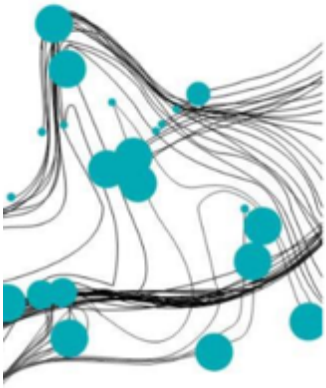

Flexibility of and complexity in cardiopulmonary resuscitation teams' communication patterns

An exploratory study of differences between high and low performing teams and teams before and after training

Aimée Muller

Faculty of Behavioural, Management and Social Sciences (BMS)

Educational Science and Technology (EST)

First supervisor:
Lida David
l.david@utwente.nl

Second supervisor:
Maaike Endedijk
m.d.endedijk@utwente.nl

Keywords: Cardiopulmonary resuscitation, action teams, communication patterns, performance, flexibility, complexity

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Acknowledgements

The completion of this master's thesis marks the end of a very special educational experience at the University of Twente. After having had a month of courses at campus, the corona virus caused an unexpected continuation of the program. From that moment on, all education took place digitally. Although this was of course not the experience I considered when starting with my master's in educational science and technology, this digital learning environment made me realize again that education is not made to be an individual process. Of course, education makes the way clear for individuals to develop themselves, but this development is for a great part depending on the individual's environment consisting of fellow students, teachers and others that stimulate and provide support for learning. I am therefore fortunate to have had a group of people around me, despite not being able to visit campus, that supported me and helped me to get the most out of the past year's learning experience. With regards to writing this master's thesis specifically, I therefore want to thank a few people in particular.

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Sas efcharistó, bedankt, thank you,

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Abstract

Cardiopulmonary resuscitation (CPR) is a complex procedure for which training is needed in order to improve performance and patient outcomes. An important component of such trainings to improve performance, is communication. Structural aspects of communication, such as its flexibility (the extent to which communication is heterogeneous instead of consistent) and complexity (the number of transitions between members and the number of involved members in these transitions) can support the extent to which performance is enhanced. In this study, coded video recordings of student teams practicing CPR (in a simulated setting) were imported in THEME software to reveal structural patterns in CPR team communication. Between-team differences (high and low performing teams) and within-team differences (before and after training) were investigated regarding flexibility and complexity. Results of this exploratory study indicated that no significant differences were present between flexibility and complexity of low and high performing teams. After training, teams showed significantly more flexibility in the communication's structure. Complexity in terms of the number of transitions between members did also increase significantly after training. A significant decrease was seen after training in complexity with regards to the number of involved actors within transitions. These findings can enhance understandings of what key focus areas within CPR trainings could be. However, in order to take considered actions in adjusting these trainings, more research is needed.

Keywords: Cardiopulmonary resuscitation, action teams, communication patterns, performance, flexibility, complexity

1. Introduction

Fatal endings of cardiac arrest can be prevented by providing cardiopulmonary resuscitation (CPR). Still, CPR is a complex procedure and oftentimes results in poor outcomes (Ibrahim, 2007; Kneebone et al., 2007). Attention needs to be paid to performance within healthcare teams, for the sake of improving such outcomes. Indeed, health care teams' performance has convincingly been linked to CPR outcomes (Grumbach & Bodenheimer, 2004). As indicated widely in previous studies, communication is of critical importance in order to improve this performance (e.g. Andersen et al., 2010; Meaney et al., 2013). This influence of communication is affected by its flexibility and complexity (Burke et al., 2006; Gardner et al., 2012; Stachowski et al., 2009; Waller & Uitdewilligen, 2008).

As CPR teams could be classified as action teams, their membership is dynamic, and their work environment is uncertain and constantly changing (Gardner et al., 2012; Sundström et al., 1990). Teams oftentimes assemble ad hoc, causing that members rarely communicate *before* working together on a case, and that communication *during* the process becomes even more important (Pittman et al., 2001; Sundström et al., 1990; Tschan, 2009; Vashdi et al., 2013). Indeed, by outwardly expressing (using verbal communication) what happens inside someone's mind during the process, team members can collectively make sense of the environment and anticipate on each other effectively, so that performance can be enhanced (Klein et al., 2010; Stout et al., 1999; Van den Bossche et al., 2011). Flexibility could support this collective sensemaking, as it ensures that members are aware of constant changes and adapt to these (Burke et al., 2006; Gardner et al., 2012). The communication's complexity level is of importance for how much information is received by team members, and thus for the extent in which they can collectively make sense of occurring situations (Bogenstätter et al., 2009; Orasanu, 1994).

Previous studies have shown conflicting results with regards to the influence of flexibility and complexity on performance. Where some indeed stated that flexibility ensures an accurate adaptation to changing situations (e.g. Burke et al., 2006; Gardner et al., 2012; Shetty et al., 2009), others mentioned that such flexibility could cause confusion and thus actually impede with collectively making sense of the environment and anticipate accurately (e.g. Kanki et al., 1991; Zellmer-Bruhn et al., 2004). For complexity, opposing views exist as well about whether more complexity provides team members with more information, and thus the opportunity to anticipate more accurately and perform better (e.g. Orasanu, 1994; Waller & Uitdewilligen, 2008), or whether such complexity diminishes performance by for example overloading working memory, so that important information for making sense of the situation could be overlooked (e.g. Bogenstätter et al., 2009; Stachowski et al., 2009). As these studies have all been performed in slightly different task contexts, studying a CPR context specifically is an important contribution when aiming to inform for CPR improvements. Further, Hunziker et al. (2011) already mentioned the need for more research on communication specifically within a context of CPR performance. Research on the specific communicational aspects of flexibility and complexity could thus make a very targeted contribution to existing studies.

Flexibility and complexity both have to do with the structure of communication. Still, studies about communication within healthcare teams mainly focus on content of communication, such as accuracy of communicated information and frequency counts of specific communication types (e.g. Bogenstätter et al., 2009; Calder et al., 2017; Tschan et al., 2015). This is despite the fact that Gorman et al. (2017) noted the importance of structural aspects by mentioning that team performance is strongly influenced by the specific orders and combinations in which interactions occur and by the changes therein. Also, especially in action team contexts, not the occurrence of certain behaviors per se, but rather the timing of such behaviors relative to each other is an important indicator for performance (Ballard et al., 2008). Regarding this, a gap in current studies exists about how specific patterns of communication and their evolvement over time contribute to CPR performance.

Moreover, existing studies about communication patterns within action teams do not look at evolution of patterns through time. Burtscher et al. (2018) investigated differences in the use of certain communication patterns between novice and expert healthcare teams. Their study revealed that novice and expert teams indeed differed in communication patterns, as certain types of communication stimulated other types of responses in both teams. However, a link to performance was not made. As well missing, was a more in-depth insight showing how such differences have developed over time (during the time novices gradually became experts). This marks another important gap in current literature, since such insights could inform about training needs with regards to communication during different developmental stadia. Delineating the development of high performing teams' communication patterns could be valuable for the design of trainings that are needed to improve CPR performance (Gabr, 2019).

Thus, the current study attempts to fill the mentioned gaps by focusing on the question: "What differences in verbal communication patterns are apparent through time between high and low performing CPR teams?", with differences in flexibility and complexity as key study areas. This would add to existing studies both for theoretical and practical reasons. For theoretical reasons it aims at creating clarity, specifically in CPR contexts, in the opposing views on links between performance and flexibility and complexity. With these variables in mind, it is furthermore aimed to close the gap in current literature regarding the study of communication patterns, while considering evolvement of such patterns over time. For practical reasons this study aims at providing insights that contribute to the improvement of CPR performance and training.

In what follows, previous research will be used for the development of four hypotheses: two concerning flexibility of communication patterns and two concerning complexity within communication patterns and their link to performance and training. Accordingly, communication patterns of both high performing as well as a low performing student CPR teams will be examined. For two teams, this will be done at two points in time. By analyzing the patterns at the beginning and end of training, it is aimed at making statements about differences in patterns' flexibility and complexity not only among high and low performing teams, but also before and after training.

2. Theoretical framework

2.1 The importance of CPR trainings and the value of simulation usage

Cardiopulmonary resuscitation (CPR) entails measures that aim at rehabilitating the vital performance of the heart in someone who has had a cardiac arrest (Lee, 2012). Measures include an integrated set of coordinated actions consisting of external chest compressions, ventilation of the lungs and defibrillations (Lee, 2012; Monsieurs et. al., 2015). For these, performance depends on an adequate rate and depth of compressions, adding a sufficient amount of air to the patient's lungs by using mouth-to-mouth or mouth-to-pocket and quick providence of defibrillations (Hunziker et al., 2009; Meaney et al., 2013; Monsieurs et al., 2015). Trainings are a main link between this theoretical basis for good performance and its implementation in practice (Greif et al., 2021). Thus, when wanting to increase performance to reduce poor CPR outcomes, the quality of trainings is a fundamental aspect to take into account.

Providing CPR trainings has repeatedly been shown to enhance CPR performance (e.g. Lerjestam et al., 2018; Lund-Kordahl, 2019). Training methods that could be used are for example (combinations of) lectures, demonstrations and role play (e.g. Alimohammadi, Baghersad, & Marofi, 2017; Chegeni, Aliyari, & Pishgooie, 2018; Lerjestam et al., 2018). Another option is the use of mannequin-based simulations. Such simulation-based CPR trainings have as well been shown to significantly improve CPR performance and are especially useful for improving teamwork and communication (Flanagan et al., 2004; Medley & Horne, 2005; Sok et al., 2020). Indeed, Flanagan et al. (2004) mention that particularly for multidisciplinary teams, a simulation-based training could make a great contribution to the improvement of team performance, as (cross-discipline) interactions are practiced.

Simulations are increasingly being used for the training of resuscitation in cardiac arrest (Sahu & Lata, 2010). Gaba (2004, p. 2) defined simulations as a technique to "replace or amplify real experiences with guided experiences, often immersive in nature, that evoke or replicate substantial aspects of the real world in a fully interactive fashion". In health care, for example in CPR trainings, this usually means that a real patient is substituted for a simulated one, in order to create realistic but controlled and safe practices (Andersen et al., 2010). Frequently there is made use of high-fidelity mannequin simulators (full-body simulated patients that show great similarities to real persons), which are shown to be realistic and useful for medical training (Gordon et al., 2004; Hammond et al., 2002; Sahu & Lata, 2010). One reason for this usefulness of high-fidelity simulators is its encouragement of active participation. Such participation positively influences learning for example by stimulating higher order thinking and inducing engagement in the learning task (Ormrod, 2012).

