Interaction Patterns of Police Teams during Escalation and De-escalation.

Master Thesis

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Enjoy reading!

Abstract

Action teams operate in high-risk, dynamic environments, demanding continuous adaptation to establish effective coordination and meet situational demands. Therefore, we investigated how these teams coordinate by studying team interaction patterns of nine police teams. Moreover, in the context of police, an essential element of successful coordination is effectively communicating with citizens. Consequently, this research also examines external communication (i.e., citizens) by looking at performed de-escalation tactics. This exploratory study analysed police teams' moment-by-moment interactions by coding video recordings of high-risk virtual reality scenarios. The pattern recognition software "THEME" was used to systematically explore patterns for the escalation and de-escalation phase through T-pattern analysis. Additionally, frequency analyses were performed to investigate team interaction and external communication within the de-escalation phase. Findings revealed teams display different interaction patterns in the escalation and de-escalation phase. However, this difference varies for the studied scenarios, indicating task demands require different ways of interacting. Additionally, the team de-escalating quickest showed more information-transferring interaction, indicating a high anticipation of other team members' information needs. Also, these teams performed different de-escalation tactics, indicating directive interaction supports quicker de-escalation. Hence, this study makes a meaningful contribution by revealing teams require different forms of coordination, in terms of team interaction and de-escalation tactics, to adapt to different task demands. Findings underscore the potential of specifically examining which team interaction and de-escalation tactics can establish effective coordination and lead to effective handling within action teams. Consequently, this study is meaningful for both science and practice, providing insights into coordination dynamics by looking at interaction.

Keywords: action teams, police teams, coordination, team adaptability, interaction patterns, team interaction, external communication, de-escalation tactics, T-pattern analysis

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Problem Statement

The ability of action teams, such as those in aviation, healthcare, firefighting, and the military, to meet task demands is vital because their performance has a major impact on human lives (Kleygrewe et al., 2022; Kolbe et al., 2014; Schraagen & Rasker, 2001; Van der Haar et al., 2017). The conditions under which these teams work are challenging, as they often operate in high-risk, dynamic environments characterized by time constraints, ambiguity, and uncertainty. This requires continuous adaptation of action teams to meet their task demands. Such teams are many times command-and-control teams, which have been described as teams representing multiple individuals with specialist and interdependent roles brought together to perform a complex, decision rich task (Jones & Roelofsma, 2000; Salas et al., 2001; Paris et al., 2000). Examples of situations command-and-control teams face are hostage situations, shootings, and arrests. To successfully perform and minimize incidents, it is vital for these teams to rapidly establish effective coordination, which involves “the use of strategies and behaviour patterns aimed at integrating and aligning the actions, knowledge, and objectives of interdependent members, with a view to attaining common goals” (p. 163, Rico et al., 2008). This is even more the case in the context of police teams, where they also have to communicate with citizens. Incidents stemming from ineffective coordination are particularly prevalent within police teams, often resulting in tragic loss of life (Engel et al., 2020; Lorei & Balaneskovic, 2023; Todak & James, 2018). Especially with regard to de-escalation, where officers have to stabilize situations and reduce potential threats through verbal and non-verbal communication with citizens (IACP, 2017). One notorious case that showed the disastrous consequences of poor de-escalation, is the tragic event in 2011, where 77 persons were killed by a terrorist in Norway. An independent commission's report described that, among other things, causes for the inadequate performance were communication problems and failure to follow trained procedures (Newswire, 2012; 22. juli-kommisjonen, 2012).

Due to the complex task environment of police operations, we ought to understand how these teams coordinate by studying their team interaction patterns and external communication (i.e., with citizens). Team interaction patterns are defined as “regular sets of coordinated behaviour in teams (i.e., verbalizations and nonverbal actions), repeated over time, occurring above and beyond chance” (p. 495, Lei et al. 2016). As team members need to collaboratively adapt to their environment, effectively coordinating a situation depends on teams’ interaction patterns instead of one single action (Stachowski et al., 2009). A more profound understanding of these patterns is necessary to gain in-depth knowledge and to train police members on how to act in their daily work.

Recent technology enables the collection of multi-modal data, offering new opportunities to study team interaction patterns and external communication patterns in detail (Fan & Wen, 2019; Muñoz, 2020). Even though we have the technology to investigate this continuous real-time data, research remains scarce, and does not exist in the field of policing to the researcher's knowledge. Therefore, this research aims to scientifically contribute by obtaining detailed insights into how police teams can functionally cooperate and how they can communicate effectively with citizens. Combining speech recordings and video observations allows for in-depth exploration of how police members interact and what behaviour they display in the context of simulated training environments. Additionally, this research intends to contribute practically by providing insights into which team interaction patterns are displayed among police teams. This could result in a better understanding of gaps between current and desired interaction, which could lead to improvements within training environments to address these gaps and train police members on specific interaction. Eventually, improved training environments have the potential to enhance performance of police teams and minimize incidents in their daily work, which could be of great value to society. Coding of interactions and observations will be combined with a T-pattern analysis to achieve the research aims.

Theoretical Framework

Collaboration within Police Teams

Police teams frequently operate in environments demanding high-stakes and time-sensitive interventions, such as performing search warrants, managing hostage crises, and responding to emergencies (Blumberg et al., 2019; Salas et al., 2001; Todak et al., 2018). Often confronted with complex, rapidly evolving situations, these teams must constantly assess the situation's context, estimate risks for themselves and others, establish communication with multiple parties, and make decisions regarding appropriate interventions, such as the use of force or provision of medical support. Given the potentially major impact of failure for police officers on colleagues, suspects, or innocent bystanders, meeting task demands is crucial. To successfully perform, it requires a joint effort of all team members to collaborate and coordinate their actions. The next section describes the importance of various verbal behaviours that teams employ to coordinate their actions, which are based on the model by Salas et al. (2005) and applied in the field of policing (Espevik et al., 2021; Espevik et al., 2022). This section will also make a connection with the observable behaviours from our code book adopted by Lei et al. (2016).

Team Adaptability

A growing number of studies acknowledge that team performance is related to the adaption of teams to their environment, especially when this environment is subject to major changes, as is the case for action teams (Lei et al., 2016; Takacs & Juhász, 2022; Uitdewilligen et al., 2018). The capability to engage in this, is called team adaptability, which is described as the team's ability to adjust team coordination and alter the course of action based on information gathered from the environment (Salas et al., 2005; Espevik et al., 2021). As police teams continuously engage in decision-making to coordinate their actions, their primary tasks are focused on (a) situation assessment, (b) planning, (c) development of action plans/action selection, and (d) the implementation of these plans (Burke et al., 2006; Salas et al., 2001). To construct a cohesive and adaptable plan, team members must capture pertinent information from their surroundings to assess the situation in which they are performing. This information is typically provided by a multitude of sources, including updates from individuals proximate to the situation, communication mediums (such as radio systems), and several technological tools as displays and sensors (for example Mobile Data Terminals and drones). Throughout this process, teams engage in a continuous cycle of planning and adjustment of actions in response to evolving circumstances and feedback from team members. Mutual performance monitoring, back up behaviour, and closed loop communication (CLC) play essential roles in this cycle and underlie effective interactions in action teams (Espevik et al., 2021; Burke et al., 2006; Salas et al. 2005). In the following part, mutual performance monitoring, back up behaviour, and CLC are explained. Based on prior theorizing on action teams, Lei et al. (2016) developed a coding scheme for capturing such interactions (Stachowski et al., 2009; Waller et al., 2004). Therefore, the connection with the observable interactions included in this code scheme is mentioned as well.

Mutual Performance Monitoring. Mutual performance monitoring refers to the capability of using suitable task strategies to establish a shared comprehension of the team environment (Espevik et al., 2021). While doing this, team members simultaneously pay attention to the performance of other members and their own behaviour (Espevik et al., 2022).

Mutual performance monitoring intends to ensure progression towards the shared team goal and enhance the accuracy of performance. Team members do this by *observing* each other (Salas et al., 2001; Salas et al., 2005). They look for errors, discrepancies between the executed tasks and the team's goal, possibilities to enhance performance, and gather information by *inquiring*. Then, they share information with their team members about the status, timing and pace of the plan they are executing, or *brief* them about what to expect in the next stage (Kozlowski, 1998). If necessary, they intervene and provide guidance by giving *commands*, or by *suggesting* another approach to reach the team's goal. This way of working, team members can provide real-time feedback, enhancing situational awareness and enabling their colleagues to adjust their actions to effectively coordinate the situation towards their shared goal (Burke et al., 2006). Prior research has found positive effects of mutual performance monitoring on team performance (Porter et al., 2010; Espevik et al., 2022)

Back Up Behaviour. By engaging in back up behaviour, team members ensure an even workload distribution to coordinate effectively throughout performance (Espevik et al., 2022; Burke et al., 2006). Back up behaviour reflects mutual supportive behaviour when requested by other team members, but also without explicit needs are being expressed. Team members anticipate one another's needs based on their understanding of respective responsibilities. To perform supportive tasks, it is important that team members notice and predict needs by other team members, and there is a shared understanding of the goal they are performing towards (Salas et al., 2001). Consequently, they are able to offer support by providing appropriate action or information. Mutual performance monitoring enables back-up behaviour, as it is used to gather information that serves as the base for back-up behaviour (Espevik et al., 2021; Salas et al., 2005). When a team detects, through mutual performance monitoring, that a member’s workload surpasses their capability, they can employ backup behaviours by reallocating work tasks to other team members. This redistribution can take place in the form of *commands*, *suggestions*, or *briefing* behaviours. Back up actions have been identified as an important behaviour contributing to team performance in previous studies (Espevik et al., 2022; Marks et al., 2002; Zhou & Pazos, 2020).

Closed Loop Communication. In order to coordinate effectively, teams must ensure that relevant information is transferred and received throughout the team (Espevik et al., 2021). Closed loop communication (CLC) is proposed as a coordinating mechanism to reach this aim. CLC is a communication model derived from military radio transmissions, emphasizing verbal feedback to ensure the team comprehends the message accurately. It involves three-steps: (1) the transmitter delivers a message to the intended receiver, for example in the form of a *briefing, suggestion*, *inquiry*, or *question* (2) the receiver verbally *answers* or a*cknowledges* receipt of the message (seeking clarification through *questions* if necessary), and (3) the initial transmitter *confirms* that the message has been received and correctly understood, thus closing the loop (Burke et al., 2004). By adhering to this, team members enhance their coordination, as they ascertain information is transferred and received properly, creating a shared understanding. Furthermore, by using CLC communication errors could be prevented, such as failing to hear critical information (Waller & Kaplan, 2016). Prior research in healthcare and policing found a negative relationship between CLC and the number of critical incidents (Lacson et al, 2016), medical errors, and an increase in working speed and team performance (El-Shafty et al., 2018; Espevik et al., 2021).

Overall, from the perspective of team adaptability, team effectiveness could be viewed as how successful teams are in altering their operations to meet changing situational demands. To achieve this, teams engage in several interactions that resemble mutual performance monitoring, back up behaviour and CLC. Accordingly, action teams may exhibit specific interaction patterns that involve the interchange of these interactions, which could enable successful coordination (e.g., Lei et al., 2016; Stachowski et al., 2009; Uitdewilligen et al., 2018; Zijlstra et al., 2012). The next section will elaborate on this.

Team Interaction Patterns

In recent decades, there is a growing interest among scientists to study interaction patterns within action teams as it has the potential to predict and increase team performance. These patterns have previously been studied in multiple fields, such as aviation, firefighting, and nuclear power plant control room crews (Lei et al., 2016; Rico et al., 2021; Stachowski et al, 2009; Zijlstra et al., 2012). Team interaction patterns can be defined as: “regular sets of coordinated behaviour in teams (i.e., verbalizations and nonverbal actions), repeated over time, occurring above and beyond chance” (p. 495, Lei et al. 2016).

Characteristics of Team Interaction Patterns

Teams may need specific interaction patterns to function effectively and meet their task demands. Several characteristics of team interaction patterns can provide insight into how teams interact, divided into quantitative and qualitative characteristics (Casarrubea et al., 2015; Magnusson, 2000; Magnusson, 2020). Quantitative characteristics include the pattern occurrence, pattern heterogeneity, mono-actor patterns, pattern length and the pattern level. Pattern strings are considered a qualitative characteristic.

