anticipating the physical threat the HS scenario posed increasing their stress levels again (Dietz et al., 2017). The timing of simultaneous stress in the scenarios supports this reasoning. For both the LS, and HS scenarios that were characterised by unknown and new elements, the simultaneous stress occurred at various parts throughout the scenario. Whereas for the MS scenario, this simultaneous stress only occurred at the end of the scenario. This indicates that the police officers knew how to cope with the beginning and middle of this scenario.

Although three separate results support the reasoning above, it should be noted that stress responses are highly individual, which is also reflected by the big standard deviations in the mean RMSSD values, and in the mean percentage of stress. Using the baseline correction for the RMSSD values, the aim was to get rid of as many influencing characteristics as possible (e.g., age, gender, and weight) (Eyre et al., 2014; Fishel et al., 2007). However, it was observed that the minimum and maximum RMSSD values within a team (i.e., during the exact same scenario) still differed. It is argued that, for example, the years of experience as a police officer and stress coping mechanisms account for this (Kirschner et al., 2014). Likely, the more experienced police officers more often encountered similar scenarios during their work than their more inexperienced counterparts. As described by Kirschner et al. (2014), albeit in the context of students in aviation, the more experienced individuals experienced less stress and used different coping mechanisms than their less experienced counterparts. Therefore, behaviours when both police officers experience (no-)stress during the scenario can be considered generally (not) stressful and the behaviours during these periods are studied more closely.

More Explicit Coordination Behaviour Displayed During Simultaneous Stress

The second goal was to investigate whether the coordination behaviours displayed differed for various levels of stress. Although the small number of teams and the paired nature thereof did not allow to perform statistical tests, a clear difference between implicit and explicit behaviour during various levels of stress was observed. In line with previous literature, it was observed that there was relatively more explicit coordination behaviour displayed during simultaneous stress than during simultaneous no-stress (Faraj & Xiao, 2006; Grote et al., 2010; Manser et al., 2008; Rico et al., 2011; Williges et al., 1966). However, in all but the MS scenario during simultaneous stress, the relative use of implicit coordination was still greater than the use of explicit coordination. An explanation for this is that the average duration of implicit coordination behaviours was longer than the average duration of explicit coordination behaviours (see Table 4).

De-Escalation Behaviours Displayed and Changes During Simultaneous (No-)Stress

Interestingly, there were only three de-escalation behaviours that changed during moments of simultaneous (no-)stress. Part of this could be explained by the way of coding for the *human*, *calm*, and *respect* behaviours. They were coded as always present unless the behaviour was clearly not displayed. However, they were always present and did thus not change for simultaneous stress versus simultaneous no-stress. Although this does not allow for detecting any changes in these de-escalation behaviours it speaks in favour of the police officers participating in our research and maybe even Dutch police officers in general. The *respect* behaviour is an effective de-escalation method according to van der Steen (2020), with an 80% effectiveness. Moreover, Todak & James (2018) found significant, positive results for the effectiveness of both the *human* and *calm* behaviour. The *calm* behaviour is related to an increased ability to self-regulate, and the *human* behaviour is related to appropriate role division (van Lith et al., 2024).

On the contrary, there was also de-escalation behaviour that was not coded at all, namely *compromise*. This behaviour can be used to de-escalate the civilian by lowering the police officers' demands in turn for cooperation. It has been shown that agreeableness as a personality trait leads to an increased likelihood of using the *compromise* behaviour (Abrahamsen & Strype, 2010). Although police officers with this personality trait likely participated in the study, the task goal did not allow for much *compromise* behaviour, as the researchers told the police officers that they had to arrest the man. Additionally, the *shoes* behaviour expressing empathy was displayed a few times during the scenarios, but not during simultaneous (no-)stress. As shown by Giacomantonio et al. (2020) *shoes* is one of the more complex de-escalation behaviours and might therefore not be mastered by every police officer.