2.2 Difficulties of working in action teams

Any group of two or more people that work interdependently to achieve a common goal can be entitled as team (Salas et al., 2005). In practicing CPR, a team of health care providers work together towards the shared goal of saving a patient's life. However, compared to teams in most other industries, CPR teams work under highly complex, unpredictable and stressful conditions (Klein et al., 2006; Sundström et al., 1990). Unlike a lot of teams in other industries, that are oftentimes formed to work together for a longer time period, CPR teams can be characterized by a dynamically changing team membership, as assembling oftentimes happens ad hoc (Sundström et al., 1990). Judging by these characteristics, a CPR team is a typical example of what Sundström et al. (1990, p.121) describe as 'action team', namely; "highly skilled specialist teams cooperating in brief performance events that require improvisation in unpredictable circumstances". Next to CPR teams, some other examples of action teams include cockpit crews, military teams and fire brigades (Ishak & Ballard, 2012). Action teams can thus be distinguished from other teams based on the fact that they (1) perform urgent and unpredictable tasks, with high consequences, (2) cope with frequent changes in team composition (Ishak & Ballard, 2012; Klein et al., 2006; Sundström et al., 1990). The frequent changes in team composition make it difficult for team members to fall back on a shared mental model, on the basis of which they can collectively make sense of the environment (Kolbe et al., 2012a; Van Ginkel et al., 2009; Vashdi et al., 2013). Such collective sensemaking (a process in which people share understandings of ambiguous and unforeseen situations and try to reach consensus on interpretations and a course of action) is needed to guide good anticipation and adaptation, which are especially important in fast paced emergency settings (Entin & Serfaty, 1999; Gardner et al., 2012; Maitlis & Christianson, 2014; Stigliani & Ravasi, 2012; Weick, 1993). Thus, within action teams the need exists to compensate for such a limitation.

2.3 The importance of communication (patterns) for action team performance

One way of providing compensation for the possible lack of shared mental models in action teams, so that team members can still collectively make sense of the situation, is by means of information sharing (Garner, H. in Lo, 2011; Weller et al., 2014). Effective communication is therefore of critical importance to ensure consistency and adequacy within action teams (Rehim et al., 2017). Indeed, in action teams, communication has been shown to be crucial for high performance (e.g. Andersen et al., 2010; Meaney et al., 2013; Pittman et al., 2001; Stout et al., 1999). Communication is then defined as the transmission of information between one person to another person or group (Garosi et al., 2019; Riggio, in Castelao et al., 2013). This could be done nonverbally, for example by the use of movement, facial expressions and eye contact, or verbally by using several different speech acts, such as questioning, answering and proposing a suggestion (Kudesia & Elfenbein, 2013; Tchupo et al., 2017; Waller et al., 2004).

Studies on content of communication and its link to performance have already revealed that the effect of verbal communication on performance may depend upon the types of communication that are used (Lehmann-Willenbrock et al., 2013). For example, communication types that are irrelevant for the ultimate goal that needs to be established or that impede the general trail of thought (e.g. interrupting statements) could damage team performance (Hoogeboom & Wilderom, 2019; Kauffeld & Lehmann-Willenbrock, 2012; Sorensen & Stanton, 2016; Swaab et al., 2008). Performance could on the other hand be increased by procedural communication types aimed at coordinating the task (e.g. structuring and directing) (Hoogeboom & Wilderom, 2019; Schultz, 1986; Lehmann-Willenbrock et al., 2013; Mesmer-Magnus & DeChurch, 2009; Sonnentag, 2001).

While these content related aspects of communication already reveal a lot about performance expectations, they leave in the middle how specific combinations of communication types and orders in which they occur affect performance. Thus, when interested in communication's flexibility and complexity and their relation to performance, different communication types should not be taken out of their context, but it should be looked at their structural interrelations. Indeed, as Pilny et al. (2016) already mentioned, communication is a continuous and evolving process. One verbal expression can trigger another one, leading to a process in which a series of fine-grained communicational parts build on each other (Leenders et al., 2016). For example, posing a question is likely to evoke giving an answer and such an answer could again trigger someone to make a statement of disagreement. Would the question not have been asked, the statement of disagreement would probably not have been made either. How such communicational parts build on each other is highly dependent on time (Cronin et al., 2011). The process of communication within teams should thus not be looked at as what McGrath et al. (2000, p. 98) mention as “chain-like unidirectional cause-effect relationships”, but rather as a dynamically developing process in which time is deep rooted (Pilny et al., 2016). A way to disaggregate the process of communication over time and instead look at this in a continuous manner, is by looking at communication patterns.

Communication patterns are recurrent, ordered series of (different) types of communication (Gorman et al., 2012; Stachowski et al., 2009). The mentioned example in which a question was followed up by an answer and subsequently by a disagreement could thus be seen as a pattern when this sequence of communication types appears recurrently. Analyzing communication patterns enables taking the order of communications into account so that the impact of time is included and better inferences about team processes such as performance could be made (Leenders et al., 2016). This is needed especially within research on action teams, as such teams need to function in uncertain and changing environments and thus quickly need to anticipate and change their responses to new situational demands (Gardner et al., 2012). As a result, action teams have to adapt their communication gradually to continuously evolving contexts, which asks for exploratory, patterned communication (Stachowski et al., 2009).

2.4 Considering flexibility of communication patterns

When communication patterns are structured flexibly, this means that, during an event, communication is structured in a heterogeneous way (Stachowski et al., 2009). Instead of showing consistent, standardized patterns, flexibility of communication patterns entails a large variety in communication types that are shown together (e.g. more different patterns). Opposing views exist about such flexibility of communication and its link to performance.

Within action team contexts, high performing teams are oftentimes characterized by highly consistent patterns of communication (e.g. Kanki et al., 1991; Kanki, et al., 1989; Zijlstra et al., 2012). For example, Kanki et al. (1991) provide supporting evidence for this, in the context of aircrews. Their study showed that high performing crews, relative to midrange and low performing crews, exhibited almost identical, homogeneous communication patterns. This importance of consistent interaction patterns for performance is explained with the idea that standardization supports accurate action (Kolbe et al., 2012b; Kanki et al., 1991). Given the time constraints action teams have to deal with, constant deviation from rules and standards would cause interruptions and take up precious cognitive capacity required for (vital) decisions about performance (Speier et al., 2003). This implies that by following established interaction norms instead, a smooth task execution is facilitated, and cognitive resources are relieved. Additionally, in such a way, ambiguity is avoided, and teams are less susceptible to confusion (Waller, 1999; Zellmer-Bruhn et al., 2004). This enables team members to assess the situation at hand appropriately and thus facilitates them to react accurately (Meaney et al., 2013).

However, disadvantageous to consistent and standardized communication patterns could be that these impede flexible adaption to unexpected situations (Burke et al., 2006). As action teams need to function in uncertain and changing environments, they quickly need to anticipate and change their responses to new situational demands (Gardner et al., 2012). For example, in their study on communication patterns of pilots within Air France Flight 447, David and Schraagen (2018) found that, when faced with an emergency situation, pilots switched from standard interaction patterns to patterns determined by direct appearing environmental cues. For CPR teams specifically, Shetty et al. (2009) found that higher performing teams adhered less to resuscitation guidelines and were better able to show flexible, adaptive behaviour. Moreover, following standardized interaction patterns instead of being flexible in this regard, is found to reduce the amount of information that is shared and thus to lower performance (Hoogeboom & Wilderom, 2019). Indeed, standardized structures diminish team members' opportunity to share and collect information (Schippers et al., 2014; Waller et al., 2004). On the other hand, Stachowski et al. (2009) found a positive link between a team's flexibility to adapt and openness to new information and knowledge. Thus, although it is sometimes stated that preparing for various unique crises is best done by using standardized norms that could be helpful during a wide range of situations (e.g. Paraskevas, 2006), such norms do not take the need for adequate responses to changing situations into account (Hollenbeck et al., 1995). Therefore, it is hypothesized that high performing CPR teams are better able to adapt to sudden situations and thus show more flexibility.

Hypothesis 1: High performing CPR teams show more flexibility of verbal communication patterns than low performing CPR teams.

Furthermore, since CPR training was found to have a positive effect on performance, it is expected that more training results in teams showing more characteristics of high performing teams. Since it was expected that more flexibility of verbal communication patterns is characteristic for higher performing teams, this leads to a second hypothesis that this characteristic becomes more prominent in better trained teams.

Hypothesis 2: The flexibility of verbal communication patterns within CPR teams increases when comparing teams' communication patterns before and after training.

2.5 Considering pattern complexity

Communication patterns can vary in complexity as well. For example, a pattern in which one team member poses a question and another provides an answer can be seen as not being that complex. Namely, it consists of only two communication types (question and answer) and is performed by only two actors. A more complex pattern would be consisting of more different communication types or a larger number of actors involved (Stachowski et al., 2009).

Contradicting views exist about the complexity of communication patterns and action team performance. There are some studies in which highly complex communication is recommended in order to avoid inaccurate information transmission and ambiguity (e.g. Waller & Uitdewilligen, 2008; Weick & Sutcliffe, in Stachowski et al., 2009). For example, in their research about cockpit talk during crises, Billings and Reynard (in Orasanu, 1994) showed that team members of better performing crews talked more overall. Thus, as more actors were involved, this would imply more complex patterns. Orasanu (1994) elaborated on these findings by underlining the importance for speakers not to assume that others have the same information as they have or know what they are thinking. According to her this information should thus be explicitly communicated. However, a large body of other studies advocate a less complex communication style (e.g. only a question and answer), in order to relieve working memory and ensure that information that really matters at a particular moment is received properly (e.g. Kanki et al., 1991; Sauer et al., 2006; Sexton, in Gross, 2014; Stachowski et al., 2009; Zijlstra et al., 2012). In a simulated study, Bogenstätter et al. (2009) highlighted the problem of an overloaded working memory, as they showed that at least 18% of transmitted information within a cardiac arrest situation was forgotten by team members. This would support the idea that, within CPR team communication, complexity should be perked to a minimum. Therefore, in line with the largest number of previous studies, it is hypothesized that high performing CPR teams show less complex communication patterns, as shown by fewer transitions between fewer team members.