Firstly, the pattern occurrence includes the number of pattern occurrences within a certain time interval and is indicative to which extent teams function in a structured and consistent way (Casarrubea et al., 2015; Lei et al., 2016; Stachowski et al., 2009). Teams displaying recurrent patterns act in a more consistent way, while teams that exhibit less recurrent patterns behave less stable. The periods in which a team displays recurrent patterns refer to a so called 'equilibrium' in their coordination (Gorman et al., 2012), indicating greater stability. Secondly, pattern heterogeneity refers to the number of different patterns that teams display. More heterogenous patterns denote a higher number of different interaction patterns, while a lower amount of different interaction pattern means that a team acts in a more homogenous way (Hoogeboom & Wilderom, 2020; Zijlstra, 2012). More heterogeneous patterns indicate more flexible, nonstandard, or prescribed interaction within the team and has been associated with more information and knowledge sharing among team members. Thirdly, mono-actor patterns refer to patterns of interaction that involve only one individual (Zijlstra, 2012). Mono-actor patterns are indicative to which extent interaction is reciprocal, or in other words, balanced. A high number of mono-actor patterns represents one-sided, non-reciprocal interaction within teams. In uncertain situations reciprocity is vital as it contributes to the exchange of information to establish and maintain a shared understanding of the task and situation. Especially when there is a gap between the situational demands and the standard ways of working, reciprocal interaction is necessary to anticipate bottlenecks and divide workload over the available resources in order to remain highly responsive (David et al., 2024; Stachowski et al., 2009; Woods et al., 2021; Zijlstra et al., 2012). Furthermore, the pattern length and pattern level are indicators for the degree of complexity displayed in interaction patterns. Pattern length refers to the number of event-types within a specific pattern. Depending on the number of behaviours patterns entail, they can be longer or shorter. Patterns could involve multiple behaviours or exist out of a single pair of behaviours. The pattern level denotes hierarchical complexity and refers to the number of behavioural sets in its hierarchical structure (Casarrubea et al., 2015). More levels are an indication of a higher degree of complexity in team interaction. The complexity is important for understanding team interaction in changing situational demands, as a lower level of complexity suggests an adaptive response to occurring events for which standard ways of working may not be available (Waller & Kaplan, 2016). Finally, the pattern string is the qualitative composition of patterns, indicating the event-types included in each pattern, in order of occurrence. This provides insight into the content of interaction patterns. All characteristics can be captured with the utilization of a T-pattern analysis. Details about the T-pattern analysis can be found in the method section.

Team Interaction Patterns and Task Demands

In previous research, two main types of situations in which team interaction patterns are studied can be distinguished; routine and non-routine events. Aligning with previous research, we define routine events as static, predictable events, that require adhering to explicit operating procedures (Howard-Grenville, 2005; Lei et al., 2016; Rico et al., 2008; Takacs & Juhász, 2022). Operations and procedures allow more time for teams to combine their diverse expertise, create plans of action and explicitly coordinate their work tasks (Lei et al., 2016). Hence, team interactions often encompass numerous rounds of iterations among members, in which ideas, information, and knowledge are exchanged, fostering a deeper understanding and anticipation of each other's behaviour (Hoogeboom & Wilderom, 2020). In routine situations, effective teams have been found to exhibit interaction patterns that are more consistent, longer, more complex and participative (Lei et al., 2016; Zijlstra et al., 2012).

As opposed to routine events, team interaction patterns have been studied in the task context of non-routine events, which are described as high-risk, unexpected situations, indicating an event that requires team members to change their existing strategy as this may not map onto existing schemas (Lei et al., 2016; Waller & Kaplan, 2016). Non-routine events require teams to quickly interpret new information and engage in shared sensemaking to decide upon strategy, within dynamic circumstances involving high time pressure and ambiguity (Rico et al., 2008; Takacs & Juhasz, 2022; Waller et al., 2004; Yu et al., 2008; Zijlstra, 2012). In contrast to routine events, during non-routine events effective teams displayed patterns that are shorter, less reciprocal, less hierarchically complex and more homogenous (Stachowski et al., 2009; Lei et al., 2016; Waller et al., 2004). In addition, Kanki et al. (1991) found that the best performing teams displayed almost identical communication patterns, indicating that effective teams display less patterned interaction, and exhibit more homogenous patterns because of their consistent interactions. Likewise, Waller et al. (2004) found that better performing teams were less involved in information exchange and interaction. These findings imply that brief and efficient interaction is important within non-routine situations. An explanation for this may be that adhering procedures responses make teams less susceptible to the confusion and stress (Zellmer-Bruhn et al., 2004). Likewise, teams that consistently follow established interaction norms may prevent the ambiguity of having to decide which tasks to prioritize and allocate tasks (Waller, 1999).

In summary, interaction patterns that are found to be effective change according to the task demands teams are facing. Therefore, it is important to study their moment-by-moment changes and spot where adaptation occurs.

External communication patterns

To successfully perform and minimize incidents, police teams require not only to rapidly establish effective interaction within their team, but also to effectively communicate with citizens by performing de-escalation tactics (Lorei & Balaneskovic, 2023). Previous studies on team interaction patterns did not focus on external communication patterns as these teams (e.g. aviation, firefighting, nuclear power plant control room crews and healthcare) rarely interact with individuals outside their team while operating (Kolbe et al., 2014; Lei et al., 2016; Rico et al., 2021; Stachowski et al, 2009; Zijlstra et al., 2012). This is different for the task-context of policing, as officers frequently engage with citizens while operating (Todak, 2017; Todak & James, 2018). Although two studies record communication with individuals outside the studied teams, their interaction patterns are not studied yet (Endedijk et al., 2018; Lei et al., 2016). We believe that including external communication in this research could be valuable to help the field move forward.

De-escalation & Use of Force

Despite the lack of a universal consensus of police officers' primary role while encountering citizens, whether it be saving lives, enforcing the law, preserving peace, or maintaining public trust, de-escalation is presented as a strategy to contribute to all of these duties as it is fundamentally rooted in the central mission of law enforcement, which is the safeguarding of human life (President's Task Force on 21st Century Policing, 2015; Police Executive Research Forum, 2016; Todak, 2017). Often, police officers are called when a situation is escalating, which involves the process by which a situation becomes more intense or volatile (Oliva et al, 2010). It often comprises an increase in tension, aggression, or conflict. Police officers can intervene by interacting with involved citizens, thereby using de-escalation tactics. Following the *National Consensus Policy and Discussion Paper on Use of Fore* (IACP, 2017), the following definition of de-escalation will be used in this research:

> Taking action or communicating verbally or non-verbally during a potential force encounter in an attempt to stabilize the situation and reduce the immediacy of the threat so that more time, options, and resources can be called upon to resolve the situation without the use of force or with a reduction in the force necessary. De-escalation may include the use of such techniques as command presence, advisements, warnings, verbal persuasion, and tactical repositioning. (p.2)

Thus, with the aim to safeguard citizens, while also protecting their own safety and the safety of team members, police teams require to effectively communicate and potentially use appropriate force to stabilize situations and reduce potential threats (IACP, 2017; Oliva et al, 2010). To accomplish this, police officers may use several de-escalation techniques, varying from verbal interaction and minimal physical contact (such as handcuffing) to the use of non-lethal force weapons like pepper spray and tasers, and, in the most extreme cases firearms, which could result in deadly force. The level of force applied is depending on what is considered appropriate according to the situation, and should be judiciously, reasonably, and in accordance with the law (Police Executive Research Forum, 2016).

Police-citizen Encounters: a Multistage Process

Beyond the concept of proportionality of the use of force, multiple scholars acknowledge that police-citizen encounters could be understood as multistage processes. From this perspective, each interaction unfolds through a series of distinct phases, wherein both police officers and civilians engage in decision-making processes and react to the choices made by the other party (Fyfe, 1986; Terrill, 2005). Binder and Scharf (1980) introduced a four-phase model for the evaluation of use of force, which emphasizes the influence of each of these stages on the eventual outcome. The first phase of this framework is *anticipation*, which refers to the moment when officers become aware of the issue. This awareness is often triggered by a radio dispatch or the officer's personal observation. The second phase is called *entry and initial confrontation,* during which officers arrive at the scene and make an initial assessment of the situation. In this phase, officers also establish police authority, set the tone for the police response, and communicate expectations to citizens. During the third phase, which is called *dialogue and information exchange*, officers interact with suspects, victims, and witnesses to gather facts. According to research of Friedell and Binder (1992) this phase has the most significant influence on whether a potentially violent situation could result in the use of lethal force. Transition to the fourth phase, called *final decision-making*, occurs when officers have identified the issue and perform a solution. During this phase, officers make the decision regarding the use of force. From this perspective, it becomes evident that officers have various opportunities right from the start of a call to take measures aimed at preventing conflict and violence. However, as argued by Fyfe (1986), most assessments of police force tend to fixate on the final moments of an encounter, often overlooking the critical impact of the officer's initial interactions on the course of events and the eventual outcome. A study from Correll et al. (2007) explored this issue, referred to as the "split-second syndrome" (p. 207), and underscored the significance of how dispatch information can shape officers' anticipation regarding the potential need for the use of force. Providing additional empirical assessment of the model, Pickering and Klinger (2023) found that the presence and actions of other officers at the scene can significantly influence an officer's decision-making process in a high-risk police-citizen encounter. Taken together, there are multiple phases during de-escalation where officers can influence the eventual outcome by communicating verbal de-escalation tactics towards citizens.

De-escalation Tactics

To avoid or reduce the use of (lethal) force and resolve the situation in the most optimal manner, police officers may employ various verbal de-escalation tactics during a potential force encounter. The *National Consensus Policy and Discussion Paper on Use of Fore* (IACP, 2017) describes various techniques of de-escalation. First, building rapport trough recognizing and acknowledging a person’s feeling. Using this technique, it is important to approach the individual calmy and maintain composure. Secondly, speaking calmy is considered as a de-escalation tactic. Using positive statements may help in the process of calming the individual. Other verbal tactics that are mentioned, are advisements, warnings, and verbal persuasions.

Todak and James (2018) conducted a study in which police officers were observed during ride-alongs to investigate how de-escalation techniques were utilized. They discovered that officers often employed de-escalation techniques during their interactions with citizens. Most frequently, the officers used *respectfulness*, efforts to minimize the power imbalance and appear more “*human*”, and *active listening*, which allowed citizens to display their perspectives. Through regression analysis, the authors discovered that *maintaining a calm demeanour* and *emphasizing humanity* were associated with citizens adopting a calm demeanour by the end of the encounter. Examining perceptions of de-escalation among officers who were considered skilled de-escalators by their peers, Todak and White (2019) also identified several de-escalation tactics. First, in line with Todak and James (2018), they found officers deployed *emphasizing humanity* in an attempt to stabilize the situation, in which officers displayed emotions, treated citizens with dignity and respect, and minimized authoritative language and police jargon. Secondly, officers used *active listening* to find out the source of the issue and to detect specific details, which can be used to calm down the involved individual. Additionally, listening can support the officer in validating the person's concerns, making them feel heard and acknowledged, and in gaining cooperation. Finally, the third tactic officers occasionally used, is *honesty.* By communicating the objective and procedures officers have to adhere to, officers may gain citizen's understanding, which could help to obtain their cooperation.

Thus, to de-escalate situations, police officers need to effectively communicate and use appropriate force. De-escalation tactics are employed to reach this goal. Therefore, this research includes de-escalation tactics to examine how police officers communicate with citizens.

Aim of the Study

Also based on findings from previous research, more and more knowledge is available about what team interaction patterns are displayed within action teams. However, this knowledge is still limited specifically for the context of policing. Moreover, prior studies did not consider communication patterns with individuals outside the studied action teams (e.g., the citizens), although it is essential for the functioning of police teams to also effectively communicate with citizens by performing de-escalation tactics. Therefore, this study aims to contribute to the extant research in action teams by investigating what team interaction patterns and external communication patterns (i.e., including citizens who are not part of the team) are displayed by members of police teams during escalation and de-escalation. The presented problem statement and theoretical framework form the base of the following research question: *What interaction patterns are displayed by members of police teams during escalation and during de-escalation?*

For answering the main research question, the following sub-questions are stated:

1) What are the differences in team interaction patterns during the escalation phase compared to the de-escalation phase?

2) In which way do team interaction patterns differ for teams that remain in the de-escalation phase for a short time compared to teams that remain in the de-escalation phase for a long time?
3) In which way do external communication patterns differ for teams that remain in the de-escalation phase for a short time compared to teams that remain in the de-escalation phase for a long time?

Method

Research Design

To explore which interaction patterns police teams display coding is combined with a T-pattern analysis (Waller & Kaplan, 2018). The data was gathered by a tech company in the Netherlands that provides training simulations for police, fire & rescue, and defence teams using Augmented Reality (AR) and Virtual Reality (VR) technology. After visiting this company, the After Action Review (AAR) software was installed on the laptop of the researcher, which contained the recorded VR scenarios.

Recordings of the VR scenarios are used to code the verbal and non-verbal behaviour of police officers. Subsequently, the behaviours were analysed aimed at detecting team interaction patterns and external communication patterns. The team interaction patterns were then analysed to identify potential differences for the escalation phase compared to the de-escalation phase. In addition, the team interaction patterns and external communication patterns were analysed to investigate if the patterns differed for teams that remained in the de-escalation phase for a short time period compared to teams that remained in this phase for a long time.

Participants

The sample includes 9 teams, of which 2 teams consisted of Dutch/Belgian police officers and 7 mixed teams (speaking Dutch/Belgian, German, and English). The teams compromise 21 employees working as police officers (9.52% female and 90.48% male). The employees were offered training in September 2022 at the facility of the tech company, which is also the reason for selecting these specific teams as the sample for this research. As police teams frequently work in an environment characterized by complexity, stress, and unpredictability, it is usually difficult to collect data for research during their work. The simulated training environment gave rise to the unique opportunity to collect detailed data about team interaction while officers are operating. Hence, convenience sampling was applied.

The training was part of a larger project called “SHOTPROS”. SHOTPROS is a European funded project which aims to address challenges experienced by officers in their daily work (SHOTPROS, 2021), for example house reaches and arresting suspects related to drugs and firearm trafficking (General Secretariat of the Council of the European Union, 2023). All nine teams that participate in this project were invited to enrol for the simulations. The team sizes varied between two and five team members. The age, nationality, years of experience and role of these team members are not recorded. Table 1 displays an overview of the sample in relation to the different scenario types.