This leaves us with three de-escalation behaviours that are used in the scenarios and during moments of simultaneous (no-)stress: *empower*, *listen*, and *honesty*. The *empower* behaviour is the least used one and one that is more complex (Giacomantonio et al., 2020). More frequently used were *listen* and *honesty*. Based on the results for coordination behaviour, where relatively more explicit coordination was shown during simultaneous stress, one can hypothesise that during stress individuals speak more. However, this hypothesis can be rejected when looking at the de-escalation behaviours. The *listen* behaviour (i.e., implicit) is relatively more displayed than the *honesty* behaviour (i.e., explicit) during simultaneous stress. Another, more plausible, explanation is that police officers have a narrowed view (i.e., selective attention) during stress (Chajut & Algom, 2003; Driskell et al., 1999). However, where Driskell et al. (1999) argue that the focus on the team is lacking, there is now reason to believe that the first to suffer from selective attention are the civilians outside the team. This means that police officers use their cognitive ability to create coordination strategies and execute teamwork, hence they cannot verbally de-escalate anymore and therefore limit this to non-verbal *listen* behaviour (Sweller et al., 2011). This strengthens the call for suitable training environments, where even under stressful circumstances police officers can learn to de-escalate both verbal and non-verbal.

Limitations

This study has several limitations that should be considered when interpreting the results. An important limitation is the small sample size, which did not allow for statistical analyses on the behavioural data, and also limits the generalisability of this study. However, due to the exploratory nature of this study, valuable conclusions were still drawn suggesting the need for further research. Additionally, because the data collection was performed on two separate days, the actor playing the male civilian differed for about half of the teams. Although both actors were instructed likewise, their counterplay towards the police officers differed and for the six teams on day two (team 6 until team 11) the amount of resistance and verbal force displayed by the male civilian was greater than for the teams on day one (team 1 until team 5). Moreover, to limit the actor's physical discomfort, the researchers therefore sometimes stopped the scenarios a bit earlier, before the male civilian was (completely) handcuffed. Differences caused by factors such as a different actor would be less influential whenever the sample size is bigger, which would therefore improve this research.

Second, a completely new method to detect psychological stress was developed for this study. It would have been more appropriate to first test this in a less dynamic environment as the task alone plays a big role in predicting HR dynamics, such as HRV (Fusaroli et al., 2016). Additionally, it should be noted that there is no completely objective way to measure stress, because it is hard to determine whether the change in the measured variables related to stress is also really a cause of stress (Crosswell & Lockwood, 2020). In line with this, the cut-off of two standard deviations away from the baseline was not validated. With a sensitivity analysis, this cut-off could be studied more closely and validated (Jasim, 2021). Lastly, lag was not considered for the time it takes to process an external cue and see its effects in the RMSSD values. This is a simplification of reality, because it already takes up to half a second before a visual cue is perceived (Haji-Khamneh & Harris, 2009). Therefore, the behaviours corresponding to the simultaneous (no-)stress would also slightly differ. However, most of the results explained were based on big differences rather than minor differences, since statistical tests were not possible.

Third, the behaviours studied were coded with codebooks either adapted from a healthcare context (i.e., Co-ACT from Kolbe et al., 2013) or from a set of behaviours that was transformed into a codebook (i.e., de-escalation behaviours from Todak & James, 2018). This study and future research on police teams regarding coordination and de-escalation behaviour would benefit from a validated codebook. However, to further enrich the current study the interrater reliability of the current dataset could also be determined. An accurate interrater reliability score can be provided by letting a second coder code 15% of the dataset (Klonek et al., 2019).

Lastly, to be able to link the amount of stress back to team performance, as described by Yerkes & Dodson (1908) expert ratings on team performance are needed. The TEAM assessment, which can be adapted from the healthcare context could have provided such expert data (Cooper et al., 2010). Expert ratings were partly conducted through the questionnaire in Appendix B. However, these were only obtained during the second day of data collection, corresponding to three out of the eight analysed teams, which would not provide sufficient information. Expert ratings on performance would have benefited this study, allowing us to distinguish between higher-performing teams and lower-performing teams. With that, information on whether the higher-performing teams display other, more effective behaviours, than the lower-performing teams would be obtained. This information could be used to structure training on effective coordination and de-escalation behaviour.