Hypothesis 3: High performing CPR teams show less complex verbal communication patterns than low performing CPR teams

Here as well, it is expected that team training, as this is positively linked to performance, has a strengthening effect on characteristics related to high performing teams. As research as well found a positive relation between the time individuals spend on interacting and shared mental model development, this would indicate that the greater amount of time teams spent together in training, the better they will become able to anticipate on each other (Jeong & Chi, 2007). Team members would then need less verbal communication to achieve good performance. Taken together, it is thus hypothesized that CPR teams' participation in training has a decreasing effect on the complexity of (recurring) communication patterns.

Hypothesis 4: The complexity of recurring verbal communication patterns within CPR teams decreases when comparing teams' communication patterns before and after training.

3. Research design and methods

3.1 Research design and participants

This mixed methods study was based on a secondary dataset consisting of video recordings (pre- and final assessments of student medical teams performing CPR) and performance scores (that were attributed to these student teams by their teachers). For this secondary dataset, sampling took place within the University of Twente, among students following an "Advanced Life Support (ALS)" course within the master program 'Technical Medicine' during the schoolyear of 2018-2019. Within this course, students trained in teams of four for the practice of CPR in a simulated context during five different meetings (of which the first consisted of the pre-assessment and the last of the final assessment). Given the time lapse between these practices, and the controllability of the simulated setting, these students were found to be appropriate participants given the aim of this research.

A classification in high and low performing teams was made based on performance scores of all teams in the secondary dataset. For this dataset, all 81 master students who enrolled to the ALS course, were asked to participate in the sampling procedure. As participation was voluntary, 79 of them confirmed that they were willing to participate. The two students that did not confirm were excluded from sampling. Students' course grade was not affected if they were not willing to give consent. Also, two students prematurely dropped out of the ALS course, which also excluded them from participating. Ultimately, this led to a total of N=77 to be considered participants for the secondary data collection, comprising 20 teams (four teams consisting of three members, the other teams consisting of four members). To answer H1 and H3, between-team differences were investigated by coding the final assessment of seven teams (N=28).[1] These teams were numbered as team 1, 2, 5, 6, 8, 10, and 15. Within-team differences were investigated, with the purpose of answering H2 and H4, by also coding the pre-assessment of two of those seven teams (team 1 and 5).[2] Thus, the study was designed longitudinally by taking into account the first as well as the last simulated CPR performance of different teams. Prior to coding and processing the secondary data, an ethical request was approved by the University of Twente's Ethical Committee of the Behavioral, Management and Social Sciences (BMS).

3.2 Materials

3.2.1 Consent form

Informed consent was provided on 14 December 2020, by the University of Twente's BMS Ethics Committee. The consent form can be found in Appendix A.

3.2.2 Performance scales

A holistic measure of team performance within the specific task context was measured by using a performance scale that included team effectiveness rates and general ALS effectiveness rates. Gibson, Cooper, and Conger (2009) developed a valid four-item scale to measure team effectiveness. The involved items focus on consistency of quality, effectiveness, errors made and general performance. With a Cronbach's alpha of 0.97 this scale is highly consistent for measuring team effectiveness. After every simulation, the present teacher rated team effectiveness based on this scale by using a Likert scale rating from 1 (very inaccurate) to 7 (very accurate). As such, items that were rated are for example "this team makes few mistakes" and "this team shows high-quality work". General effectiveness of

[1] It was chosen to use the recordings of these specific 7 teams since the key to other teams' data was (unexpectedly, due to personal circumstances of the keyholder) not available

[2] Again, the choice for coding these two pre-assessments was based on a lack of access to other teams' data of pre-assessments

the provided ALS was rated based on five themes that were chosen by the teachers themselves in order to match the course to the utmost extent. These were rated using a five-point Likert scale. Examples of themes are “therapeutic plan” and “execution of actions”. A high consistency was found for this scale as well, as Cronbach’s alpha was 0.88The complete list of performance scales can be found in Appendix B.

3.2.3 Simulators

The videos were recorded within a simulated Intensive Care Unit (ICU) and simulated operation room (OR) of the Experimental Centre for Technical Medicine (ECTM) at the University of Twente. These settings allowed for a simulation of in-hospital cardiac arrest by using a Human Patient Simulator (ICU) or mobile METIman Patient Simulator (OR). By offering a lifelike appearance, with among others cardiac and CPR features, these simulators enables realistic but controlled training (CAEHealthcare, 2014a; CAEHealthcare, 2014b).

3.2.4 CPR equipment

To provide all necessities for performing CPR, both simulation rooms were as well equipped with an Infinity patient monitor and a Philips defibrillator. The patient monitor enabled insight into the patient’s vital medical signs, such as blood pressure and pulse rate. The defibrillator enabled the provision of an electric shock to attempt to restore a normal heartbeat.

3.2.5 Recording materials

Video recordings were made using the METIvision video and audio system. This system was developed for fully recording healthcare simulation situations (CAEhealthcare, 2014). For this, three cameras and microphones were mounted on the simulation room’s ceiling.

3.3 Procedure

During a 7-week course, starting in March 2018, participating Technical Medicine students became familiar with theoretical as well as practical aspects of CPR settings. Theoretically they learned about how to interpret results of, among others, the patient monitor, anamneses or x-thorax and about different possible therapies, their goals and operation. Regarding practical aspects, students practiced among others with executing shockable and non-shockable protocols, analyzing a patient's condition using the ABCDE method (Airway, Breathing, Circulation, Disability, Exposure and Environment) and with communicating using a closed loop (in which they learned to name the person to whom a message is addressed and to confirm when a message is received). Each student practiced these aspects from various roles, including that of a medication nurse, CPR administrator and team leader. After this 7-week during course, it was aimed that students were adequately able to conduct effective CPR. The course was ended with a practical final assessment. Within this study, focus lays on the practical part of the course (in which learned theory needed to be applied as well), by using data from the first practical lesson and the final practical assessment.

The first practical simulation exercise took place in March 2018 and the final assessment took place in April 2018. Both were situated at the simulator rooms (ICU and OR) of the ECTM at the University of Twente. For each simulation session, 20 minutes were scheduled. During these sessions, one teacher and one medical expert for resuscitations were present in the ICU and one other teacher and medical expert were present in the OR. As well, four medical students, forming the CPR team, were present in each room, so that two simulation cases could be performed simultaneously (one in each room). Each team member was randomly assigned one of the following roles: 1) team leader (with responsibilities such as distributing tasks and monitoring performance), 2) medication nurse (regulating drug administrations and connecting devices to the patient), 3) two CPR administrators (regulating chest compression and airway management). After a teacher explained one of ten fictional cases to the team leader, the CPR practice began. Students were not informed about the precise content of the unfolding scenario, which led to a practice characterized by high uncertainty. All possible scenarios had a similar difficulty but differed in whether they involved shock or not. One scenario consisted of a combination of both shock and non-shock. Four scenarios consisted of a shockable situation and the remaining five scenarios consisted of a non-shock situation. The end of the practice was marked by a successful resuscitation or a notification of the teacher. After each simulation, the team effectiveness and ALS performance score forms were completes by the teacher, which took about 2 minutes per team. For the purposes of this study, recordings and performance scores of two pre-assessment and seven final assessments were used.

3.4 Transcription, codebook and coding

Structural aspects of communication, such as flexibility and complexity, are inherently based on substantive aspects of communication. To illustrate, as high flexibility indicates that communication is heterogeneous instead of consistent, a basis needs to be established in which this heterogeneity can be found. This could be done for instance by gaining insight in the communication types that are used and that form the foundation for patterns. Therefore, and for the THEME software to discover patterns, communication within the video recordings was coded for used communication types.

3.4.1 First round of coding

For coding the video recordings, first a deductive (top-down) coding approach was applied on the final assessment of team 1 and team 15, by using the previously created and validated codebook of Hoogeboom and Wilderom (2020) as basis. This codebook (see Appendix C) exists of 18 mutually exclusive codes, enabling a detailed look at structural components of communication patterns. Examples of codes are: “Task monitoring” (asking team members for clarification and confirmation about (the progress on) their tasks) and “Defending one’s own position” (emphasizing one’s leadership position; emphasizing self-importance). As the codes within this codebook were developed specifically for studying patterns of communication within teams that execute complex tasks that could not simply be characterized by unidirectional cause-effect relationships, it forms a suiting foundation for studying communication patterns within an action team context (Hoogeboom & Wilderom, 2020). However, originally, this codebook was developed to code for leader-follower interactions within these complex task contexts (Hoogeboom & Wilderom, 2020). Codes and their definitions are therefore written from the perspective of the leader and his behavior. However, since this study focusses on the communication patterns between all team members (while classifying the ‘team leader’ similar to the other team members), definitions are used in their broad sense, making them applicable to all team members instead of only the team leader. For example, the aforementioned definition of “task monitoring” would then not only include the team leader asking team members for clarification about (the progress on) their tasks, but also other team members asking for this information. In such a way, most of the codes, despite originally written from a leadership point of view, could still be used in a broader team context.

The transcription software program Atlas.ti was used to code the video recordings. The transcribed video recordings were inserted into Atlas.ti and subsequently coded by having a sentence or word that is “meaningful in itself, regardless of the meaning of the coding categories” as unit of analysis (Strijbos, Martens, Prins, & Jochems, 2006, p.37). Thus, within the sentence “Would you want to prepare the intubation equipment already and then we are going to intubate after the next thirty compressions", two parts can be distinguished that would also be meaningful when standing alone. The first part is "would you want to prepare the intubation equipment already" and was coded (based on Hoogeboom and Wilderom's codebook) as directing, since a team member is given a task to perform at this point of time. The second part is "and then we are going to intubate after the next thirty compressions" and was coded as structuring since structure is given to the meeting by mentioning the order in which (coming) actions will follow on each other. In this example, the units of analysis are sentences, since separate words here are not meaningful in itself. Sometimes the unit of analysis didn't consist of a whole sentence, but of a single word that was meaningful in itself. This could for example be the case when agreeing upon a previously mentioned comment by simply stating 'yes'. An exception with regards to the unit of analysis was made when the code 'interrupting' had to be applied. Interrupting could be done by for example providing newly obtained information (informing) or by criticizing a team member's behaviour, for example to prevent harm when the behaviour would be continued (providing negative feedback). Thus, valuable information about the used communication within a team could be lost when the whole sentence would be coded as interrupting. Therefore, in the case of interrupting, only the first second of the unit of analysis was coded as interrupting and the sentence or word in its entirety as meaningful unit was coded as the type of communication with which was interrupted. As such, ultimately, both the final resuscitation simulations of team 1 and team 15, starting from the beginning of the reanimation session until a successful resuscitation took place or the teacher stated that the assessment was over, were divided into meaningful sentences or words in order to be assigned a code from the preset codebook. However, this resulted in some units of analysis standing alone, not suitable to be assigned a fitting code. This could have been the case because the codes of Hoogeboom and Wilderom (2020) were not especially developed for communication within *action* teams. This type of teams do exhibit some specific, oftentimes more dynamic, interactions that are not present in *'normal'* teams. As well, some codes of the preset codebook appeared not to be relevant for this study's particular data, mainly because here no distinction is made between communication of leaders and followers and some codes were strongly focused on a leadership role. Hence, a second round of coding was started in which the used codebook was revised.