Table 1

Overview Sample and Scenario Types

Scenario type	Duration (minutes)	Language	Team members	Gender
The Confused Person	08.23	Dutch	2	Female
	04.43	Dutch	5	Male
	04.48	English, German	3	Male
The Arrest	10.20	English	3	Male
	10.05	English	2	Male
	08.41	English, Dutch	3	Male
The Shooting	02.16	English, German, Dutch	5	Male
	01.21	English, German	5	Male
	01.21	English, German	5	Male

Note. The Shooting scenario is three times performed by the same team. The other scenarios are performed three times by different teams.

Procedure

The software program “Black Suit” is used to record the simulated scenarios. Various devices and tools (see Figure 1) are employed to make the simulation look like the daily work environment of the participants. A headset is used to display the simulation, and to emit sound effects and radio chatter. The headset is also equipped with a microphone to enable communication between the participants and the trainer. The armament of the participants consists of a holstered replica pistol, a replica rifle with a built-in pus-to-talk radio torch, and custom responsive gear, such as flashbangs and pepper spray. The duration of the simulations varies between 01.21 and 10.20 minutes, and the spoken languages entail English, Dutch/Belgian, and German.

Figure 1

Black Suit

In this research, nine simulations are used consisting of three scenarios. Each scenario is performed three times. The first scenario type is performed three times by different teams. Two teams consisted of three officers; one team consisted of two officers. In two recordings the working language was Belgian/Dutch, whereas in one recording the officers communicated in English and German. The second scenario type is also performed three times by different teams. Two teams were compromised by three members, one team consisted of two officers. Two teams communicated solely in English; one team also occasionally used the Dutch language. In contrast with the other two scenario types, the third scenario type is performed three times by the same team, consisting of 5 officers. They used English and German as their working language.

In the first scenario, the officers enter a house and must search for unusual objects, such as weapons. Later in the scenario, the officers encounter an individual person holding a weapon, who is considering suicide. The officers needed to de-escalate the situation and safely escort the person outside. The second scenario also takes place in a simulated house, where officers had to search for objects and suspects. The officers encounter an aggressive person which they eventually have to arrest. During one of the simulations, one team member experienced motion sickness which caused the team to stop performing the scenario after arresting the first suspect. In the third scenario, the officers enter a shopping mall where they encounter shooters and have to de-escalate the situation.

All scenario types included an objective that the participants were informed about before entering a scenario, for example arresting someone who is on a search list or de-escalating a shooting without using lethal force on the attackers. Besides the objective, no information was provided to the participants. In each scenario, one or multiple human actors were involved where the officers could interact with. The actors played attackers in a shooting, violent persons on a wanted list, or a confused person considering suicide. In addition, several digital actors occurred in the scenarios, existing of a barking dog, a child sitting on a chair, and citizens running away for a shooting. Each team member participated in the VR simulations on voluntary base and consented to utilize the data for this research. The ethical review board of the University of Twente approved this study (no230225).

Instrumentation

The simulations were accessed through AAR Software, which is displayed in 3D and includes several functionalities to review the simulations. Figure 2 displays an example of a recorded simulation. These functionalities include the audio sound of the simulation (communication between team members, instructor, suspects speaking, and dogs barking) and the viewing perspective, which entails switching between bird's eye view, the walking track of the participants, and several angles of participants (shoulder, eye, and weapon).

We combined and built upon earlier validated codebooks used for coding the verbal behaviours of actions teams (Lei et al., 2016; Stachowski et al., 2009; Waller et al., 2004). The codebook (see Table 1) is specially developed for capturing interactions that frequently take place in action teams and is grounded in prior theorizing on action teams. The coding aims to distinguish different types of behaviour, which is the required input for identifying patterns in the data analysis. Some of the original codes were excluded since they did not occur in the dataset (e.g. "interruption" or "disagreement").

Figure 2

Example of a Simulation

As the previous codes are focused on team interaction, the codebook was extended by introducing specific codes to capture detailed external communication, involving verbal interactions of officers with individuals outside their team. Based on the de-escalation tactics described in the theoretical framework, the following interactions were included: "verbal use of force," "ask for information," "honesty," and "emphasizing humanity" (International Association of Chiefs of Police, 2020; Oliva, et al., 2010; Todak & James, 2018; Todak & White, 2019). Moreover, the codes "using handcuffs", “shoot” and "opening a door" were incorporated to capture specific nonverbal actions related to the use of weapons and equipment (Schrom-Feiertag et al., 2021). Eventually, all codes were then categorized into three overarching meta-groups: team interactions, de-escalation, and actions. A "zero behaviour" category was also created for (verbal and nonverbal) actions that were incomprehensible. In total, the final codebook consists of eighteen mutually exclusive behavioural categories. The codebook can be found in Table 2.

In this study, team interaction and external communication displayed by police teams during training simulations is analysed. The unit of analysis, when systematically coding the recordings, are speech segments that reflect a complete statement (Bales, 1950), and the specific non-verbal behaviours, such as handcuffing, opening a door, and shooting. For example, when a team member says, “There are three explosives in the bedroom”, this is coded as *observe*. Using the predefined codebook, a code to every speech segment in the entire scenario is assigned. Specialized coding software "The Observer XT" is used to code the nine videos (Noldus et al., 2000; Spiers, 2004). To import the recorded simulations into the software, a requirement was to convert the recordings, which were stored in the after-action review, into a mp4 file. After exploring multiple options, the simulations were recorded using the built-in Windows screen recording tool. Subsequently, the videos were imported into "The Observer XT" and the team members were anonymized. To ensure accurate and consistent coding, two students (from a total group of three students) from the University of Twente's Master's program in Educational Science and Technology independently coded the simulations. To facilitate the coding process, transcripts were generated for each simulation (Waller & Kaplan, 2018). More than 15% of each simulation was coded by a rotating student to allow for assessing the level of inter-rater agreement (Bakeman et al., 2005). Every student had to code identical behaviour occurring within a 2-second time frame (Hoogeboom et al., 2021). Any coding of similar behaviour outside this 2-second window resulted in disagreements. In the first round, an inter-rater reliability of 74.0% (Cohen's Kappa = .78; Cohen, 1960) was achieved, indicating a substantial level of agreement (Landis & Koch, 1977). To enhance the level of agreement, students discussed discrepancies and adjusted their assigned codes based on their final consensus. This resulted in a final inter-rater reliability of 90.9% (Cohen's Kappa = .91; Cohen, 1960), representing an almost perfect level of agreement.

Table 2

Codebook

Code Name	Definition	Example
Team interactions		
Command	Specific assignment of responsibility.	"You look left; I look right."
Observe	Noting a fact or occurrence.	"There is a door on the right."
Suggest	Recommendation for action.	"Let's go in one line."
Opinion	Expression of one's own opinion.	"I think we should escort him outside."
Inquiry	Request for information, statement, analysis.	"What is that?"
Question	Request for confirmation or rejection statement.	"Should I open the door for you?"

Acknowledgement	Confirmation (“yes”) or rejection (“no”) statements to indicate that a message has been received or for yes/no replies to questions.	“Yes.”
Answer	Supplying information beyond acknowledgement.	“I can see a gun.”
Briefing	Information to team members on what to expect in the next stage. Also used to code the providing of information without request.	“When I open the door, you are directly in line.”
Expression	Comment, emotional remark.	“I'm behind you.”
Standby	Used when the speaker has heard the message but needs a moment to process or respond.	“Standby.”
Actions		
Open a door	Used when a team member opens a door.	-
De-escalation (towards individuals outside the team)		
Ask for information	Using questions to solicit additional information.	“Who are you?”
Emphasising humanity	Social communication with a calm demeanour**.**	“What’s the dogs name?”
Honesty	Explaining the goal, rules or process to an external individual.	“We are searching for a suspect.”
Verbal use of force	Using verbal commands.	“Get down on your knees!”
Shoot	Used when a team member is shooting.	-
Use handcuffs	Used when a team member handcuffs a suspect.	-

Data preparation

The phases are distinguished based on the definition for de-escalation used in this study (IACP, 2017):

> Taking action or communicating verbally or non-verbally during a potential force encounter in an attempt to stabilize the situation and reduce the immediacy of the

> threat so that more time, options, and resources can be called upon to resolve the situation without the use of force or with a reduction in the force necessary. De-escalation may include the use of such techniques as command presence, advisements, warnings, verbal persuasion, and tactical repositioning. (p.2)

The phrase "during a potential force encounter" indicates a starting point of the de-escalation phase, as it refers to the first moment of contact with an individual or group from which a certain level of threat arises. Therefore, the researcher and two students from the University of Twente's Master's program in Educational Science and Technology considered the escalation phase to end at the moment of contact with at least one subject, which is viewed as the starting point of the de-escalation phase. The duration of the two phases for each scenario type are displayed in Table 3.

Table 3

Overview Duration Scenarios Escalation and De-escalation Phase

Scenario type	Duration (minutes)	Escalation	Percentage of total scenario	De-escalation	Percentage of total scenario	Total coded behaviours
The Confused Person	08.28	05.15	62%	03.13	38%	
	04.42	02.35	55%	02.07	45%	
	04.16	01.44	40.6%	02.32	59.4%	
The Arrest	10.41	01.46	16.5%	08.55	83.5%	
	09.57	02.21	23.6%	07.36	76.4%	
	02.42	01.22	50.6%	01.20	49.3%	
The Shooting	02.19	00.13	9.4%	02.06	90.6%	
	00.55	00.13	23.6%	00.42	76.4%	
	01.04	00.18	28.1%	00.46	71.9%	

Data Analysis

A T-pattern analysis (TPA) was conducted using the coded behaviours to explore differences in interaction patterns during the escalation phase and during the de-escalation phase.
The software "THEME" was used to perform this analysis separately for both phases. THEME has the ability to detect behavioural patterns that occur in a specific sequence over time (Magnusson, 2000; Magnusson, 2017). The algorithm predicts if the presence of behavioural sequences within a particular time interval occur significantly more frequent than the likelihood of random events. T-patterns represent such sequences of temporal behaviours. This software has been utilized in published studies within the fields of animal behaviour, psycho-pharmacology, child psychology, sports science, ethology, and also recently in team research to detect nonobvious temporal patterns of behaviour (Casarrubea et al., 2018; Hoogeboom & Wilderom, 2020; Magnusson, 2017; Lei et al., 2016; Stachowski et al., 2009).

Identifying interaction patterns by simply looking at sequential strings of coded data can be very challenging, especially when other behaviours occur in between the ones forming a pattern (Magnusson, 2000; Waller et al., 2021). The THEME algorithm overcomes this challenge and detects patterns in sequential data by performing three steps. The initial detection by THEME pertains to patterns which encompass two sequential behaviours occurring significantly more frequently than expected by chance. Subsequently, after the detection of the two-behaviour T-patterns, the algorithm goes through the data numerous times to search for and "build" increasingly complex, hierarchical patterns involving multiple behaviours. This "bottom-up" approach to pattern detection initially detects simple patterns, followed by the identification of larger patterns as a combination of the simpler patterns. Finally, the less complex and smaller initial patterns are then eliminated as they will be regarded as less complete than the more complex and extensive patterns.

Figure 3

Visual Representation of Team Interaction Patterns within THEME

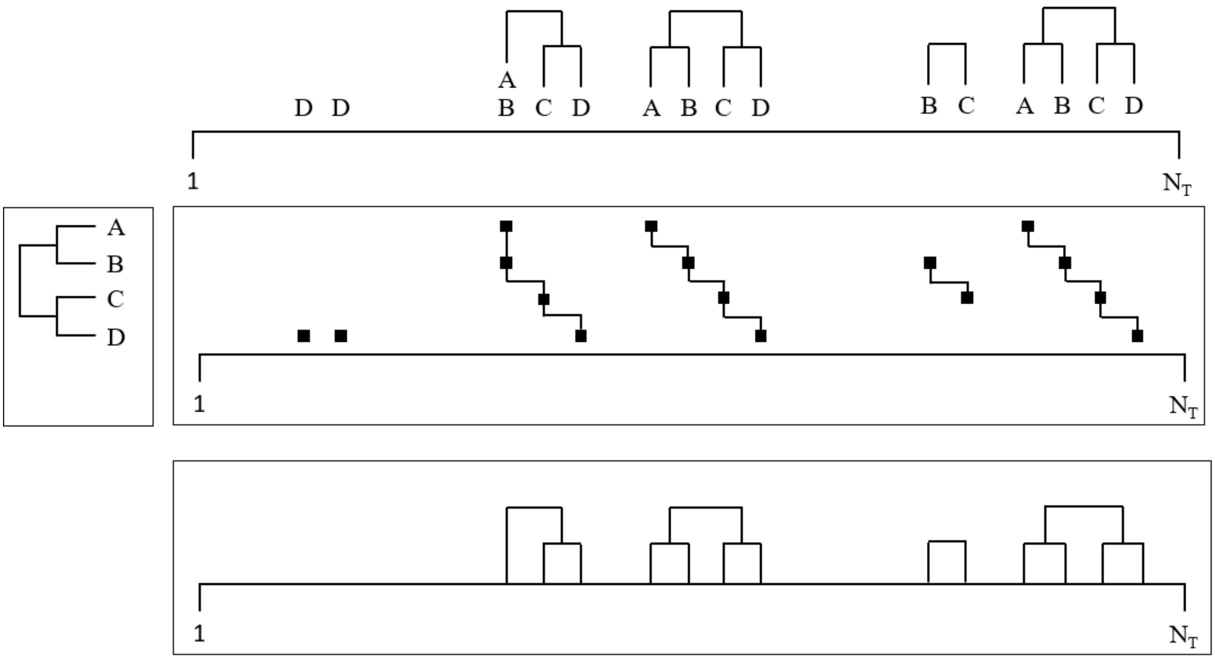


Figure 3 displays a visual representation of a fictional pattern. THEME offers many options for the usage of specific parameters. Earlier studies who investigated team interaction patterns (Hoogeboom & Wilderom, 2020; Kanki, Folk & Irwin, 1991; Lei et al., 2016; Stachowski et al., 2009; Zijlstra et al., 2012) focused on subsets of parameters, involving pattern occurrences, pattern heterogeneity, mono-actor patterns, pattern length, pattern level and pattern strings. This study builds on previous research by including the following parameters about the detected T-patterns: (a) the number of pattern occurrences, meaning the total number of patterns that are detected in the interaction; (b) the number of different patterns, which refers to the amount of different patterns that could be distinguished in the interaction; (c) the mean of pattern length, indicating how long the patterns are on average; (d) the mean number of pattern levels, referring to the hierarchal complexity of patterns, meaning that patterns consisting of multiple levels are higher in complexity; (e) the mono-actor patterns, indicating patterns of interaction that involve only one individual, referring to the extent of reciprocal interaction. The frequencies of the parameters could be influenced by the different time duration of both phases. Hence, to enable a comparison, the absolute frequencies were standardized according to the shortest phase using a formula provided by Endedijk et al. (2018): standardized frequency of patterns in phase X = frequency of patterns phase X * (duration of the shortest phase / duration of phase X).