Theoretical Implications

This research contributes to existing literature in at least three ways. First, it employs a multimodal approach to capture team dynamics, using physiological (i.e., HRV) and video observation data for unbiased stress detection and behaviour analysis over time. Thereby, it extends the frameworks of Kolbe et al. (2013) and Todak & James (2018) by adding stress as another, important, variable, where other studies fail to adopt such a fine-grained approach into team dynamics. Enabling us to link physiological stress to specific behaviours.

Second, it links simultaneous stress with a shift in coordination (i.e., from implicit to explicit) and reduced de-escalation behaviours, supporting theories that stress narrows attention and promotes self-focus (Chajut & Algom, 2003; Driskell et al., 1999). We found that the selective attention theory of Driskell et al. (1999) may be even more nuanced, as the team perspective decreases under stress, but only after individuals outside of the team are first neglected. These novel findings contribute to our understanding of narrowed attention under stress, which can only be attained by combining coordination and de-escalation behaviours with physiological stress.

Third, the simulation-based training environment allowed police officers to safely practice skills, revealing improved stress management over scenarios, especially those caused by similar stressors. This quick and safe way of learning can enhance safety for both police officers and civilians. However, in contrast with findings from Driskell et al. (2001) and McClernon et al. (2011) we should be cautious assuming that stress training is generalisable to novel stressors.

Practical Implications

As mentioned above, the use of simulation-based training environments as a facility to train skills provides good conditions to foster this. During this study, it became apparent that a shift from verbal resistance or force towards a scenario including physical resistance and threat elicited a whole new stress response. Therefore, for future training, it would be beneficial to practice every scenario at least two times with a similar stressor.

Moreover, during this study, the trainers from the IBT were not allowed to give feedback to the police officers in between the scenarios, because it could compromise the study results. When using such simulation environments as training, it would be beneficial to also provide feedback to the police officers participating, resulting in even better and smoother performance (Bosse et al., 2015). This feedback could be easily provided in between the scenarios. To avoid cognitive overload, we would suggest "that instructors should carefully prioritise instruction points and keep the number of pointers low" (Hutter et al., 2023, p. 15).

Lastly, it would be possible to transfer the data collection for the physiological stress to other environments, such as the work field. The Zephyr allows to capture the ECG signal and stores this internally, so no transmitter or receiver are needed and therefore there are no restrictions regarding its reach. Police officers would get equipped with a Zephyr at the start of their shift and the Zephyr's capacity allows to store all data during this shift. This gives researchers more information on the actual stress responses police officers have during their work. However, transferring video observation to the work field would pose more difficulties for both the practical side (i.e., do you still capture all relevant information) and the ethical side (i.e., is it ethical to film civilians).

Future Research

For future research building on the current research, a few study directions are advised. First, the used methods require validation. Both the codebook and the HRV method have proven to be useful in their current form, but to make these methods usable for other research a few more steps need to be taken. For the codebook, the first step is to provide an interrater reliability score. This would give insights into the interpretation of the codes, which for generalisability should be interpreted in the same way. Furthermore, because of the highly dynamic environment this study took place in and the physical movement of the police officers it could have impacted the HRV. Therefore, to assess if psychological stress was actually detected a study eliminating physical movement, but adding stressors can validate this (van Lier et al., 2020). Moreover, a sensitivity analysis to test the cut-off value of two standard deviations from the baseline to detect stress should be validated (Jasim, 2021).

Second, in this study, the simultaneous (no-)stress moments, were based on whether neither or both police officers were stressed. However, with the collected data it is also possible to not only detect simultaneous (no-)stress, but also to get information on physiological synchrony. Physiological synchrony has been of interest lately because it also measures dynamic constructs, for example it was able to link it to group cohesion and coordination (Gordon et al., 2020). When writing code for physiological synchrony it is suggested to apply the sliding window approach (Gorman & Wiltshire, 2024). Performing a sliding window approach for cross-correlation on the RMSSD values gives more fine-grained synchrony data. Studies have used cross-correlation to identify synchrony before, however these studies did not do so over time (Coutinho et al., 2021; Tschacher & Meier, 2020). A start for a script is already made but could not be validated sufficiently, because it was beyond the scope of this study. Therefore, the script written in Matlab is added in Appendix F, for future use.