3.4.2 Second round of coding

In the second round of coding, an inductive (bottom-up) coding approach was used in order to diminish unusable codes from Hoogeboom and Wilderom's (2020) codebook and add missing ones based on the units of analysis that could not be categorized under available codes. Again, the transcripts of the final assessment of team 1 and team 15 were used as starting point. On the basis of this, a new codebook (see Appendix D) was created in which six codes of Hoogeboom and Wilderom's (2020) original codebook were diminished, and five additional codes were added. Of these additional codes, two originated from Zijlstra et al. (2012), two from Kolbe et al. (2012b) and one was created for this study in order to match the observed teams' communication uttermost. With these adjustments in the codebook an exhaustive codebook was created with which the remaining transcripts could also be coded. In what follows, a further explanation is given of how the definitive codebook was established.

From the codebook of Hoogeboom and Wilderom (2020), six codes were excluded for the purposes of this study. This was done either because no cases were apparent in the dataset for which this code could be used, or because the code overlapped with newly added codes and thus impeded mutual exclusivity. As stated by Klonek, Quera, Burba and Kauffeld (2016), mutual exclusivity is needed to ensure a reliable study of dynamic communication patterns.

An overview of diminished codes and the reason for abandoning them is given in Table 1.

Table 1

Overview of codes that were diminished from definitive codebook

	Code	Definition	Reason for abandoning
1	Idealized influence behavior/Inspirational motivation	Talking about an important sense of vision; talking about important values and beliefs	No cases in the data where this act emerged
2	Showing disinterest	Not taking any action (when expected)	No cases in the data where this act emerged
3	Defending one's own position	Emphasizing one's leadership position; Emphasizing self-importance	Too leadership focused for the purposes of this study. No cases in the data where this act emerged
4	Giving own opinion	Giving one's own opinion about what course of action needs to be followed for the organization, department or team	Based on the dataset, the broader code 'suggestion' (derived from Zijlstra et al., 2012) was added to codebook. In order to keep mutual exclusivity, 'giving own opinion', which also included recommendations for action, was abandoned
5	Agreeing	Agreeing with something; consenting with something	Based on the dataset, the broader code 'acknowledgement' (derived from Zijlstra et al., 2012) was added to the codebook. This, in order to also code communication aimed at letting team members know their comments were heard, without specifically consenting with them. In order to keep mutual exclusivity, 'agreeing' was abandoned
6	Giving personal information	Sharing personal information (e.g. about the family situation)	Personal information of team members was not shared among them. Personal information was only shared by actors outside of the team (e.g. teachers in the role of bystanders) and thus coded as environmental cue. In order to keep

			mutual exclusivity, 'giving personal information' was abandoned

The units of analysis that remained without code in the first round of coding formed the basis for deciding which codes to add in the second round. As this mainly concerned action team specific communication acts, additional codes were derived from former studies in this specific area.

Two additional codes were derived from Zijlstra et al. (2012), which were specifically compiled for the study of communication in action teams (ad hoc formed aviation teams). These concern the codes 'inquiry' (request for information) and 'suggestion' (recommendation for action). With adding the code 'suggestion', the less involving code 'giving own opinion' could be diminished (see table 1, point 4).

The codebook of Kolbe et al. (2012b), which was created to observe coordination behavior within acute care teams (thus action teams), provided two additional codes as well. These included: "action-related talking to the room" (includes comments on the performance of own current behaviour) and "information related talking to the room" (coded if a team member appeared to address a communication not to a specific team member but to the room at larger). Both these codes added to the previously available codes, since they comprise communication that is not directed to a specific team member, but to the room at large. This was a type of communication that emerged frequently from the dataset but couldn't be coded with the codes from Hoogeboom and Wilderom (2020). Due to the specific focus on the room at large, which wasn't present in any of the other already available codes, no codes needed to be diminished in order to keep mutual exclusivity.

Lastly, an additional code was personally created in order to provide an exhaustive codebook for the purpose of this study. This concerns the code 'acknowledgement' (agreeing with something or showing that a comment has been heard). It emerged from the dataset, that frequently a case occurred in which a team member acknowledged something that was said by a fellow team member, without specifically (dis)agreeing with it. For example, a comment like 'yes' was frequently stated not to state that it was agreed with the preceding comment, but to acknowledge its appearance. In order to code such statements, the code 'acknowledgement' was added. In order to keep mutual exclusivity within the codebook, the overlapping, but less involving code 'agreeing' from Hoogeboom and Wilderom (2020) was diminished (see table 1, point 5).

In the second round of coding, all nine video recordings were coded using the above-mentioned codes (and provided with an exact timing in seconds of when the coded unit took place) by a MSc student from the faculty of the Behavioural, Management and Social sciences (BMS). In addition, one of these nine videos (the final assessment of team 15, thus representing more than 10% of total transcriptions) was also coded by a PhD candidate from this same faculty to allow for assessment of interrater reliability. Cohen's kappa for this video coding was .91, indicating a highly acceptable interrater agreement (McHugh, 2012).

3.4.3 Third round of coding

After the second round of coding, the coders discussed their coding and came to the conclusion that for the purpose of this study, in which the focus lays on team member communication, all communication that was not provided by actual team members (but for example by the present teacher, also when playing a role within the case (e.g. bystander)) should be coded differently. Thus, the code 'environmental cue' was added (resulting in a definitive codebook, see Appendix E) in order to enable an analysis of only team member communication while using transcriptions of situations in which teachers were present as well (next to the team members). In a third round of coding, coded transcripts were revised and all communication that was provided from anyone else than a team member was, regardless of its content, coded as environmental cue. Recalculating the interrater reliability based on the same data (thus again representing more than 10% of total transcriptions), with concerning codes being switched to environmental cue, resulted in an even higher interrater reliability (Cohen's kappa = .96). Hence, the primary coder's coding of the nine video recordings was used for analysis purposes.

3.5 Data analysis

3.5.1 Team performance

The performance scores per team, as obtained from the performance scales that were completed by teachers, were inserted into SPSS (IBM, 2009) in order to enable a calculation of means, medians and standard deviations of the teams to be analysed. This was done separately for the team effectiveness scores (7-point Likert-scale) and the ALS performance scale (5-point Likert-scale). These descriptive statistics are shown in table 2.

Table 2

Means, standard deviations, and medians of relevant teams

	Team effectiveness			ALS performance		
	M	*SD*	*Median*	*M*	*SD*	*Median*
Pre-training team 1	4	0	4	3.20	0.45	3
Pre-training team 5	3.75	0.50	2	2.40	0.55	2
After training team 1	6	0	6	4.20	0.45	4
After training team 2	5.50	1	6	4.20	0.45	4
After training team 5	6.25	0.50	6	4.20	0.45	4
After training team 6	5.50	0.58	5.50	4.40	0.55	4
After training team 8	6.50	0.58	6.50	4.80	0.45	5
After training team 10	5.50	0.58	5.50	3.80	0.45	4
After training team 15	4.50	1.29	4.50	3.60	0.89	3

Subsequently, the teams to be analyzed were categorized as high or low performing by using the median split of the team effectiveness as well as ALS performance variable. For the sake of getting more accurate results in this regard, the median split was based on all teams in the secondary dataset. As can be seen in table 3, considering the team effectiveness variable, team 1, 2, 5, and 8 were classified as high performing and team 6, 10, and 15 as low performing. Table 4 shows that, when considering the ALS performance variable, all teams except for team 15 would be classified as high performing. Using the Spearman correlation coefficient, a significant positive relation between the two scales was found ($r_s = .89$, $p < .001$ (two-tailed)). Therefore, and because a higher internal consistency was found for the team effectiveness scale compared to the ALS scale (Cronbach's Alpha = .97 compared to .88), it was chosen to use the median split scores of the team effectiveness scores as basis for classifying high and low performing teams. Thus, for further analyses, team numbers 1, 2, 5, and 8 are classified as a high performing teams and team numbers 6, 10, and 15 as low performing.

Table 3

Median split based on team effectiveness (Gibson et al., 2009)

Team number	Team effectiveness[a]	Teams with effectiveness above or similar to Median	Teams with effectiveness below Median
1	6	1	3
2	6	2	6
3	4	4	9
4	6	5	10
5	6	7	11
6	5.5	8	13
7	7	12	15
8	7	14	16
9	5.5	18	17
10	5.5	19	20
11	5		
12	7		
13	4.5		
14	6		
15	4.5		
16	5.5		
17	5.5		
18	6		
19	6		
20	3		
Median	**5.75**		

Note. [a]7-point Likert scale

Table 4

Median split based on ALS performance

Team number	ALS performance[a]	Teams with ALS performance above or similar to Median	Teams with ALS performance below Median
1	4	1	13
2	4	2	15
3	5	3	18
4	5	4	20
5	4	5	
6	4	6	
7	4	7	
8	5	8	
9	4	9	
10	4	10	
11	4	11	
12	5	12	
13	3	14	
14	5	16	
15	3	17	
16	4	19	
17	4		
18	3		
19	5		
20	3		
Median	4		

Note. [a]5-point Likert scale

3.5.2 T-pattern analysis

The analysis of patterns within the coded interactions was employed using the software program THEME (PatternVision, 2020). This program enables looking for patterns in temporal order, so called T-patterns. This entails that the program looks for combinations of two interactions (two coded sentences or words, used by specific team members) that happen in the same sequence more often than by chance (Borrie et al., 2002). An example is represented in figure 1, in which a timeline is shown in combination with different types of communication (w, a, k, etc.). Two (related) T-patterns are shown (a, b and c, d). This combination of T-patterns is seen again later on the timeline.