For THEME to be able to identify the patterns, a category table and syntax files had to be created (Magnusson, 2017). To create syntax files, the Noldus data first needed to be adjusted in Excel. Eventually, the information included in Excel involved the specific time at which team members began performing certain interaction and the time they stopped performing these. All other data from Noldus was removed as it did not have relevance for the pattern analysis. Additionally, the naming of the codes was adjusted in order to import the data into THEME, as THEME can solely handle alphanumeric data. For instance, the code "Ask for Information" was changed to "Ask_for_Information". In total, 27 syntax files are created. One syntax file for each video, and one for each phase, divided into team interaction and external communication. Subsequently, a category table (variable-value table) was created because the THEME software requires this file to recognise which categories the data includes. This table consists out of three categories. The first category includes the team members (called actors), varying from team member 1 to team member 5. The second category is the timestamp, which contains the beginning ("B") and ending ("E") of certain interactions. The type of interaction is the third category, and corresponds with the codes of the codebook. The complete category table can be found in Appendix A.

THEME allows users to specify frequency and probability criteria for pattern detection. Guided by prior research, the default of pattern occurrences is set at "3", which means a pattern had to occur at least three times during the scenarios to be considered a pattern by THEME (Hoogeboom & Wilderom, 2019; Lei et al., 2016; Stachowski et al., 2009; Zijlstra et al., 2012). Furthermore, following previous research, a requirement of 95% probability was set that patterns occurred above and beyond chance. To gain insight into the validity of the detected patterns, the THEME data was tested by running 5 shuffling rounds of simulation randomisations. This compares the average number of detected patterns in the randomized dataset and the actual observed patterns, to determine if the data contains meaningful patterns (Hoogeboom & Wilderom, 2019).

After analysing the data in THEME, a Wilcoxon Signed-Rank test was performed to investigate significant differences between the mean of pattern length and level. This is a non-parametric test utilized to examine whether there is a difference between two dependent samples (Field, 2017). In this research specifically, the test aims to provide insights into the differences in team interaction patterns during the escalation phase compared to the de-escalation phase. The decision to utilize a non-parametric test is because the normality assumption of the dataset is violated. Two out of four required assumptions for this test are fulfilled. First, the samples should be randomly selected. Because convenience sampling is applied, this assumption is unfortunately not fulfilled. Secondly, the two samples should be at least ordinally scaled. The pattern length and level are ratio variables, meaning they are measured at continuous level, and thus fulfil the assumption. Thirdly, the test requires two sets of measurements that are related or paired. This assumption is fulfilled because the data in the escalation and de-escalation phase is from the same teams. Fourthly, the distribution of the difference scores should be symmetric (Thas et al., 2005). The Wilcoxon Signed Rank Test does not make specific assumptions about the overall distribution of measurements. Instead, it focuses on the differences between paired observations, assessing whether the median difference is zero. Unfortunately, this assumption is not fulfilled for most sample groups in this research. Consequently, results of this test should be interpreted with caution.

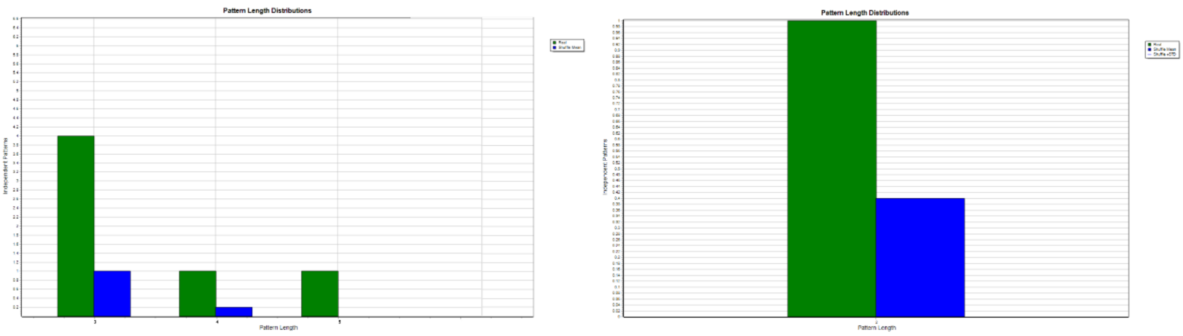
Results

Validity of the Patterns

In this research, a total of 654 separate behavioural events were coded, and THEME detected 386 behavioural patterns. The pattern validity for each scenario is investigated by performing he Monte Carlo Randomisation and Shuffling of Means 5 times for each phase. This option within THEME compares the actual number of patterns with the average number of patters in randomized data to investigate if the patterns are valid or due to chance. For the Confused Person Scenario, we see in Figure 4 that the real data surpasses the randomized data, indicating a statistically valid foundation for the interpretation of the detected patterns.

Figure 4

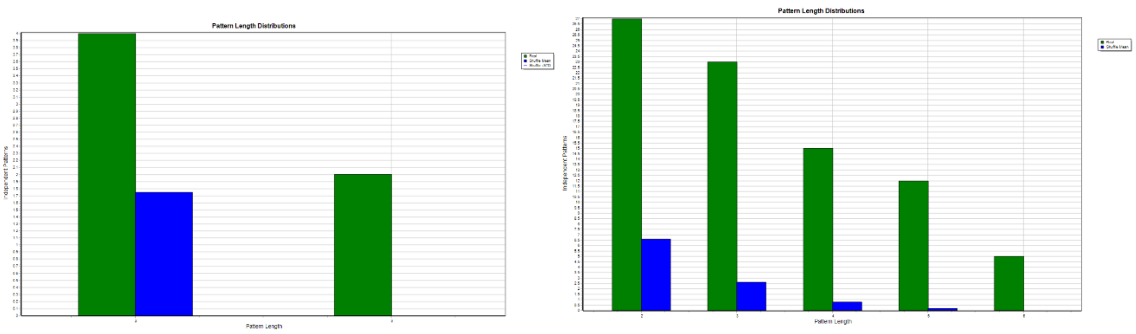
Comparison Real vs. Randomized Data of Pattern Length for the Confused Person Scenario of the Escalation and De-escalation Phase. Within THEME, the Monte Carlo Randomisation and Shuffling of Means are performed 5 times.



For the Arrest Scenario we see in Figure 5 that the real data surpasses the randomized data, meaning that the detected patterns have a statistical valid basis for interpretation. For the Shooting scenario, no patterns were found in the escalation phase. One pattern was detected for the de-escalation phase. However, this pattern showed the same frequency as the randomized dataset, suggesting a low statistically valid foundation for interpretation. After looking into the qualitative data, it appeared the pattern was not meaningful. Therefore, the results for this scenario will not be described and the data will be omitted in the continuation of this research.

Figure 5

Comparison Real vs. Randomized Data of Pattern Length for the Arrest Scenario of the Escalation and De-escalation Phase. Within THEME, the Monte Carlo Randomisation and Shuffling of Means are performed 5 times.



Comparison Escalation and De-escalation Phase

The following section presents the quantitative and qualitative results of the T-pattern analysis. The aim of this section is to address the first research question, involving what differences in team interaction patterns occur during the escalation phase compared to the de-escalation phase. In the quantitative output, the descriptive statistics are presented, including the means and standard deviations of the pattern length and level. In particular, the Wilcoxon Signed-Rank Test is performed to investigate significant differences between the mean of pattern length and level. Furthermore, other characteristics are described, such as the number of pattern occurrences, different patterns and mono-actor patterns. The qualitative section outlines the pattern diagram for the escalation and de-escalation phase for both scenarios. In this diagram, the content of the most prominent pattern for both phases will be presented and compared.

Quantitative Output

Table 4 shows the characteristics for the team interaction patterns of the Confused Person Scenario for the specific set of parameters as described in chapter 3. This parameter set includes standardised frequencies of pattern occurrences, the number of different patterns, the mean pattern length, the mean pattern level, and the mono-actor occurrences. The total number of pattern occurrences is 32 for the escalation phase and 3 for the de-escalation phase. Remarkably, the de-escalation phase shows only one type of pattern, which is presented for a short percentage of the observation period (7%). This indicates that there generally seems to be a more disordered way of interaction compared to the escalation phase, where 9 different patterns were found. What is also interesting, is the difference in the occurrence of mono-actor patterns for both phases. In the escalation phase, the mono-actor patterns composed 28% of the total pattern occurrence, which indicates reciprocal behaviours between team members. Respectively, the de-escalation phase displays merely one pattern, which is a mono-actor pattern and therefore composes 100% of the total pattern occurrences. This indicates non-reciprocal behaviours between team members in the de-escalation phase. Overall, these findings suggest more consistent and participative team interaction during the escalation phase, whereas interaction for the de-escalation phase appears to be more disordered and one-directed.

Table 4

Team Interaction Pattern Characteristics for the Confused Person Scenario

Parameters	Relative Frequency	
	Escalation	De-escalation
Pattern occurrences	32	3
Different patterns	9	1
Pattern length mean*	2.32	2
Pattern length SD	0.81	0
Pattern level mean*	1.50	1
Pattern level SD	0.81	0

Mono-actor occurrence	9	3

Note. To measure if the differences between the escalation and de-escalation phase are significant, a Wilcoxon Signed-Rank Test is conducted for the pattern length and pattern level. Concerning pattern length, the related-samples Wilcoxon Signed-Rank Test on the relative frequencies for each phase revealed significant differences in the mean pattern length. In particular, the mean pattern length of the escalation phase, $M = 1.7$, was significantly lower than the mean pattern length of the de-escalation phase, $M = 2$, $Z = -2.946$, $p = .003$, with a small effect size, $r = .21$. This indicates less elaborate interaction within teams during the de-escalation phase. A Wilcoxon Signed-Rank Test also revealed significant differences in the mean pattern levels. Specifically, the mean pattern level of the escalation phase, $M = 1.7$, was significantly higher compared to the mean pattern level of the de-escalation phase, $M = 1$, $Z = -6.195$, $p = .000$, with a moderate effect size, $r = .44$. This indicates lower hierarchical complexity in the de-escalation phase.

$^{*}p < .05$

Table 5 shows the relative frequencies for the Arrest Scenario for the specific set of parameters as described in chapter 3. The total number of pattern occurrences is 22 for the escalation phase and 99 for the de-escalation phase. Also for this scenario, the number of different patterns and the composition of mono-patterns in each phase is interesting. During the escalation phase, the teams display 6 different patterns whereas in the de-escalation phase they display 25 different patterns. In the escalation phase the mono-actor patterns composed 82% of the total pattern occurrences, whereas mono-actor patterns encompass 26% of the total pattern occurrences in the de-escalation phase. This indicates more reciprocal behaviours between team members during the de-escalation phase compared to the escalation phase. Combined, these findings suggest a more structured and reciprocal way of team interaction in the de-escalation phase compared to the escalation phase.

Table 5

Team Interaction Pattern Characteristics for the Arrest Scenario

Parameters	Relative frequency	
	Escalation	De-escalation
Pattern occurrences	22	99
Different patterns	6	25
Pattern length mean*	2.33	1.02
Pattern length SD	0.52	0.38
Pattern level mean*	1.33	0.63
Pattern level SD	0.52	0.28
Mono-actor occurrence	18	26

Note. To measure if the differences between the escalation and de-escalation phase are significant for the pattern length, level, and mono-actor occurrence, a Wilcoxon Signed-Rank Test is performed. Regarding the pattern length, the related-samples Wilcoxon Signed-Rank Test on the relative frequencies for each phase revealed significant differences in the mean pattern length. Particularly, the mean pattern length of the de-escalation phase, $M = 3.1$ was significantly higher than the mean pattern length of the escalation phase, $M = 2.3$, $Z =-6.814$, $p = .000$, with a large effect size, $r = .48$. This indicates the involvement of more behaviours during team interaction for the de-escalation phase. Regarding the pattern level, the Wilcoxon Signed-Rank Test also revealed a significant difference. Specifically, the mean pattern level of the de-escalation phase, $M = 1.9$, was significantly higher compared to the mean pattern level of the escalation phase, $M = 1.3$, $Z = -7.255$, $p = .000$, with a large effect size, $r = .51$. This finding suggests a higher hierarchical complexity in team interaction during the de-escalation phase.