Third, because this research highlights the individual stress response to stressors it would be interesting to further investigate what external cues act as stressors. Data regarding this is partly present because of the coded actions of both police officers and civilians. To link these actions to stress, the moments right before a period of stress can be studied. In the current study, the focus was merely on moments during simultaneous (no-)stress, but moments just before these phases would be relevant to detect external stressors. Additionally, more insight into the police officers' coping mechanisms to deal with psychological stress would be beneficial to determine the best ways to cope.

Fourth, to further extend the behavioural frameworks of Kolbe et al. (2013) and Todak & James (2018), a study that adds an expert assessment of performance to this multimodal study would be highly recommended. Differentiating between higher- and lower-performing teams, would shed a light on the truly effective coordination and de-escalation behaviours of teams. On the basis of this, training can be optimised and police officers can learn the best way to tackle different scenarios.

Conclusion

This study provided insight into the coordination and de-escalation behaviours of police officers during moments of simultaneous (no-)stress in a simulated training environment. Training in simulation environments not only fosters a safe training environment for both police officers and civilians, but also allows for unobtrusive multimodal data collection. This led to rich data that enhanced the detection of individual stress moments, and simultaneous (no-)stress moments, which enabled us to connect these to coordination and de-escalation behaviours. The insights from this explorative study showed that during times of simultaneous stress police officer's coordination behaviours shift from implicit to explicit coordination. At the same time, the attention of the police officers shifts away from explicit de-escalation behaviour. This study paved the way for future studies regarding multimodal studies comprising HRV data. A novel method was developed to contribute to the call for dynamic measurements. Therefore, this study contributes to advancing the knowledge on displayed coordination and de-escalation behaviour of police officers impacted by simultaneous stress. Thereby, it contributes to both research and practice, where complex team dynamics like coordination and de-escalation behaviours are connected to temporally observed stress.

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Appendix A: Questionnaire Before Scenario

VRAGENLIJST 1:

Proefpersoon nummer: ……….

Geslacht: M / V

Leeftijd: ………. jaar

Hoeveel jaar bent u werkzaam binnen de politie? ………. jaar

Hoeveel jaar bent u werkzaam binnen de politie in deze functie? ………. jaar

Appendix B: Questionnaire After Scenario

VRAGENLIJST 2: Na elk scenario

Proefpersoon nummer: ……….

Scenario nummer: ……….

Kleur muts: ……….

Teameffectiviteit
Kruis per stelling elke keer **één** antwoord aan (●): wij garanderen vertrouwelijkheid van uw antwoorden.

	Tijdens het scenario…	Geheel mee oneens	Oneens	Enigszins mee oneens	Neutraal	Enigszins mee eens	Mee eens	Geheel mee eens
1.	was mijn team effectief	O	O	O	O	O	O	O
2.	maakte mijn team weinig fouten	O	O	O	O	O	O	O
3.	leverde mijn team continu hoge prestaties	O	O	O	O	O	O	O
4.	zorgde mijn team voor werk met een hoge kwaliteit	O	O	O	O	O	O	O