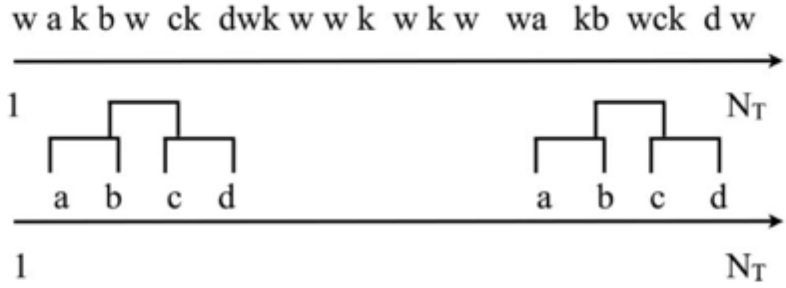

Figure 1. Example of T-patterns in interactions.
Derived from Zijlstra, Waller, & Philips, 2012.

After detecting T-patterns, the THEME software looks for more complex relationships among them. Thus, in this way, complex communication patterns could be found by combining the simpler T-patterns (PatternVision, 2020). A last step that is taken by the program, is the exclusion of patterns that look like they stand alone but are actually just smaller parts of a larger pattern. As Borrie et al. (2002, p. 847) explain:

> "a pattern Q = (ABCDE) may be partially detected as, for example, (ACDE) or (BDE) or (ABCE); since elements of Q are missing, these three patterns constitute less complete descriptions of the underlying patterning. A newly detected pattern Q_x is thus considered equally or less complete than an already detected pattern Q_y if Q_x and Q_y occur equally often and all events in Q_x also occur in Q_y."

When the program detects such a less complete pattern as Q_x, this pattern is excluded.

THEME has already been used within diverse disciplines in the past (e.g. animal behaviour, psycho-pharmacology, and, only recently team research), to detect non-obvious temporal patterns in behaviour (Lei et al., 2016). In order to find such easily overlooked patterns in this study's communication data as well, coded and timed data was inserted in the THEME software program (PatternVision, 2020). To do so, several steps were taken; a category table was made in order to set out the possible category variables that were included, the team's communication was written out in syntax, meaning that labels were aligned to the behavioural happenings so that the software could read them, and thereafter the pattern analysis could be run. Below, each step will be presented in more detail.

3.5.3 Creating a category table

To insert data into THEME, first a category table (variable-value table, or 'vvt' file) was made in a separate notepad document (outside of the THEME program). Three variables (classes) were used for this study: 1) actors, 2) timestamp, and 3) communication type. These variables were written out one below the other. Elements belonging to the variable of actors were 'actorone', 'actortwo', and so on until the last 'actorsix'. The timestamp variable was inserted with the reserved name 'b_e' and needed to be the second variable in the vvt file. Corresponding elements were 'b' for beginning and 'e' for ending. Elements belonging to the variable of communication types corresponded to the codes that were present in the definitive codebook (as presented in Appendix E). Examples are thus 'acknowledgement', 'suggestion' and 'directing'. The created vvt file has been added in Appendix F.

Syntax. The behaviour that was accounted for within the variables, was written out in a syntax in order for the software to read. This was done as well in separate notepad documents. One document was made per resuscitation simulation. In the first line of the syntax, two column headings are added: 'time' and 'event'. In the next row, the start of the observation is indicated by a colon (':') under the event column and the accompanying timing in seconds under the time column. The following rows include the time stamped beginning of each coded interaction (the exact seconds the coded interaction took place, marked with 'b' for beginning) and the separate stamped endings of each coded interaction (the exact seconds the coded interaction ended, marked with 'e' for ending). These are linked to the team member that showed this interaction (in this study indicated with a number ranging from 1 to 6, as six was the total of team members and teachers that were present during a session). The end of a resuscitation simulation is marked in a new row, with an ampersand (‘&’) in the event column. A brief example of how this comes together into syntax is shown below.

time	event
0	:
20	actorone,b,environmentalcue
43	actorone,e,environmentalcue
44	actortwo,b,directing
46	actortwo,e,directing
49	&

3.5.4 Running pattern analyses

After the category table and syntax were made in notepad, a dedicated project folder with all necessary files (vvt file, syntax) could be made. This folder forms the basis for running an analysis in THEME. When opening this folder within the software, an overview of summary statistics before T-pattern detection is given automatically. This includes, among others, the amount of used communication types and event types (the combination of communication type, actor and beginning or ending).

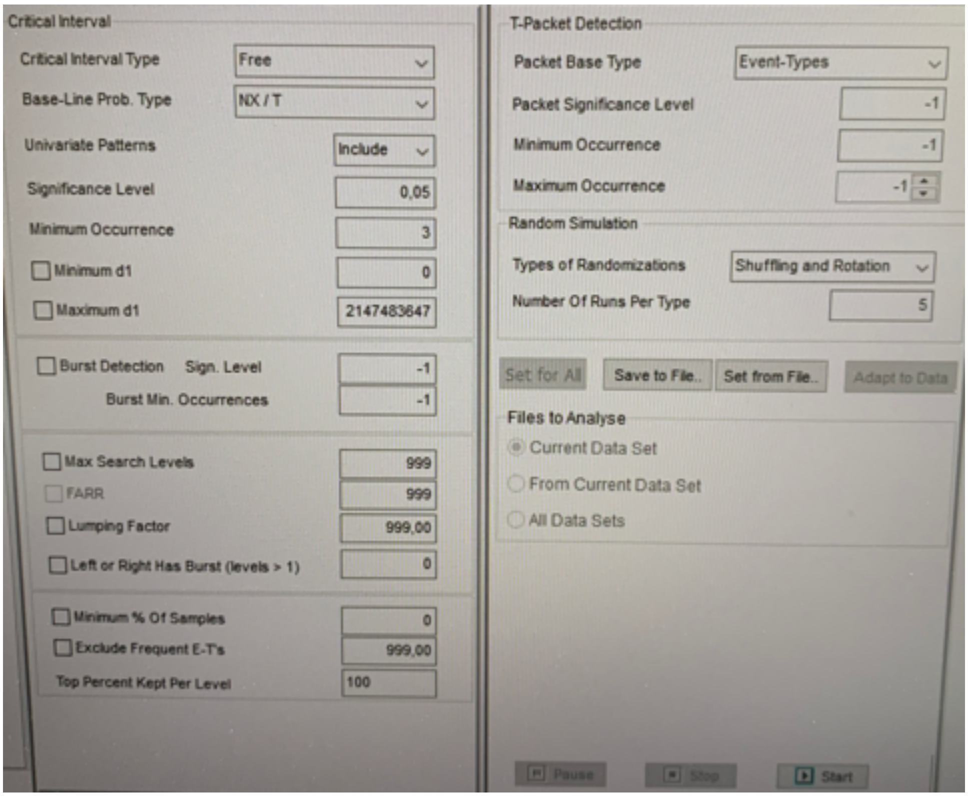

Figure 2. Set search parameters for running the T-pattern analysis in THEME.

For running the actual T-pattern analysis, search parameters need to be set. An overview of set parameters is given in figure 2. As can be seen from this figure, a frequency requirement (minimum occurrence) of ‘3’ was applied for pattern detection. This default entails that patterns considered were only those that occurred at least three times during the (20 minute) task. This number is in line with previous team research using THEME (e.g. Hoogeboom & Wilderom, 2009; Lei, 2016; Stachowski et al., 2009; Zijlstra et al, 2012). Furthermore, as threshold for pattern detection, a significance level of .05 was chosen, indicating a probability requirement of 95%. This means that detected patterns may not be due to chance in 95% of cases.

In order to answer the hypotheses, statements need to be made about the flexibility and complexity of found patterns. For this, THEME provided various data to be used. **Flexibility** of communication patterns is seen as opposite to a homogeneous manner of structuring verbalizations over the course of an event (Stachowski, 2009). In an event with highly homogeneous communication patterns, one speech act (e.g. an inquiry) will recurrently be followed up by one specific speech act (e.g. a suggestion). Thus, when it is deviated from this pattern (and, for example an inquiry is not followed up by a suggestion but by another inquiry), the pattern is considered flexible. To bring up the degree of heterogeneity in order to inform about flexibility (H1 and H2), several parameters within THEME can be used. In appendix G an overview table can be found of the used parameters and their labels within THEME. Below, a further specification of the parameters related to flexibility will be given.

The number of different patterns that are present within a team's communication tells something about flexibility, as a higher number of unique patterns indicates a more heterogeneous communication structure. Thus, when a high number of different patterns is present within a team's communication, this communication could be classified as more flexible.

The number of pattern occurrences within a team's communication indicates the total number of patterns that occurred during the communication. Thus, dividing the number of different patterns by the number of pattern occurrences makes clear how often unique patterns occur relatively. This information indicates flexibility even better than when only looking at the absolute number of different patterns. Indeed, how many different patterns are found within a team's communication could also be caused by a bigger amount of communication overall.

Complexity within communication patterns (H3 and H4) is accounted for when the patterns are built up of large numbers of different communication types or larger numbers of actors are involved (Stachowski et al., 2009). Thus, it follows from this definition that a dichotomy can be made within the concept of complexity; it could be looked at in terms of the communication's *structure* (where, for example, the number of different communication types comes under) and in terms of the *involved actors*. To get a more detailed picture of complexity, parameters will be used for both these components separately. An overview of the used parameters and their labels within THEME is included in appendix G. Below, relevant parameters for information about pattern's complexity are described in more detail. First parameters for complexity in terms of structure will be given. Parameters concerning complexity in terms of involved actors will be given secondly.

Complexity in terms of structure

Pattern length provides insight in the number of event types that are present in a pattern. Thus, when pattern length is high, this indicates a higher complexity in terms of components.

Pattern levels that are on average present within patterns inform about how complex the communication's structure is constructed hierarchically. This is illustrated in figure 3, where a pattern is shown with a length of six and a level of three. As such, when patterns on average involve a higher number of levels, this indicates a higher complexity.