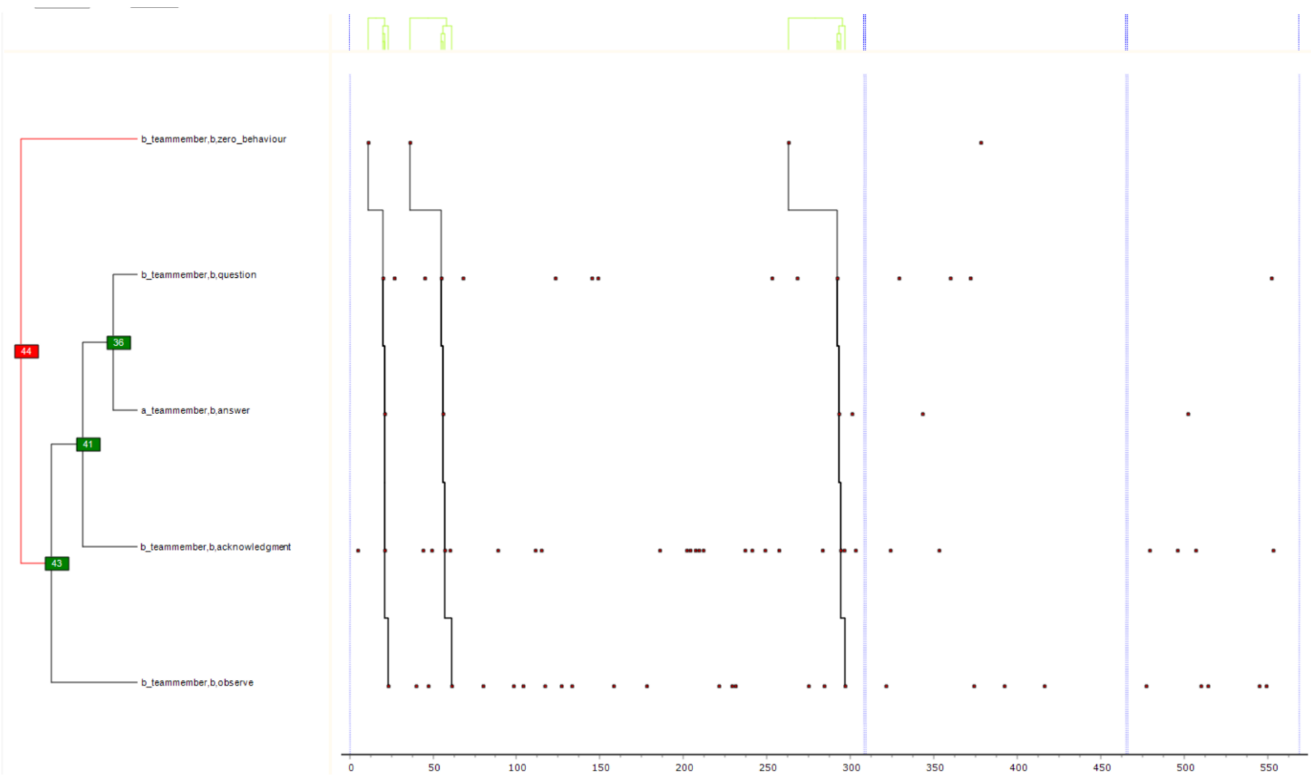
$^*p < .05$

Qualitative Output

The Confused Person Scenario. THEME presents the most predominant pattern string in the pattern diagram. This diagram will be used for interpreting the qualitative data, because it is a visualisation of the pattern that recurred most in the data, is the longest and has the most levels. The diagram shows of which lower-level patterns and event-types this pattern is build. Figure 6 shows the predominant pattern for the Confused Person Scenario in the escalation phase. All event types that are part of this pattern are displayed in the detection tree on the left side of the figure, along with their hierarchical relationships to lower-level patterns. The top of the figure presents an occurrence tree, which presents how many times the pattern appeared over time. The lines and dots in the middle of the figure present the connection chart, which displays at which specific moments the predominant pattern, including the lower-level patterns, are detected. Finally, the bottom box of the figure shows the full pattern string and characteristics. The most predominant pattern for the de-escalation phase is displayed in Figure 7.

Figure 6

Pattern Diagram of the Confused Person Scenario in the Escalation Phase.



Teammember_b_zero_behaviour | teammember_b_question | teammember_a_answer | teammember_b_acknowledgment | teammember_b_observe

N = 3 | Length = 5 | %Duration = 13

Note. This diagram shows the most predominant pattern of the Confused Person Scenario for the Escalation Phase. The pattern string and characteristics are displayed in the bottom box.

Figure 7

Pattern Diagram of the Confused Person Scenario in the De-escalation Phase.

Teammember_a_observe | teammember_a_briefing

N = 3 | Length = 2 | %Duration = 7

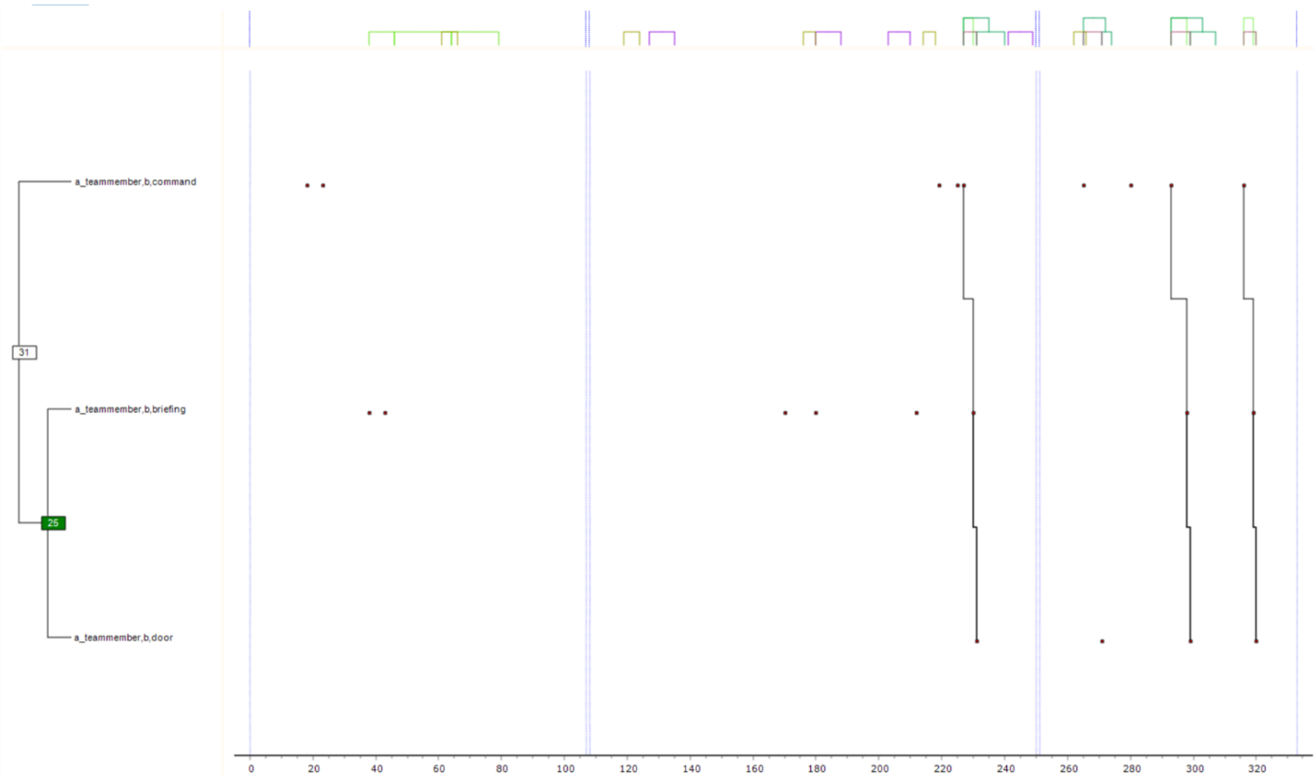
Note. This diagram shows the most predominant pattern of the Confused Person Scenario for the De-escalation Phase. The pattern string and characteristics are displayed in the bottom box.

Comparing Figure 6 and 7, the predominant pattern of the escalation phase is longer and consists of multiple levels compared to the predominant pattern of the de-escalation phase, indicating more hierarchical complexity. This suggests more structured interaction, whereas the de-escalation phase showed more adaptive interaction. Additionally, it is interesting that the pattern percentage duration (how much of the time is covered by the predominant pattern) differs, although the predominant pattern occurs three times in each phase. In the escalation phase, the pattern covers 13% of the total time duration for the specific phase, whereas in the de-escalation phase this is 7%. This indicates more structured and stable team interaction during the escalation phase, whereas the de-escalation displays more flexibility in the interaction.

Furthermore, there are several interesting points regarding the qualitative content of the pattern composition. Figure 6 shows that the most predominant pattern of the escalation phase includes closed-loop-communication behaviours (a question is followed by an answer, which is then followed by and acknowledgment), signifying information exchange between team members. However, Figure 7 displays that these behaviours are not present anymore in the predominant pattern of the de-escalation phase, indicating a decrease in closed-loop-communication. Instead, the behaviours “observe” and “briefing” suggest that information sharing (by a specific team member) has a more prominent role in this phase. These findings indicate a more balanced interaction in the escalation phase, whereas the interaction in the de-escalation phase seems to be more one-sided.

Figure 8

Pattern Diagram of the Arrest Scenario in the Escalation Phase.



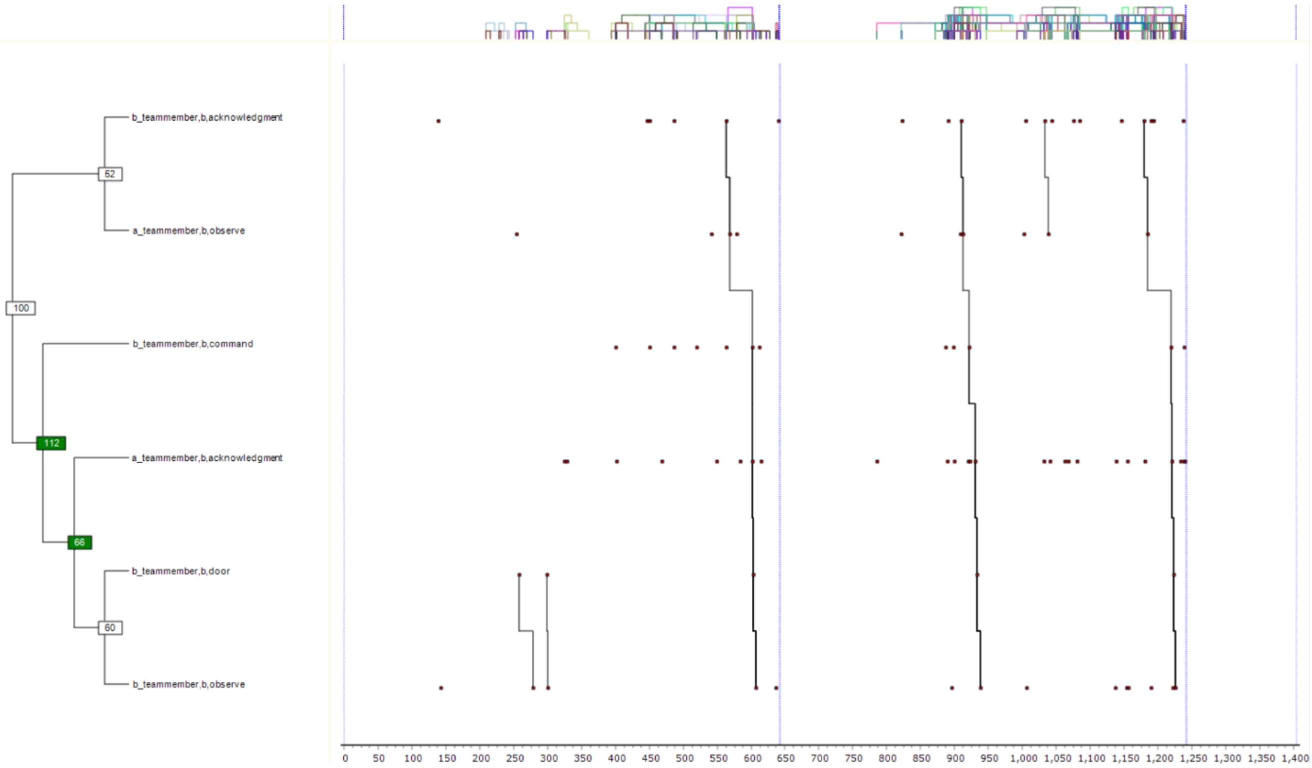
Teammember_a_command | teammember_a_briefing | teammember_a_door

N = 3 | Length = 3 | %Duration = 5

Note. This diagram shows the most predominant pattern of the Arrest Scenario for the Escalation Phase. The pattern string and characteristics are displayed in the bottom box.

Figure 9

Pattern Diagram of the Arrest Scenario in the De-escalation Phase.