BEOORDELINGSSCHAAL SUBJECTIEVE SPANNING

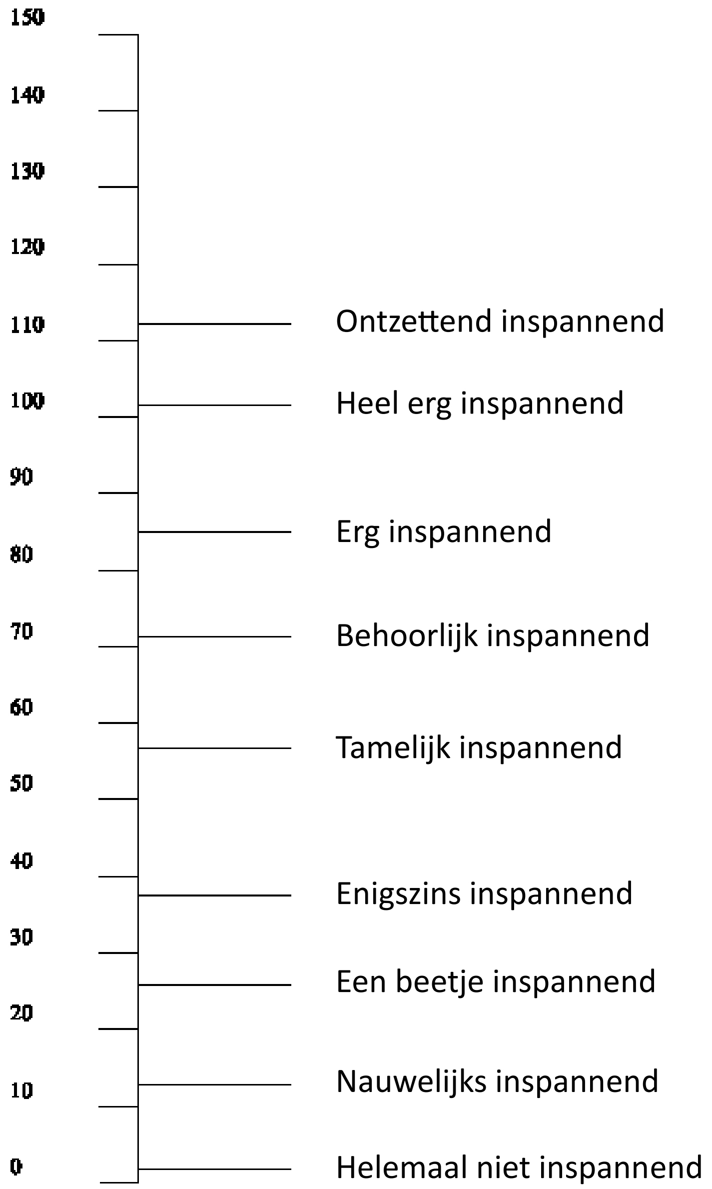
Hieronder staat een soort thermometer.
Wil je op de thermometer aankruisen hoeveel spanning je ervaren hebt tijdens het scenario?

in het geheel *geen* spanning

heel erg veel spanning

BEOORDELINGSSCHAAL SUBJECTIEVE MENTALE INSPANNING

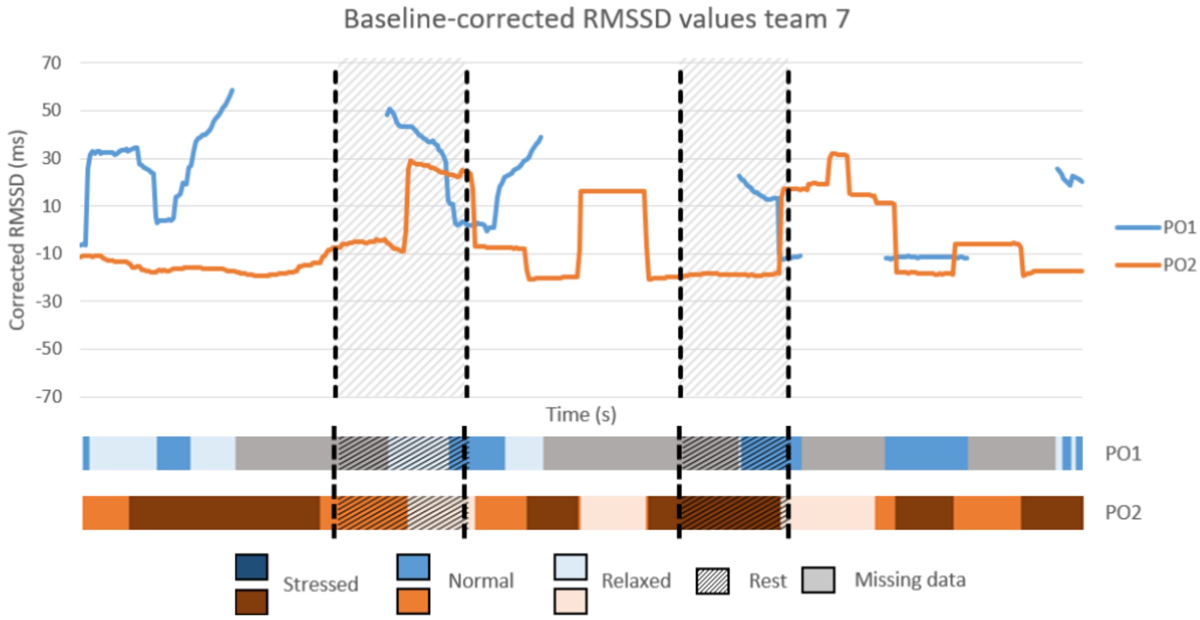
Hieronder staat een soort thermometer.
Wil je op de thermometer aankruisen hoe je de mentale inspanning ervaren hebt tijdens het scenario?