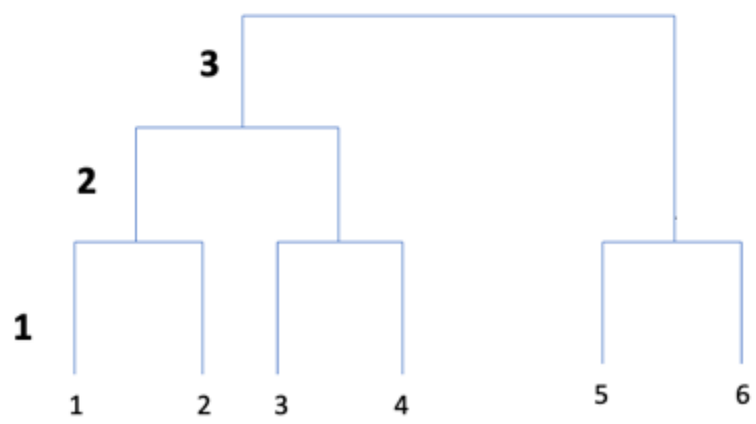

Figure 3. Pattern with three levels and a length of six.

The number of loops within patterns can as well function as useful information about complexity, complementary to the data about pattern length. Loops occur within a pattern, when it has at least two similar event types in it. In other words, they occur when repetition of the same behavior is present within a pattern. So, when a lot of loops are present within a pattern, this means that it involves less different components, thus indicating less complexity.

Complexity in terms of involved actors

The number of actors that are on average involved within a pattern informs about complexity, as the bigger number of involved actors contributes to greater complexity.

The number of actor switches that are on average apparent within communication patterns does as well inform about complexity. In addition to the involved number of actors, that Stachowski (2009) mentions as important indicator for complexity, the number of switches gives important extra information about the communication's structure. For example, when three actors are involved within a pattern, one could say that this is less complex then when four actors are involved. However, when also investigating switches, a more in-depth insight can be gained. To illustrate; the pattern with four actors could include one actor giving a direction and the other three actors acknowledging with it, while the pattern with three actors could include one actor giving a direction, one actor disagreeing with this, another interrupting to inform about something, after which the first actor uses this new information to substantiate it's provided direction and the second actor acknowledges. Comparing these two cases would result in the conclusion that the case with three actors, although having less actors involved, has a more complex structure. Thus, by looking at the number of actor switches, a more elaborated picture could be made of the communication's complexity, where more switches between actors would indicate greater complexity.

The number of single-actor patterns gives insight in the number of involved actors within a team's communication patterns as well. When a greater amount of different single-actor patterns is present, this implies less complexity with regards to involved actors in patterns.

The number of multi-actor patterns gives insight in the complexity with regards to involved actors in patterns, in an opposite way as the number of single-actor patterns does. Whereas more single-actor patterns would indicate a smaller complexity, more multi-actor patterns indicate a greater complexity.

3.5.5 T-tests

In order to test the hypotheses, means of above-mentioned parameters were compared using t-tests. For this, assumptions about normal distribution and equal variances were met within the used data. Using a (one-tailed) independent t-test, a comparison between the high and low performing team was made with regards to parameters relevant to flexibility and complexity in communication patterns. A comparison between a team's flexibility and complexity of communication before and after training was made using a (one-tailed) paired t-test.

3.5.6 Effect sizes

Given the small sample size that was used in this study, effect sizes of found statistics were added. Indeed, as Schäfer and Schwarz (2019) mention, mentioning effect sizes is important since they can provide information about the size of an effect regardless of the study size. For measuring the t-tests' effect sizes, Cohen's d was used (Cohen, in Lakens, 2013). As previous studies in the same area are scarce and thus a mean of typical effect could not be calculated, the most conventional division in small, medium and large effect was used, as it was recommended by Cohen (in Lakens, 2013). Effects were seen as small when the effect sizes were around .20, as medium when around .50 and as large when around or above .80.

3.6. Results

Table 5 presents the absolute frequency (N), percentage of total number of (different) patterns (%, when relevant), mean (M) and standard deviation (SD) of the parameters concerning flexibility or complexity within low and high performing teams' communication patterns. These data are shown in table 6 for the pre- and after training groups. An overview table of descriptive statistics of all teams separately is provided in appendix H. Appendix I shows an overview of the frequencies of codes per type of team.

3.6.1 Flexibility

In H1 it was stated that high performing CPR teams show more flexible communication patterns than low performing teams. As can be seen in figure 4, high performing teams showed a relatively higher percentage of different patterns within their communication than low performing teams.

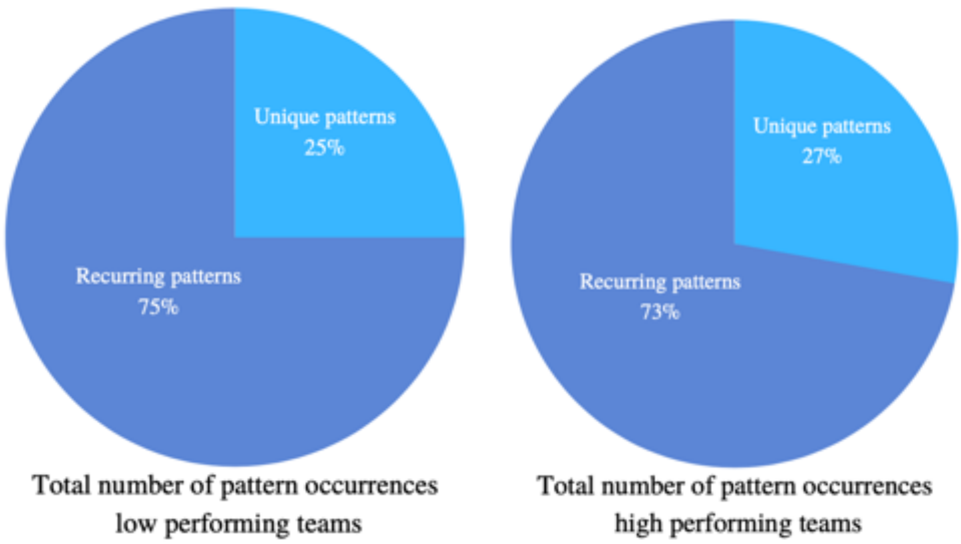

Figure 4. Unique patterns relative to the total number of pattern occurrences for low and high performing teams.

In absolute numbers (see table 5), both the number of different patterns as the number of pattern occurrences were as well higher for high performing teams (number of different patterns; $M = 2152$, $SD = 1497.27$; number of pattern occurrences; $M = 8014$, $SD = 5034.71$) compared to low performing teams (number of different patterns; $M = 1600$, $SD = 947.08$; number of pattern occurrences; $M = 6334$, $SD = 3317.19$). However, for both, these differences were not found to be significant; number of different patterns: $t(4.94) = 0.59$, $p = .29$; number of pattern occurrences: $t(4.98) = 0.53$, $p = .31$. Thus, these findings indicate that H1 was rejected.

With regards to teams pre- and after training, H2 assumed that flexibility would increase after training. Indeed, figure 5 shows that, relatively, more unique patterns were present within teams' communication patterns after training.

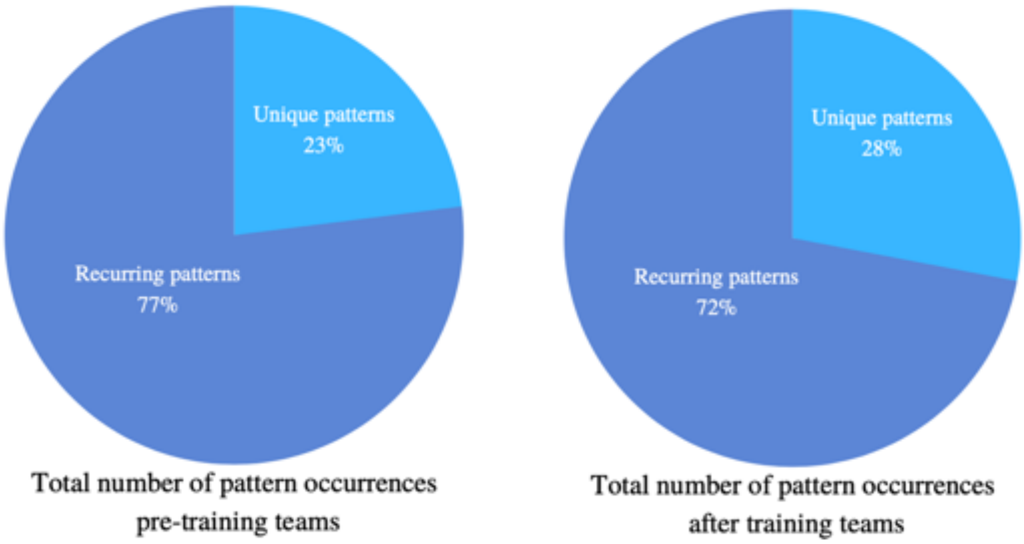

Figure 5. Unique patterns relative to the total number of pattern occurrences for pre- and after training teams.

This finding was supported by the absolute numbers as they are presented in table 6. Here as well, a higher number of different patterns was found to be present within teams after training (M = 3442, SD = 135.76) compared to teams pre-training (M = 404.50, SD = 282.14). For this difference, significant support with a large effect size was found, $t(1) = 10.28$, $p = .03$; d = 7.27. Thus, these data support H2 and indeed indicate an increase of flexibility after training.