Teammember_b_acknowledgment | teammember_a_observe | teammember_b_command | teammember_a_acknowledgment | teammember_b_door | teammember_b_observe

N = 3 | Length = 6 | %Duration = 9

Note. This diagram shows the most predominant pattern of the Arrest Scenario for the De-escalation Phase. The pattern string and characteristics are displayed in the bottom box.

The Arrest Scenario. The most predominant pattern of the Arrest Scenario for the escalation phase is displayed in Figure 8. Respectively, Figure 9 presents the most predominant pattern of the Arrest Scenario for the de-escalation phase. Comparing Figure 8 and 9, the predominant pattern of the escalation phase is shorter and consists of fewer levels compared to the predominant pattern of the de-escalation phase, indicating less hierarchical complexity. This suggests more adaptive interaction, whereas the de-escalation phase showed more structured interaction. Another interesting finding is that the pattern percentage duration differs for both phases, although the predominant pattern occurs three times in each phase. In the escalation phase, the pattern covers 5% of the total time duration for the specific phase, whereas in the de-escalation phase this is 9%. This indicates more flexible interaction the escalation phase, whereas the de-escalation phase displays more stability in the interaction. Another interesting finding is that the pattern in both phases appears to occur between the middle and ending of the time periods when a team is performing, suggesting the patterns emerged over time. This indicates that through time, teams started coordinating their interaction and behaving more consistently.

Furthermore, there are some interesting points to mention regarding the qualitative content of the pattern composition. Figure 8 shows that the most predominant pattern of the escalation phase includes behaviours specifying a particular responsibility (command) followed by providing information or potentially preparing on what to expect in the next stage (briefing), then followed by an action (opening a door). These behaviours suggest coordinative interaction before entering an uncertain situation (the scene behind the door). Although not identical, Figure 9 displays similar behaviours, possibly resembling mutual performance monitoring. Before entering an uncertain situation (opening a door), situational awareness is created and actions are aligned (observe, command, acknowledgment). After entering an uncertain situation, the situational awareness of the team is adjusted by immediately sharing new information about the environment (door, observe).

Combining the findings of both scenarios, these qualitative elements indicate that team interaction adapts to the demands of the task context at the time of occurrence (escalation or de-escalation).

Interaction in the De-escalation Phase

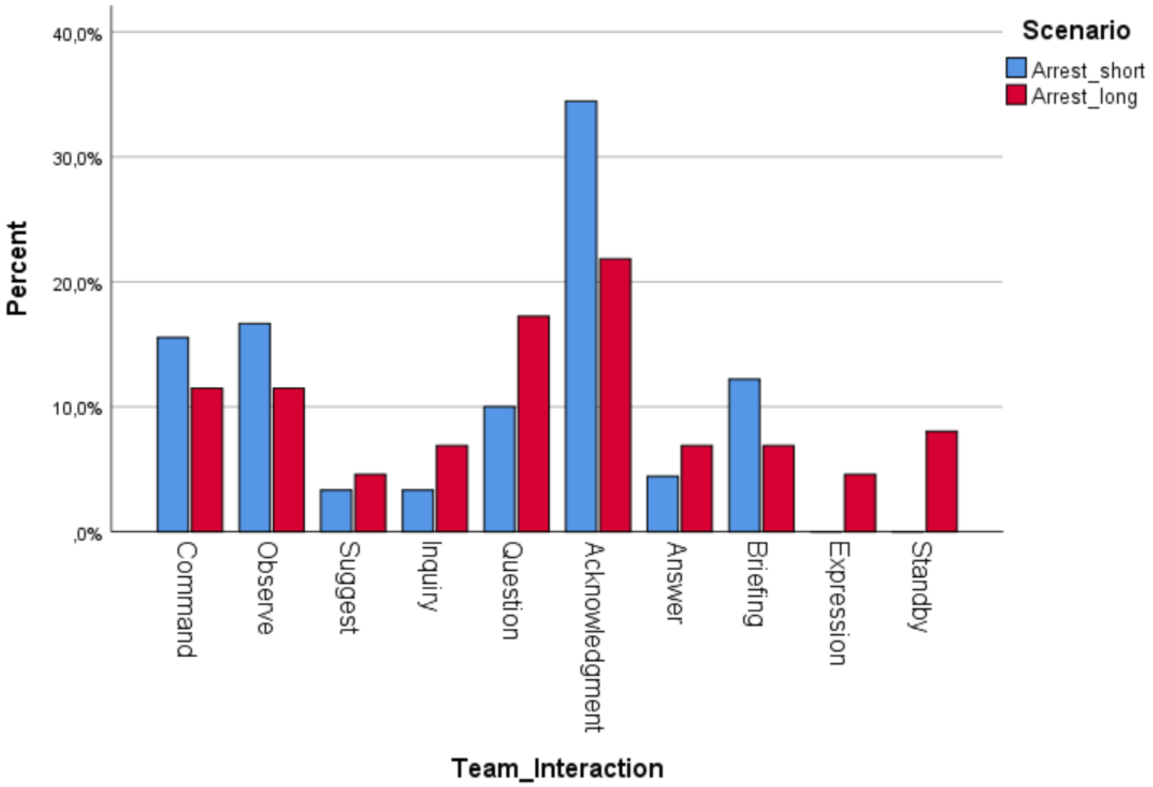
The following section aims to address the second and third research question, involving in which way team interaction and external communication differs for teams who remained in the de-escalation phase for a shorter time compared to teams that remained in the de-escalation phase for a longer time. Regarding team interaction in the de-escalation phase, unfortunately no comparison was possible for the Confused Person Scenario. The reason for this is that only one team had enough data points (27) to do an analysis. The other two teams displayed merely 3 and 4 team interactions. For the Arrest scenario we did not have enough data points for the de-escalation phase to run a T-pattern analysis. Therefore, a frequency analysis is used to provide insights into the comparison in team interaction for the Arrest Scenario. This also applies to the external communication within both scenarios.

Team Interaction Arrest Scenario. Team interaction in the de-escalation phase lasted 455 and 503 seconds respectively, meaning the second team used 11% more time to de-escalate than the first team. Figure 10 displays the differences in relative percentages for the Arrest Scenario. The highest difference in frequency is the usage of the interaction "acknowledgment". The team that de-escalated fastest, showed this behaviour in 34% of their total team interaction. For the team that took longest to de-escalate, this was only 22%. The purpose of using "acknowledgment" in team interaction is to ensure clear communication, a shared understanding, and alignment towards common goals. Therefore, this finding could indicate that the first team interacted more in a way that supports team performance compared to the second team. Furthermore, the team that de-escalated quickest displays higher frequencies for the following interactions: acknowledgment, observe, command, and briefing. These behaviours can be considered information transferring behaviours. The other team showed higher frequencies for the following interactions: question, standby, inquiry, expression, and answer. These behaviours indicate a higher amount of information requesting behaviours. Combining these findings, it appears that information transferring behaviours played a more prominent role in the team that de-escalated quickest, such as observe and briefing. In the interaction of the team that took longest to de-escalate, information requesting behaviours played a more dominant role, such as question and inquiry. Moreover, the second team displayed slightly more variety in their team interaction. Contradictory to the first team, they also used the behaviour expression and standby while interacting.

Overall, these findings indicate that the team that de-escalated quickest displayed more information transferring interaction compared to the team that took longer to de-escalate, who showed relatively more information requesting interaction.

Figure 10

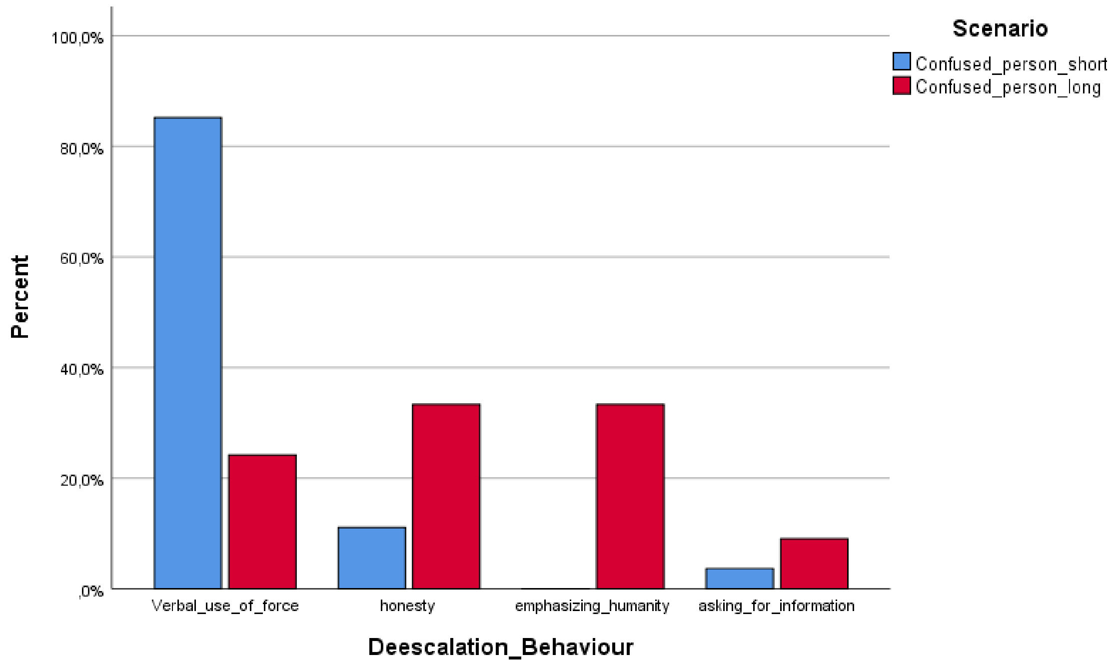
Comparison Team Interaction during De-escalation - Arrest



External communication Confused Person Scenario. The external communication in the de-escalation phase for the teams lasted 126 and 186 seconds respectively, meaning the second team used 48% more time to de-escalate than the first team. Figure 11 displays the differences in relative percentages for the Confused Person Scenario. An interesting finding is the difference in frequency usage of the behaviour "verbal use of force". The team that de-escalated fastest, showed this behaviour in 83% of their total communication with people outside the team. For the team that took longest to de-escalate, this was only 22%. Furthermore, the second team displayed more variety in their external communication. The most frequent identified behaviours where "honesty" and "emphasizing humanity", both accounting for more than 30% of the total external communication. These findings indicate that consistently utilizing a certain de-escalation tactic helps to de-escalate the situation more quickly than employing various de-escalation tactics. Additionally, the findings suggest that utilizing a more steering de-escalation tactic could support in de-escalating a situation quicker than utilizing tactics that are less steering.

Figure 11

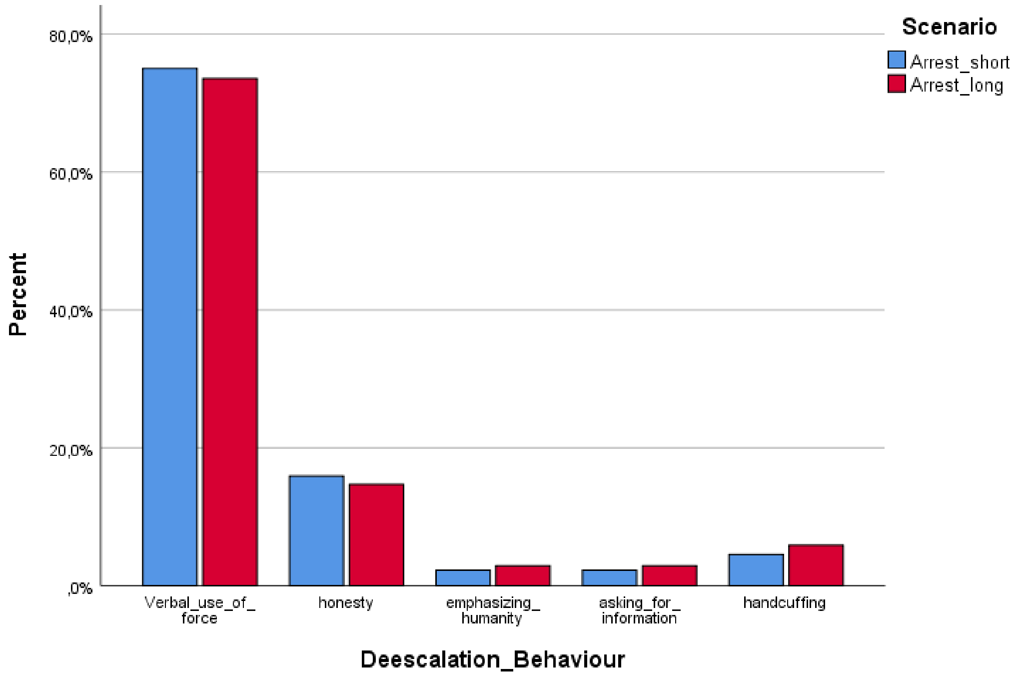
Comparison External Communication during De-escalation - Confused Person



External communication Arrest Scenario. The external communication in the de-escalation phase for the teams lasted 317 and 351 seconds respectively, meaning the second team used 11% more time to de-escalate than the first team. Figure 12 displays the differences in relative percentages for the Arrest Scenario. Interestingly, the teams display similar relative frequencies of the utilized de-escalation tactics. This finding could be explained by the small time difference between both teams; the team that took longest to de-escalate lasted 11% longer in the de-escalation phase than the team that took shortest to de-escalate. The de-escalation tactic "verbal use of force" was used for more than 70% of the time, which indicates that both teams perceived this tactic as most effective to use within the task context of the specific scenario.