Appendix C: Stress Figures of Excluded Teams

Figure 11

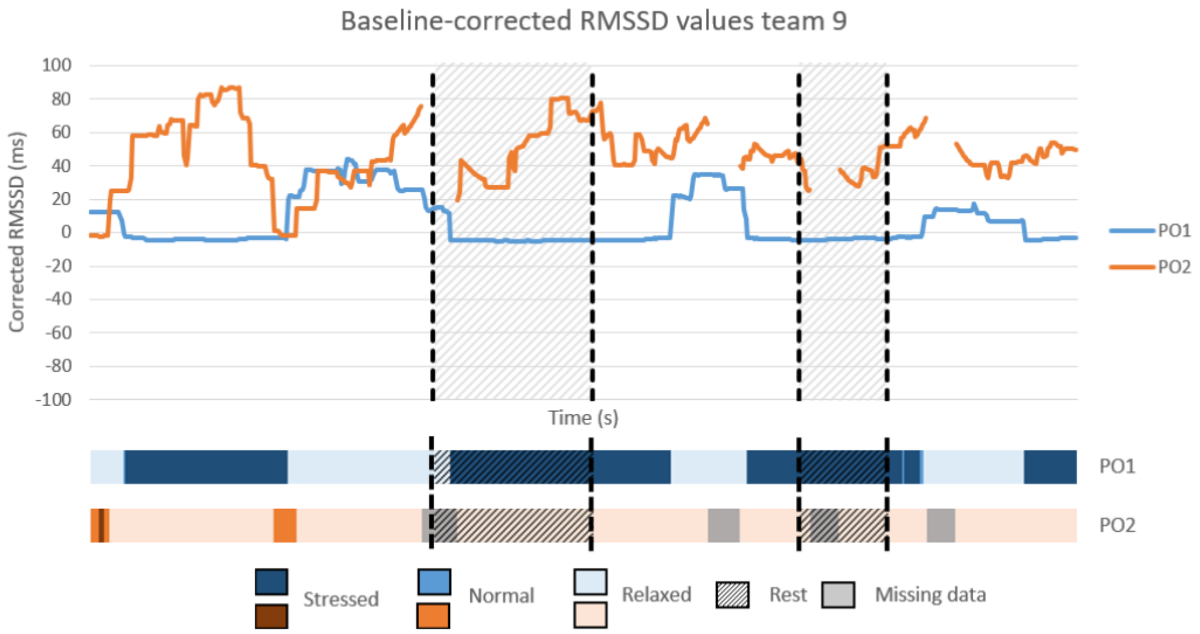
Baseline-Corrected RMSSD Values of Team 7 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