Table 5

Comparison between low and high performing teams of communication pattern characteristics

		Low performing (*N*=3)				High performing (*N*=4)						
		N	%	*M*	*SD*	*N*	%	*M*	*SD*	*t*	*p*	*d*
Characteristics concerning	*Parameters*											
	Number of different patterns	4800	25.26	1600	947.08	8604	26.84	2151	1497.27	0.59	0.29	0.45
Flexibility	Number of pattern occurrences	19002		6334	3317.19	32056		8014	5034.71	0.53	0.31	0.41
Complexity (structure)	Pattern length	196		65.33	11.02	286		71.50	3.42	0.94	0.22	0.71
	Average number of pattern levels	10.87		3.62	1.16	15.87		3.97	0.88	0.45	0.34	0.34
	Number of loops	2508		836	637.96	4623		1155.75	1063.99	0.49	0.32	0.38
Complexity (involved actors)	Average number of actors	8.83		2.94	0.29	11.66		2.91	0.42	0.10	0.46	0.08
	Average number of actor switches	8.76		2.92	0.71	11.56		2.89	1.04	0.05	0.48	0.03
	Number of single-actor patterns	303	6.31	101	36.01	417	4.85	104.25	25.73	0.14	0.45	0.11
	Number of multi-actor patterns	4497	93.69	1499	917.57	8187	95.15	2046.75	1479.71	0.60	0.29	0.46

Notes.
one-tailed t-tests were executed
a significance level of p = .05 was used
effect size (Cohen's d) was considered small for d = .20, medium for d = .50, and large for d = .80

Table 6

Comparison between pre- and after training communication pattern characteristics

		Pre-training (*N*=2)				After training (*N*=2)						
		N	*%*	*M*	*SD*	*N*	*%*	*M*	*SD*	*t*	*p*	*d*
Team effectiveness score[a]		2		3	1.07	2		6.13	0.35			
ALS performance score[b]		2		2.8	0.63	2		4.2	0.42			
Characteristics concerning	*Parameters*											
Flexibility	Number of different patterns	809	22.64	404.50	282.14	6884	27.83	3442	135.76	10.28	0.03	7.27
	Number of pattern occurrences	3573		1786.50	911.46	24734		12367	213.55	13.30	0.03	9.40
Complexity (structure)	Pattern length	101		50.50	10.61	148		74	2.83	2.47	0.12	1.75
	Average number of pattern levels	5.80		2.90	0.78	9.31		4.66	0.62	1.79	0.16	1.26
	Number of loops	315		157.50	157.68	4142		2071	207.89	7.40	0.04	5.23
Complexity (involved actors)	Average number of actors	4.59		2.29	0.69	6.52		3.26	0.24	1.47	0.19	1.04
	Average number of actor switches	3.24		1.62	0.74	7.15		3.58	1.07	1.53	0.18	1.08
	Number of single-actor patterns	134	16.56	67	5.66	240	3.49	120	29.70	3.12	0.10	2.20
	Number of multi-actor patterns	675	83.44	337.50	276.48	6644	96.51	3322	165.46	9.55	0.03	6.75

Notes.
one-tailed t-tests were executed
a significance level of p = .05 was used
effect size (Cohen's d) was considered small for d = .20, medium for d = .50, and large for d = .80
[a]7-point Likert scale by Gibson et al. (2009)
[b]5-point Likert scale

3.6.2 Complexity due to structure

It was proposed in H3 that high performing CPR teams would show less complex verbal communication patterns than low performing CPR teams. The means of parameters concerning structural complexity (which thus give substance to the way in which patterns are constructed) are shown for high and low performing teams in figure 6.

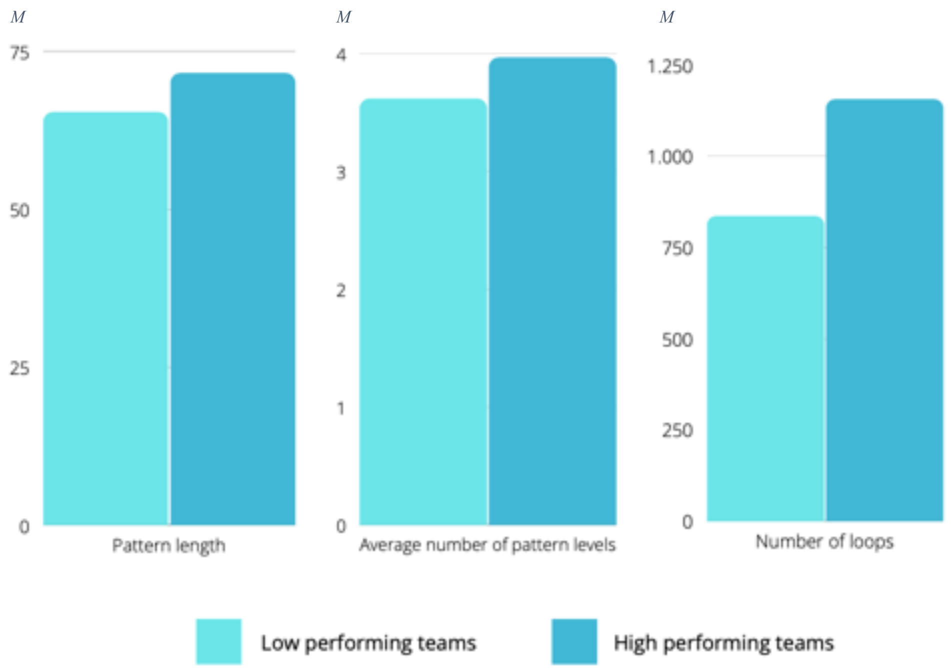

Figure 6. Comparison of low and high performing teams' means with regards to structure complexity parameters

Here, it can be seen that for all three parameters (pattern length, average number of pattern levels, and number of loops) the mean for high performing teams was higher than for low performing teams. In exact numbers (displayed in table 5), pattern length, which indicates the number of event types within a pattern, was found to be the highest for high performing teams ($M = 71.50$, $SD = 3.42$ relative to $M = 65.33$, $SD = 11.02$). However, this effect was not significant, $t(2.29) = 0.94$, $p = .22$. A similar situation is apparent for the average number of pattern levels. For this parameter as well, the high performing teams ($M = 3.97$, $SD = 0.88$) seem to show higher complexity than the low performing teams ($M = 3.62$, $SD = 1.16$), although this could not significantly be substantiated, $t(5) = 0.45$, $p = .34$. With regards to the number of loops, the high performing teams appear to show more loops ($M = 1155.75$, $SD = 1063.99$ compared to $M = 836$, $SD = 637.96$), but this could equally not be demonstrated significantly, $t(4.88) = 0.49$, $p = .32$. Overall, no support could be found for H3 on the part of complexity due to structure.

When comparing teams' communication patterns pre- and after training, H4 proposed that complexity would decrease after training. Figure 7 illustrates a comparison between the means of structure related parameters for pre- and after training teams.

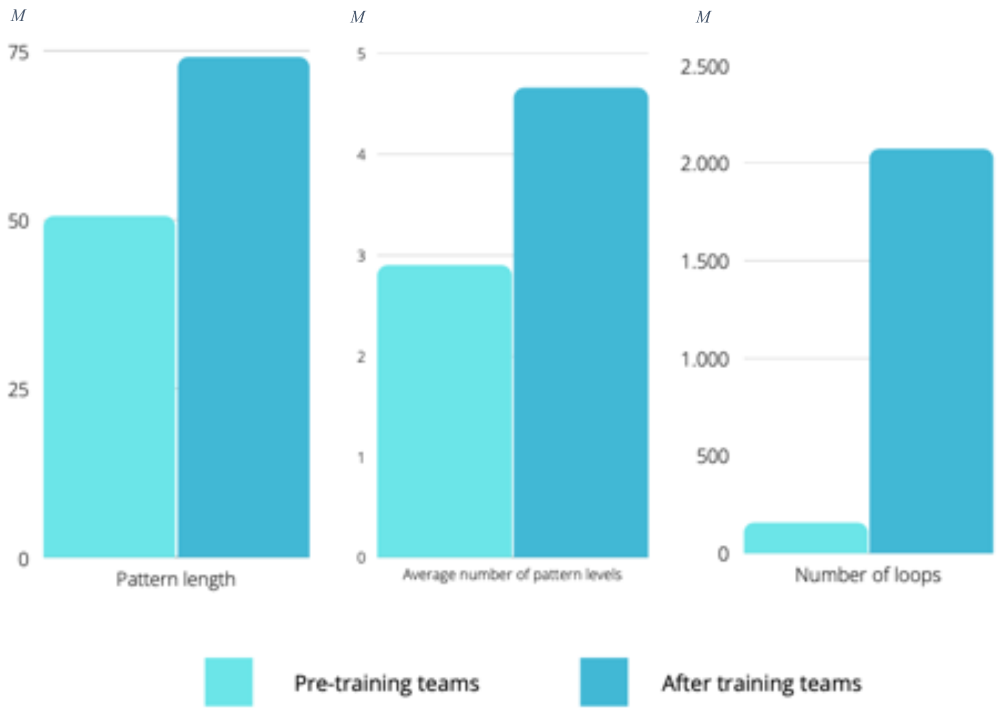

Figure 7. Comparison of pre- and after training teams' means with regards to structure complexity parameters

From this figure it can be seen, that the presence of all three parameters is higher after training than before training. However, the higher pattern length after training ($M = 74$, $SD = 2.83$) compared to before training ($M = 50.50$, $SD = 10.61$) could not be proven significantly, $t(1) =$

1.47, *p* = .12. The same holds true for the higher average number of pattern levels that was present after training (*M* = 4.66, *SD* = 0.62) compared to before training (*M* = 2.90, *SD* = 0.78). This difference was also not found to be significant, *t*(1) = 1.79, *p* = .16. On the other hand, for the greater number of loops that is present in the communication patterns after training (*M* = 2071, *SD* = 207.89 relative to *M* = 157.50, *SD* = 157.68), significant support could be found with a very large effect size, t*(1)* = 7.40, *p* = .04; *d* = 5.23. Thus, the finding of higher pattern length and average number of pattern levels after training (that would both indicate higher complexity) could not be significantly supported, but such significant support could be found for the higher number of loops (that indicates a less complex structure). These findings therefore support H4 as far as structural complexity is concerned.

3.6.3 Complexity due to involved actors

As shown in figure 8, high performing teams showed slightly less single-actor patterns than low performing teams.