Figure 12

Comparison External Communication during De-escalation – The Arrest



Discussion

This exploratory study aimed to contribute to the extant research in action teams by investigating the actual interactions displayed during several high-risk scenarios. In the study, we specifically zoomed-in on which team interaction and external (i.e., including citizens who are not part of the team) communication is displayed by members of police teams during escalation and de-escalation phases. This helps us to understand how police teams/action teams can quickly de-escalate a high-risk situation. To answer our questions, we took a process-perspective and temporally investigate what actually happens in the specific phases. To systematically explore the patterns of interaction the software "THEME" was used, and a T-pattern analysis was conducted using coded behaviours to explore differences for both phases (Magnusson, 2000; Waller & Kaplan, 2018). A frequency analysis was also performed to investigate team interaction and external communication during the de-escalation phase.

Team Interaction Patterns: Escalation vs. De-escalation

First, this research aimed to explore the differences in team interaction patterns during the escalation phase compared to the de-escalation phase. Overall, the findings show that there is a difference in displayed interaction patterns during the escalation and de-escalation phase. However, this difference varies for the *Confused Person* scenario and for the *Arrest* scenario. This most likely can be attributed to the difference in task demands faced in both scenarios. This is also in line with current literature showing that task complexity influences team interaction (Entin & Serfaty, 1999; Gorman et al., 2010; Grote et al., 2018; Lei et al., 2016; Rico et al., 2021). The following section elaborates on this.

The Confused Person Scenario. Looking at the quantitative findings for the Confused Person scenario, multiple patterns were identified for the escalation phase, that were more elaborate and of higher hierarchical complexity than for the de-escalation phase. In contrast, only one (mono-actor) pattern was detected for the de-escalation phase. Hence, interaction for the escalation phase seemed more consistent and participative, whereas interaction for the de-escalation phase appeared to be disordered and one-directed. This could be explained by the task demands the teams were facing in both phases. In the escalation phase, they had to perform a house search. Although performing in an uncertain environment, there was no direct threat or time pressure. These circumstances allow teams to perform according to operating procedures (in this case, of performing a house search) and explicitly coordinate their work by formulating plans and strategies (Lei et al., 2016; Salas et al., 2001; Zechner et al., 2023). Therefore, members often engage in multiple rounds of iterations to exchange information and develop a shared understanding and one another's responsibilities (Burke et al., 2006; Salas et al., 2005). This explanation is supported by the qualitative findings of the most predominant pattern, which displayed information exchange in the form of CLC. Specifically, this pattern encompassed a question followed by an answer, which was then followed by an acknowledgment. These findings are in line with previous research that found teams exhibit interaction patterns that are consistent and participative in similar situations (Lei et al., 2016; Zijlstra et al., 2012).

In the de-escalation phase, the team's interaction became more disordered and one-directed compared to the escalation phase. Additionally, whereas the behaviours within the predominant pattern of the escalation phase suggested coordinated information exchange, the behaviours within the predominant pattern of the de-escalation phase indicate one-sided information sharing. These findings could mean that team members are changing their strategy to respond to new task demands (Lei et al., 2016; Waller & Kaplan, 2016). In the de-escalation phase, the teams faced new task demands as they were confronted with a confused person speaking threatening language and holding a weapon. Likely, the change in team interaction results from switching to de-escalation tactics as a strategy to coordinate the situation, which manifests through external communication with the confused person instead of team interaction. De-escalation via external communication with citizens is inherent to perform successfully in the context of police teams (Lorei & Balaneskovic, 2023; Todak & James, 2018). This is in line with previous research of Kent (2022) who investigated which techniques were most appropriate in diverse scenarios and stresses the importance of building knowledge regarding the best de-escalation practices in different law enforcement situations. Furthermore, the one-sided information sharing suggests that team interaction in the de-escalation phase is more directive compared to the escalation phase. Due to the need of performing de-escalation tactics to stabilize the situation, there appears to be no more room for checking with other team members about the course of action. This is similar to findings of previous studies, which showed that teams displayed patterns that are shorter, less reciprocal, and less hierarchically complex when task demands became increasingly complex (Stachowski et al., 2009; Lei et al., 2016; Waller et al., 2004).

The Arrest Scenario. In the *Arrest* scenario, patterns displayed during the escalation phase were shorter and less hierarchical complex on average compared to the de-escalation phase. Additionally, much fewer (different) patterns were detected, which consisted more out of mono-actor patterns. Contradictory to the results for the *Confused Person* scenario, these findings suggest that interaction during the escalation phase seemed less structured and participative compared to the de-escalation phase. An explanation for these contradictory findings could be the observation period for both scenarios. For the *Confused Person* scenario, there is a minor difference in time duration between both phases. On average, the escalation phase lasted 52.5% and the de-escalation phase 47.5% of the total observation period. However, for the Arrest scenario, the escalation phase accounted for 30.3% and the de-escalation phase for 69.7% of the total observation period. The fact that the teams spend 39.4% more time in the de-escalation phase during the Arrest scenario could have influenced the development of interaction patterns. Especially since a pattern had to occur at least three during the scenarios to be considered a pattern by THEME (Hoogeboom & Wilderom, 2019; Lei et al., 2016; Stachowski et al., 2009; Zijlstra et al., 2012).

An alternative explanation for the contradictory findings could be the difference in task demands for both scenarios. Whereas the assignment for the *Confused Person* scenario was to perform a house search, the assignment for the *Arrest* scenario was to arrest a person who was on a blacklist, indicating a threatening and high-impact situation from the beginning of the escalation phase. In the de-escalation phase, the teams encountered the person that was on a blacklist, but also another person pointing a gun at them. Consequently, the situation became more dynamic, and the impact and threat increased. Hence, these task demands required more collaboration to coordinate and de-escalate the situation effectively (Burke et al., 2006). Enhancing their collaboration, the team most likely started interacting more intensively which led to the emergence of more complex and participative patterns. The qualitative findings of the predominant patterns in both phases support this explanation. They both displayed coordinative interaction, however the pattern for the de-escalation phase was more complex than the pattern of the escalation phase. Specifically, the predominant pattern for the de-escalation phase included behaviours that resemble CLC and mutual performance monitoring, whereas this could not be clearly deduced from behaviours compromised in the predominant pattern for the escalation phase.

Taken the findings from both scenarios together, the influence of task demands on team interaction seems paramount. Task demands can require different ways of interacting during escalation and de-escalation, where crucial factors involve for example time pressure, impact of the intervention and the level of threat. Whereas one context leaves room for elaborate and participative interaction while escalating, another context requires short and directive interaction. Just as one context requires increased team interaction to enhance coordination and de-escalate quickly, another context demands decreased team interaction and increased external communication with citizens instead.

Team Interaction Differences in the De-escalation Phase

Secondly, this research aimed to explore in which way team interaction differs for teams that remained in the de-escalation phase for a short time compared to teams that remained in the de-escalation phase for a long time, ultimately to better comprehend what effective de-escalation tactics are. The findings show that the team who de-escalated quickest showed relatively more information transferring (observe, briefing, and acknowledgment) interaction and less information requesting behaviours (question and inquiry). This is the other way around for teams that took longer to de-escalate, who displayed relatively more information requesting behaviours and less information transferring behaviours. These findings resonate with theory about the anticipation ration (Entin & Serfaty, 1999). This ratio depicts the proportion of coded information transfers to coded information requests. Information transfers involve team members providing information without a specific request, announcing a certain action, or acknowledging plans for action. Information requests include explicitly requesting information, because it had not been provided by other team members or had been provided in an insufficient manner (for example incomplete of confusing). A high ratio suggests team members are anticipating other team members needs for information, thereby “pushing” information prior to a request, denoting higher implicit coordination and shared situational awareness (Entin et al., 1994; Stachowski et al., 2009). The other way around reflects a lack of anticipation, resulting in team members’ need to “pull” information from one another. This may explain why the team showing predominant information transferring interaction, possibly resembling back-up behaviour, was able to de-escalate quickest. Through interacting this way, team members anticipated on other team members information need, which could have led to enhanced coordination, enabling the team to quicker de-escalate the situation compared to teams who interacted predominantly information requests.

External communication Differences in the De-escalation Phase

Thirdly, this research aimed to explore in which way external communication differs for teams that remained in the de-escalation phase for a short time compared to teams that remained in the de-escalation phase for a long time. Overall, the findings show that utilizing directive interaction (such as verbal use of force) supports de-escalating a situation more quickly. The findings also indicate that consistently using one specific de-escalation tactic helps to de-escalate quicker than using multiple de-escalation tactics. This is contradictory with previous literature about employed de-escalation techniques by officers during interactions with citizens. Todak and James (2018) and Todak and White (2019) found that officers, who were considered experts at de-escalating, most frequently used de-escalation tactics that minimize the power imbalance and let them appear more “human”, by showing emotions and respect (e.g. emphasizing humanity in our code scheme). This contradictory finding could be explained by the difference in perspective on the use of force. In this research, following the National Consensus Policy and Discussion Paper on Use of Fore (IACP, 2017) and the use-of-force continuum described by Oliva et al. (2010), a distinguish is made between physical (such as handcuffing and shooting) and verbal use of force (such as warnings, verbal persuasions and commands). Therefore, in this research, verbal use of force is considered a de-escalation tactic and included in our code scheme. In the studies of Todak and James (2018) and Todak and White (2019), use of force is described as a violent physical intervention during police-citizen encounters, and de-escalation tactics are described as means to avoid this physical use of force. Consequently, the researchers used a code scheme that fitted to this viewpoint, including interaction codes such as respect, honesty, listen, and emphasizing humanity, leaving out the verbal use of force element. Combined with our findings, it illustrates the need for consensus about a clear framework to study external communication with citizens in detail, in which multiple concepts (e.g. use-of-force continuum and de-escalation tactics) and aspects of interaction (verbal and physical) are integrated.

Theoretical Implications

This exploratory study adds value to research in the field of action teams and de-escalation on multiple levels. First, this study adds to a deeper understanding of changes in interaction during various levels of task complexity. This study adds to team literature in general by providing evidence that task complexity is an important factor to consider when examining temporal team interactions. Although the studied scenarios differ, task complexity increased in both scenarios when teams switched to the de-escalation phase. By studying team's moment-by-moment interaction, we were able to observe that adaption occurs when task complexity increased. When switching to the de-escalation phase, teams adapted their coordination by focussing more on information transferring interaction. By "pushing" information prior to a request, they anticipate other team members needs for information, thereby enhancing implicit coordination and shared situational awareness (Entin et al., 1994; Stachowski et al., 2009). Furthermore, to the researchers' knowledge, this is the first study that investigated de-escalation at team level by examining non-verbal and verbal interactions. Existing literature on de-escalation focusses on police-citizens encounters by either analysing verbal de-escalation tactics employed by individual officers (e.g. IACP, 2017; Oliva et al., 2010; Todak & James, 2018; Todak & White, 2019) or focussing solely on the physical use of force (e.g. Binder & Scarf, 1980; Fridell & Binder, 1992; Pickering & Klinger, 2023). However, these perspectives neglect the influence of verbal interaction and the collaborative performance of officers as a team. This study therefore contributes to the field by providing insights into interactions to coordinate police-citizens encounters. Depending on the demands of the task, teams can adapt either by engaging in interaction with citizens or by enhancing their team interaction to effectively coordinate a situation.

Second, this study is the first that examines external communication patterns with citizens. Previous research on action teams has focused solely on team interaction patterns as the studied teams rarely interacted with individuals outside their team (Kolbe et al., 2014; Lei et al., 2016; Rico et al., 2021; Stachowski et al, 2009; Zijlstra et al., 2012). This is different for the task-context of policing, as officers frequently engage with citizens while operating (Todak, 2017; Todak & James, 2018). This study has uncovered signals that police teams require not only to rapidly establish effective communication within their team, but also to effectively interact with citizens to successfully perform. Specifically, utilizing directive interaction supports de-escalating a situation more quickly. Thus, there appears to be an effect of performing different de-escalation tactics. Consequently, this research outcome points to the potential value of including de-escalation tactics while examining interaction patterns of teams. More specifically examining these tactics in the de-escalation phase is important and can lead to police teams handling this crucial phase more effectively.

Third, this study implicates that differences in VR scenarios require different forms of coordination. The findings of this study illustrated a difference in team interaction and performed de-escalation tactics for both scenarios. Although both scenarios consisted of an escalation and de-escalation phase, specific skills were trained in each phase by a variety of task demands. For each phase, teams differed in interaction to coordinate and address these demands, demonstrating that specific skills require different ways of interaction to coordinate the situation. For example, in one scenario teams engaged in CLC, whereas in another scenario teams coordinated by displaying mutual performance support. Hence, to make sure teams respond swiftly and effectively, a good understanding of the situation and what de-escalation tactics are effective in such situations can optimize their functioning. By using VR as a research tool, we were able to capture teams' responses to different scenarios and reveal what their interaction looks like. To the researchers' knowledge, this is the first study that uses VR as a tool to study team interaction patterns within action teams. Previous research on action teams is conducted within simulators (Stachowski et al., 2009; Lei et al., 2016; Zijlstra et al., 2012) or real-life teams (Kolbe et al, 2014). These findings do not only imply that VR can be tailored to train specific ways of coordinating (Kleygrewe et al., 2023a), but also positions VR as a suitable tool for in-depth exploration of interaction, bringing us closer to understanding the intricacies of team dynamics.