Figure 12

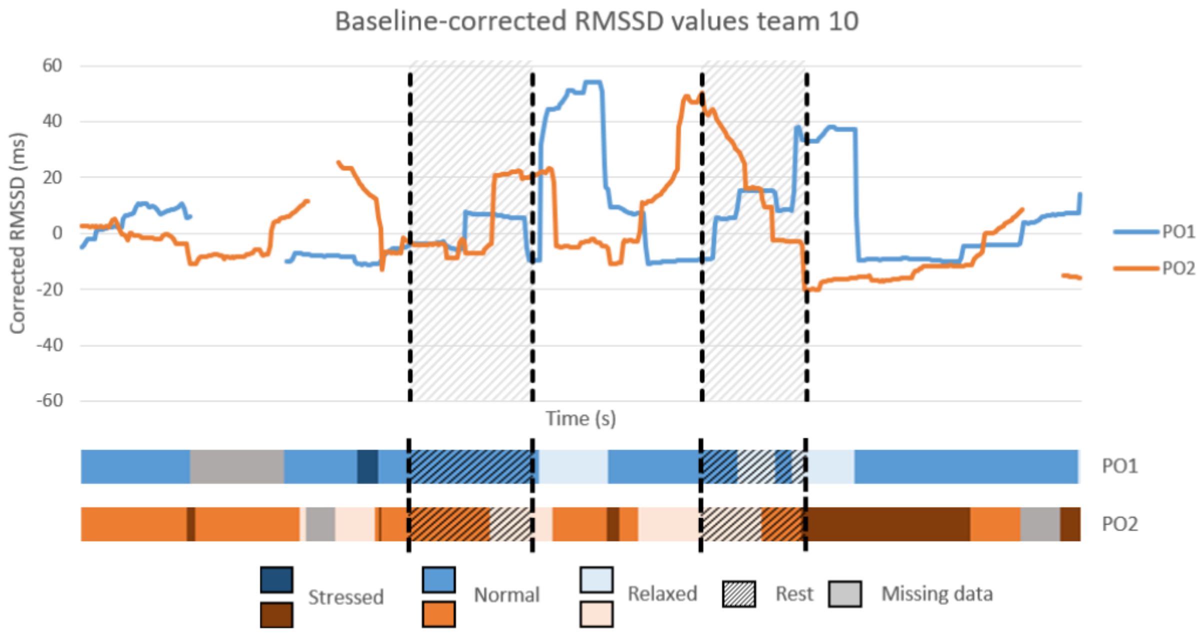
Baseline-Corrected RMSSD Values of Team 9 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

Figure 13

Baseline-Corrected RMSSD Values of Team 10 Over Time



Note. The baseline-corrected RMSSD values for police officer 1 (PO1) and police officer 2 (PO2) were plotted over time. The horizontal bars below the line graph indicate whether the police officers deviate (>2 SD) from their baseline value (RMSSD = 0 ms), indicating either a stressed or relaxed state.

Appendix D: Percentage of Time Spent on Coordination During Simultaneous (No-)Stress

Table 9

The Percentage of the Time During Simultaneous (No-)Stress Spent on Coordination Behaviour per Scenario Per Team

Team #	Simultaneous stress			Simultaneous no-stress		
	LS	MS	HS	LS	MS	HS
1	61.54	0.00	N/A	10.81	25.00	48.24
2	N/A	42.11	34.81	39.66	45.00	25.00
3	29.17	43.33	85.14	63.89	33.33	40.38
4	N/A	N/A	N/A	N/A	59.52	38.89
5	N/A	N/A	N/A	29.71	35.79	39.08
6	N/A	N/A	N/A	28.06	20.48	34.72
8	40.74	28.57	46.27	16.67	N/A	N/A
11	21.05	46.88	42.59	51.79	43.75	15.00
Average	38.12	32.18	52.20	34.37	37.55	34.47

Note. N/A differs from 0.00. For N/A there were no moments of simultaneous (no-)stress present. For 0.00 there were moments of simultaneous (no-)stress present, but they did not occur in the category.

Appendix E: Percentage of Time Spent on De-Escalation During Simultaneous (No-)Stress

Table 10

The Percentage of the Time During Simultaneous (No-)Stress Spent on De-Escalation Behaviour per Scenario Per Team

Team #	Simultaneous stress			Simultaneous no-stress		
	LS	MS	HS	LS	MS	HS
1	50.00	28.57	N/A	16.22	0.00	21.18
2	N/A	7.89	12.03	28.74	32.78	16.67
3	18.75	0.00	5.41	25.00	15.38	0.00
4	N/A	N/A	N/A	N/A	9.52	0.00
5	N/A	N/A	N/A	26.45	10.00	3.45
6	N/A	N/A	N/A	13.78	8.43	3.70
8	10.19	4.29	0.00	8.33	N/A	N/A
11	0.00	0.00	0.00	17.86	3.75	3.33
Average	19.73	8.15	4.36	19.48	11.41	6.90

Note. N/A differs from 0.00. For N/A there were no moments of simultaneous (no-)stress present. For 0.00 there were moments of simultaneous (no-)stress present, but they did not occur in the category.

Appendix F: Matlab Script Physiological Synchrony

```
% find crosscorrelation using sliding window approach
clear all
clc
close all
% load file and convert to easy-to-use arrays
NameFile = "NEW.xlsx";
data = readtable(NameFile, "ReadVariableNames",true);
time=data{:,1}; % data in hh:mm:ss format
NPO1=data{:,2}; % baseline corrected RMSSD values PO1
NPO2=data{:,3}; % baseline corrected RMSSD values PO1

% change the time array to time duration type data
time_duration = duration(time, 'InputFormat', 'hh:mm:ss');

% change the time duration array to seconds from the start of the scenario
time_seconds = seconds(time_duration - time_duration(1));

% handle NaN values by removing them -> not ideal, look for solution
valid_idx = ~isnan(NPO1) & ~isnan(NPO2); % find time stamps where neither is NaN

% extract data, not containing NaN data
NPO1_valid = NPO1(valid_idx);
NPO2_valid = NPO2(valid_idx);
time_valid = time_duration(valid_idx); % keep original time format for storing

% make sure the signals are the same length -> process not ideal
min_length = min(length(NPO1_valid), length(NPO2_valid));
NPO1_valid = NPO1_valid(1:min_length);
NPO2_valid = NPO2_valid(1:min_length);
time_valid = time_valid(1:min_length); % adjust time_valid to the new length

% define parameters for sliding window
window_width = 30; % 30 seconds window
slide_step = 1; % 1 second slide
Fs = 1; % a sampling rate of 1 Hz is present

% calculate number of samples per window = 30 in this case
samples_per_window = window_width * Fs;

% calculate the number of steps for the sliding window
num_steps = floor((length(NPO1_valid) - samples_per_window) / slide_step) + 1;

% initialize arrays to store zero-lag cross-correlation with time points
zero_lag_corr = zeros(num_steps, 1);
time_points_hhmmss = strings(num_steps, 1);

% loop through the data with the sliding window
for i = 1:num_steps
    start_idx = (i-1) * slide_step * Fs + 1;
    end_idx = start_idx + samples_per_window - 1;

    if end_idx > length(NPO1_valid)
        break;
    end

    % extract the windowed segments
    segment_NPO1 = NPO1_valid(start_idx:end_idx);
    segment_NPO2 = NPO2_valid(start_idx:end_idx);
```

```
    % calculate cross-correlation
    [c, lags] = xcorr(segment_NPO1, segment_NPO2, 'crosscor');

    % find the zero-lag index and store the corresponding value
    zero_lag_idx = find(lags == 0);
    zero_lag_corr(i) = c(zero_lag_idx);

    % store the corresponding time in hh:mm:ss (middle of the window) ->
    % not ideal
    time_points_hhmmss(i) = time_valid(start_idx + floor(samples_per_window / 2));
end

% combine the time stamps and zero-lag correlation values into a table
result = table(time_points_hhmmss, zero_lag_corr, ...
    'VariableNames', {'Time', 'ZeroLagCrossCorrelation'});

% optional: save the result to a CSV file with a given name
% writetable(result, 'zero_lag_cross_correlation.csv');

% plot the zero-lag cross-correlation over time
figure;
plot(datenum(time_points_hhmmss), zero_lag_corr);
datetick('x', 'HH:MM:SS');
xlabel('Time (hh:mm:ss)');
ylabel('Zero-Lag Cross-Correlation');
title('Sliding Window Zero-Lag Cross-Correlation');
grid on;
```