Practical Implications

The current study adds practical value regarding the training of action teams on several levels. First, by studying team interaction, our research has illustrated that training scenarios with different task demands and complexity require a different way of coordination.

Therefore, this study implies that practitioners require to incorporate training scenarios with a variety of task demands (such as decision-making under pressure) and complexity (accomplished through differentiation, for example one attacker versus multiple) when designing training curricula for action teams. In doing so, it is important to distinguish between an escalation and de-escalation phase in the training design. Additionally, after performing the training scenario it is important to clearly discuss in a de-briefing which different behaviors were displayed during these phases (Kleygrewe et al., 2023b; Zechner et al., 2023). This way, a broad spectrum of coordination dynamics is trained to effectively handle real-life practice. Including a variety of task demands and complexity within training scenarios is also emphasized by Hutter et al. (2023), who presented criteria for high quality training of police officers. In their daily work, police officers often encounter unique situations, which requires them to adapt trained skills to the specific situations (Benell et al., 2020; Korner & Staller, 2021; Mugford et al., 2013). Team adaptation processes manifest as variations of patterns, in which cognitive structures provide support for teams to cope with changing circumstances (Uitdewilligen et al., 2018). Therefore, practicing adaptability and flexibility in training scenarios encompassing a mix of specific skills is crucial. Also, this study highlights that the team who used primarily information transferring interaction de-escalated quickest, which implies that interaction aimed at anticipating other team member's information need should be included in VR training for police officers. Virtual reality scenario-based training offers a realistic environment for police officers to train these dynamic high-risk situations (Kleygrewe et al., 2023a).

Second, this study implies that police trainers should be aware of and recognize the broad spectrum of coordination in the form of team interaction and de-escalation patterns. Trainers could enhance trainees' learning by jointly reflecting on the specific behaviours related to these patterns, thereby enhancing awareness of how they are preforming. Currently, experienced police trainers identify key performance indicators and provide feedback to assess performance (Kleygrewe et al., 2021; Zechner et al., 2023). Consequently, training delivery and assessment is heavily dependent on expertise of the instructor. Taking a more data-driven approach, by reflecting upon team interaction and de-escalation patterns, gaps between current and desired interaction can be identified and addressed to coordinate more effectively. Hence, it has the potential to improve performance.

Third, this study implicates that participants need to get acquainted with the usage of VR equipment before engaging in a VR training system. A lot of participants experienced difficulties while performing the training scenarios. Some participants had problems with the physical elements (opening a door, handcuffing) or with the hardware features (headset, hearing each other clearly). According to Hutter et al. (2023) conditions require to resemble the real-life practice as closely as possible. Learning takes place through the interaction between the learner and the environment, therefore realistic characteristics need to be in place to increase the likelihood of transfer to daily work (Pinder et al., 2011). Consequently, a practice situation should be well-designed and reflect realistic problems and solutions. The difficulties faced by the trainees might have influenced their immersion with the training scenario and their interaction with team members, as they encountered problems they would not experience in real life (Zechner et al., 2023). To address this, it is recommended to explain the usage of VR equipment via a tutorial. Subsequently, the trainees should be offered to practice with the equipment before participating in training scenarios.

Strengths, Limitations and Future Research

In spite of the contributions noted above, this research has several limitations that need to be acknowledged. To start, several points should be mentioned about the data, sample, and the sampling procedure. First, we had a limited amount of data points in each separate observation during the de-escalation phase due to short observation periods (between 01.20 and 08.55 minutes). This prevented us from performing a T-pattern analysis to compare interaction patterns from the team that de-escalated quickest to the team that took longest to de-escalate. Consequently, we were not able to view how interactions within these teams unfolded over time, limiting our understanding of how their team interaction and external communication looks like. However, short observation periods are typical for VR training (Kleygrewe et al., 2024a, Kleygrewe et al., 2024b). Nevertheless, the data still provides valuable knowledge about team interaction and performed de-escalation tactics. Using frequency analyses, we were still able to identify the occurrence of specific interactions, detect variations and make a comparison across teams. Consequently, the exploratory nature of this research revealed initial insights about team member's interaction and external communication. Having more data points could have allowed performing a T-pattern analysis. Therefore, instead of only comparing two teams, future research should use a bigger sample size when making a comparison between teams that de-escalated quickest compared to teams that took longer to de-escalate. Grouping multiple teams in these two categories may provide more data points and allow the identification of T-patterns. Another point that needs to be noted about the data, is that information about team performance was unavailable. Although this exploratory study contributes to our understanding of team interaction within police teams, we were not able to make any implications about the effectiveness of specific interactions and patterns. A recommendation for future research would be to include expert raters (e.g., instructor ratings) to assess team performance. This offers the opportunity to link team performance to interaction patterns, enabling us to assess and make implications about the effectiveness of specific interaction. To assure interrater agreement, more than one expert rater should be employed to determine the team performances (Zijlstra et al., 2012).

Next to limitations regarding the data, we only had access to a small sample size of police teams which was retrieved via convenience sampling. Using a small sample size has negatively influenced the statistical power and generalisability of our findings (Field, 2017). It even resulted in unfulfilling one of the assumptions for the Wilcoxon Signed Rank test, the non-parametric test used in this research, meaning our results should be interpreted with caution. The findings' statistical power and generalisability could have been increased when a larger number of teams had been available, because a parametric test such as the paired t-test could have been conducted (Field, 2017). Therefore, future research should preferably use a larger sample size to increase the statistical power and generalisability of findings. Although the sample size is small, the data can be considered rich (i.e., 654 behavioural events within 45 minutes of video recordings). Moreover, due to practical limitations, it is common for research within high reliability contexts to examine relatively few teams (e.g., Lei et al., 2016; Stachowski et al., 2009; Zijlstra et al., 2012). Studying dynamic change in coordination patterns, David et al. (2024) even analysed one team for a long observation period, revealing very rich data. Despite the small sample size in our research, all behaviours were reliably coded using a predefined coding scheme. Until today, detailed analysis of team behaviours has been difficult, and studies on team dynamics have mostly focused on a limited series of briefly captured moments rather than looking at how interactions unfold over time (Leenders et al., 2015). In line with the growing emphasis on studying temporality-sensitive phenomena within teams (Kozlowski, 2015; Lei et al., 2016; Waller & Kaplan, 2016), a process-perspective was applied to explore team interaction using the pattern recognition software THEME. Moving forward, future research on action teams could greatly benefit from using continuous-time data to understand the patterns of team interaction more thoroughly. Besides the small sample size, convenience sampling was applied. The teams were offered training in September 2022 at the facility of the tech company. Although the simulated training environment gave rise to the unique opportunity to collect detailed data and the involved teams had various nationalities, the sampling method has its limitations. That is, it does not accurately reflect the entire population of police teams and lacks diversity. For example, there is merely one team out of nine that consists of women, whereas the other eight teams comprise solely male officers. To represent the population of police teams there should have been teams included that comprise mixed genders. Hence, the non-random nature of selection affects the generalizability of the study. Replicating this research on a larger scale using randomly selected teams is recommended to determine whether the results of this study are generalizable.

Furthermore, information is lacking about the team's tenure and experience. This could have been of value to consider while interpreting the detected interaction patterns. The team's tenure may be an important factor to consider, as newly formed teams and existing teams could differ in their interaction (Gorman et al., 2010). Although prior research indicates that teams quickly establish patterns upon formation (Zijlstra et al., 2012), these patterns are expected to evolve continually as team members gain experience working together (Edmondson et al., 2003; Reagans et al., 2005; Uitdewilligen et al., 2018). Teams that have previously worked together, may thus already have developed interaction patterns, while newly formed teams may have started forming interaction patterns from the moment they began performing in the VR scenarios. Additionally, information regarding experience is unknown. Since experienced officers may have had to switch teams more often, the emergence of interaction patterns in experienced teams may occur more rapidly than in novice teams (Zijlstra et al., 2012). Experience could thus have influenced the displayed interaction patterns. To overcomes these limitations, future research should include characteristics regarding the team's tenure and the experience of team members during data collection. While recognizing that the findings of this study might not be generalizable due to the sample size, sampling procedure, and the limited availability of the team's characteristics, they still provide a valuable basis for future research to examine and potentially verify the results within the context of police teams.

Regarding the VR technology there are two points that warrant mentioning. First, we faced some technical limitations with the After Action Review software. In one case, conversations between officers that were not participating in the specific scenario could be heard. This could possibly have distracted the team members participating in the scenario, and therefore have influenced their interaction. Additionally, as the police officers were often talking simultaneously, it was sometimes difficult to distinguish their interaction while coding the data. Unfortunately, the AAR software did not have the option to emit the interaction of the officers separately. Consequently, the code "zero behaviour" had to be added to code this data. Since no actual meaning could be attached to this code, the quality of the data slightly impaired. For example, when looking at the content of the pattern diagram in Figure 6. To improve quality, it is recommended to add the functionality of muting/unmuting specific participants to the AAR software.

Moreover, the difficulties experienced by the participants while using VR equipment need to be considered. For example, some team members could not hear well, notified they did not have armour, or faced difficulties while opening doors. As a result, a substantial amount of the interaction included how to use VR equipment and complaints about the difficulties. Another issue the officers experienced within the VR environment was motion sickness, which in one case led to a premature ending of the scenario. Consequently, these technical limitations have influenced the officers' interaction and potentially their engagement with the simulations (Kleygrewe et al., 2023a). Future research could overcome the equipment difficulties by explaining the usage of VR equipment in a tutorial. Subsequently, the trainees could be offered to practice with the equipment before participating in the studied scenarios. Furthermore, the main cause for motion sickness has found to be the sensory mismatch between visual and vestibular senses (Park et al., 2023). This might be reduced by implementing a rest frame into the screen space, for example a Motion Singularity Point/Region, which refers to the reference object that remains fixed in position with respect to the user. Therefore, it is recommended for future research to verify if such measures are taken to limit the chance of motion sickness. By overcoming the limitations of interruptive interaction and premature endings of observation periods, the quality of the collected data may be improved.

Another aspect worth noting is the distinction between the phases in this study. It would have been interesting to take the decision-making model regarding the use of force into account, provided by Binder and Scharf (1980). As described in the theoretical framework, this model distinguishes four subphases in coming to a decision on how to de-escalate a situation, including: *anticipation*, *entry and initial confrontation*, *dialogue and information exchange*, and *final decision-making.* According to the model, the interplay between police and citizens is central and eventually leads to a decision regarding de-escalation. However, the data in this study did not show clear points that could be linked to the beginning and ending of the multiple phases. Consequently, we decided to consider the start of the de-escalation phase based on the moment of contact with a citizen. This research has discovered differences in the effect of different team interaction and de-escalation tactics in the de-escalation phase. More specifically examining this crucial phase by looking at the proposed subphases by Binder and Scharf (1980) has the potential to gain insights into how police officers can perform more effectively. Therefore, it would be interestingly for future research to build on this knowledge and zoom in on what team interaction and de-escalation tactics are effective in these subphases. This appears important because different phases of the police-citizen encounters require different interaction to lead to an optimal outcome (Fridell & Binder, 1992; Pickering & Klinger, 2023). Additionally, it would bring us another step closer in understanding coordination dynamics.

Lastly, it would be interesting for future research to combine pattern analyses with physiological data. Action teams operate in dynamic, high-risk environments, often involving stressful situations. Therefore, these teams face the challenge to maintain successful coordination within high-stress circumstances. Combining interaction patterns with stress level data could lead to a more comprehensive understanding of what moment-by-moment interaction occurs while teams experience various levels of stress. Subsequently, it could be investigated if these patterns are desirable and if teams could be trained to regulate the influence of stress. Existing research recognizes heart rate variability (HRV) as a valid indicator for assessing real-time stress levels (Laborde et al., 2017; Umair et al., 2021). The Medtronic Zephyr Bioharness 3.0, an adjustable electrode belt measuring physiological parameters, appears to be a promising tool to gather real-time data about HRV (Gancitano et al., 2021; Nazari et al., 2018). Previous research experienced the device as reliable and relatively resistant to high levels of body movement (Zechner et al., 2023). This is especially relevant in the context of action teams, as their performance often involves a lot of movement. Providing these insights have the potential to improve coordination within high-risk situations, thereby enhancing team performance.

Conclusion

This exploratory study shed light on interactions and patterns displayed by action teams during several high-risk scenarios. Specifically, we zoomed in on which team interaction and external communication (i.e., including citizens who are not part of the team) is displayed by members of police teams during escalation and de-escalation phases. Utilizing the pattern recognition software “THEME” we were able to study team's moment-by-moment interaction and observe that adaption occurs when task demands change. This study makes a meaningful contribution by revealing that teams require different forms of coordination in terms of team interaction and de-escalation tactics to adapt to different task demands.

Findings underscore the potential of specifically examining what team interaction and de-escalation tactics can establish effective coordination and lead to effective handling within action teams. Consequently, this study is of meaning for both science and practice, providing insights into coordination dynamics by looking at interaction.

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Appendix

Appendix A: variable-value table

actors
a_teammember
b_teammember
c_teammember
d_teammember
e_teammember
b_e
b
e
team_interactions
command
observe
suggest
opinion
inquiry
question
acknowledgment
answer
briefing
expression
standby
zero_behaviour
actions
door
handcuffs
shoot
de_escalation
ask_for_information
emphasizing_humanity
honesty
verbal_use_of_force