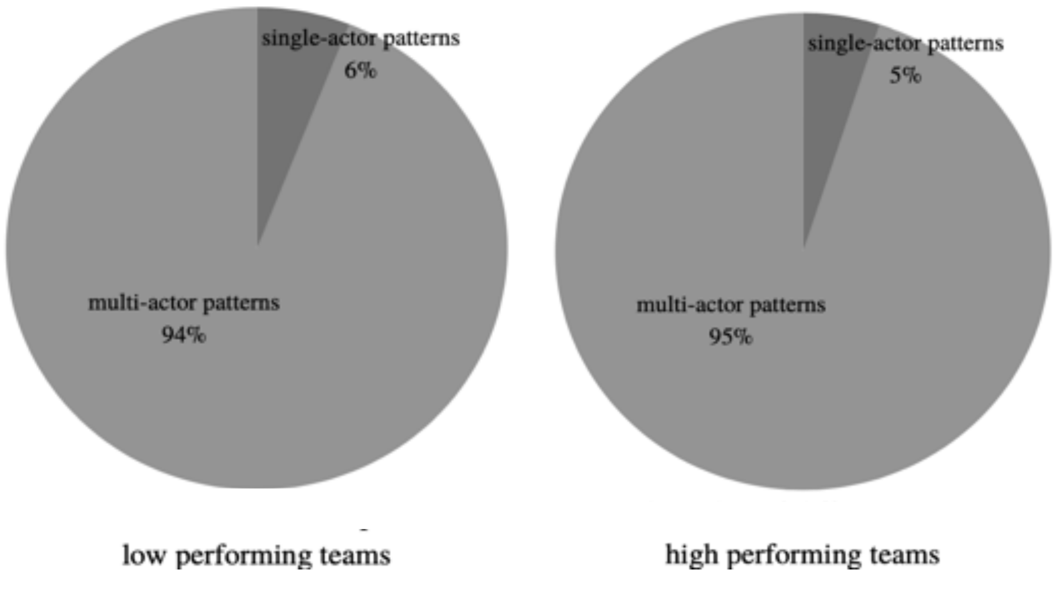

Figure 8. Single- and multi-actor patterns as percentage of the total number of different patterns for low and high performing teams

However, this smaller number of single-actor patterns within high performing teams' communication was found to be non-significant $t(5) = 0.14$, $p = .45$. The greater amount of multi-actor patterns for high performing teams ($M = 2046.75$, $SD = 1479.71$) compared to low performing teams ($M = 1499$, $SD = 917.57$) was also non-significant, $t(4.92) = 0.60$, $p = .29$. The average number of actors involved within patterns was found to be lower for high performing teams ($M = 2.91$, $SD = 0.42$) than for low performing teams (2.94, $SD = 0.29$). Also, with regards to the average number of actor switches, high performing teams showed less of these switches within their communication patterns ($M = 2.89$, $SD = 1.04$) than low performing teams did ($M = 2.92$, $SD = 0.71$). Nevertheless, both these differences could not be proven significantly; average number of actors, $t(5) = 0.10$, $p =.46$; average number of actor switches, $t(5) = 0.05$, $p = .48$. As a consequence, even as for complexity in terms of structure, no significant support could be found for H3 with regards to complexity in terms of involved actors.

Figure 9 shows that, for teams pre- and after training, relatively less single-actor patterns were apparent after training.

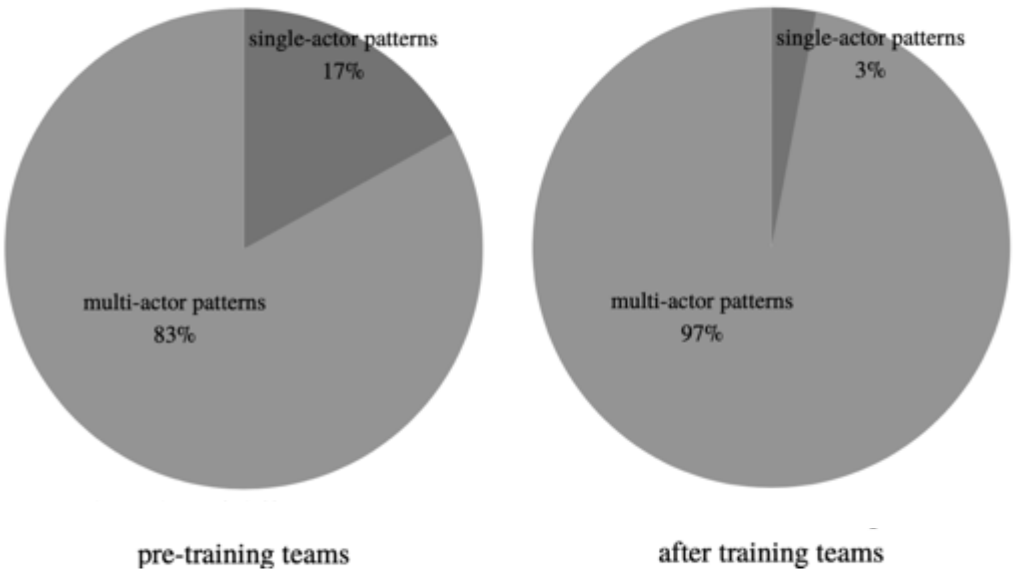

Figure 9. Single- and multi-actor patterns as percentage of the total number of different patterns for pre- and after training teams

This difference, however, could not be proven to be significant, $t(1) = 3.12$, $p = .10$. What also logically follows from figure 9, is that the communication after training consisted of relatively more multi-actor patterns. The paired sample t-test revealed that there was significant support for this finding with a large effect size, $t(1) = 9.55$, $p = .03$; $d = 6.75$. Additionally, the average number of actors and actor switches are both higher after training ($M = 3.26$, $SD = 0.24$ and $M = 3.58$, $SD = 1.07$) than before training ($M = 2.29$, $SD = 0.69$ and $M = 1.62$, $SD = 0.74$), but these findings could not be supported significantly, $t(1) = 1.47$, $p = 0.38$ and $t(1) = 1.53$, $p = 0.37$. These data thus reveal that non-significant support could be found for H4 in terms of involved actors within communication patterns pre- and after training. The significant finding of more multi-actor patterns after training does not provide support, as it is contrary to what was expected in H4.

4. Discussion

This study aimed to examine in a structure-, rather than content-wise manner, what differences in verbal communication are apparent between high and low performing CPR teams and how these develop over time. Hereby, the focus was on structure in terms of flexibility and complexity. This involved looking for flexibility of and complexity in communication patterns of both high and low performing student CPR teams and at two points in time (before and after training). By doing so, it was aimed at closing the gap in literature with regards to linking team performance to specific orders and combinations of interactions (instead of looking only at content of communication, such as counting the frequency of certain communication types, and thereby neglecting how this content takes part in the bigger picture) specifically within a CPR context. These insights could form a contribution not only to research, but also to the practical improvement of CPR training and performance.

It was hypothesized that high performing CPR teams would show more flexible verbal communication patterns than low performing CPR teams (H1) and that this flexibility increases when comparing teams before and after training (H2). Also, with regards to complexity, it was expected that less complex communication patterns would be present in high performing teams compared to low performing teams (H3) and that such complexity would decrease after training (H4). The findings showed that only some (parts of) these hypotheses could be supported. There were no significant differences in flexibility of the communication between high and low performing teams. However, when comparing teams before and after training, flexibility increased significantly after training. Also, although complexity did not differ significantly between high and low performing teams' communication, significant differences were found between teams pre- and after training. As to complexity in terms of structure, H4 could be supported and a significant decrease in complexity after training was found. As to complexity in terms of involved actors, the findings indicated significant support for more complexity after training, which was thus contrary to what was expected.

4.1 Theoretical implications

It could not significantly be shown that high performing teams have more flexible communication patterns than low performing teams. This is different from what was expected in H1. Indeed, previous research suggested that high performance and flexibility in communication were linked, as flexibility would increase opportunities for sharing and collecting information, which are important proceedings within ad hoc formed teams (e.g. Stachowski, 2009; Weller et al., 2014). Previous research, however, is barely done within a CPR context specifically. The differences in findings with regards to flexibility in high and low performing teams thus indicate that, for CPR teams specifically, flexible communication could be less characteristic for high performance than it is in other action team contexts. Nevertheless, the finding that high performing teams do not have significantly more flexible communication than low performing teams is also not in line with the findings of Shetty et al. (2009), which did study a CPR context. Their findings indicated that, within CPR teams, higher performing teams adhered less to standardized guidelines and thus were more flexible in their behaviour. An explanation for this discrepancy, even within a same context, could be that there is no one-to-one link between high performance and flexibility, as was expected in H1, but that this link is mediated by another variable. Indeed, in their research, Shetty et al. (2009) mention the importance of leadership in order for the flexibility to contribute to higher performance.

For teams before and after training, as was expected within H2, significantly more flexibility was seen in teams' communication after training compared to their communication before training. The greater number of different patterns that occurred during teams' communication after training could thus also be expected for other teams that take part in a similar CPR training. Based on previous research, this finding could be substantiated by the fact that simulation-based CPR trainings have been shown to improve teamwork (Flanagan et al., 2004). This would suggest that team members become more attuned to each other through training, allowing more flexibility in communication. Also, another indication of this finding would be that teaching standardized guidelines does not necessarily impede the development of flexibility. Now, within the training that was observed for this study, the main focus was on teaching protocolled guidelines and systematic methodologies (see Appendix J for all learning objectives of the ALS course). Nevertheless, as this study's findings suggest, flexibility could possibly still develop despite the great attention to systematics.

High performing teams did not show significantly less complex communication patterns than low performing teams. This is contrary to what was expected based on previous research. For example, Bogenstätter et al. (2009) showed that complex communication, although it enabled information transmission, could overload working memory so that the transmitted information does not actually stick. Given the importance of sharing information for performance (as it enables collective sensemaking within the action team), this would indicate that better performing teams communicate with less complexity. However, (although not significantly proven) findings of the current study suggest a difference in the opposite direction (high performing teams showing more complex communication). Indeed, four out of seven parameters point to more complexity within the high performing teams; for these teams pattern length, average number of patterns and number of multi-actor patterns are higher and number of single-actor patterns are lower. This would be in line with the idea that more complexity diminished ambiguity and thus enables teams to perform better (e.g. Orasanu, 1994; Waller & Uitdewilligen 2008). It is noticeable that these differences in the direction of more complexity are mainly apparent for parameters concerning the structural aspect of complexity. This indicates that performance could possibly be improved (perhaps due to less ambiguity) by letting those actors who communicate be more extensive (instead of involving more actors within the communication).

Considering complexity of communication before and after training, H4 could partly be supported. For structural complexity, it was found that teams showed significantly more loops within their communication after training. This means that more repetition of the same behavior was present within their communication patterns, making these patterns less complex. Pattern length and the average number of pattern levels were also higher after training, indicating, by contrast, an increase of complexity. However, this increased complexity was found to be non-significant. Looking thus at the significant findings, training seems to lower the complexity of communication structures. Given the risk of an overloaded working memory when communication is very complex, as mentioned for example by Bogenstätter et al. (2009), this finding seems logical. Less complexity would increase performance, as the transferred information can be better processed (Sepp et al., 2019). Since more characteristics of high performing teams would be approached when a team is provided with CPR trainings, it is thus in line with literature that more training results in less complexity (Lerjestam et al., 2018, Lund-Kordahl, 2019).

Contrary to what was expected in H4 was the finding that, as to complexity in terms of involved actors, significant support was found for more complexity after training. After training, the average number of actors involved in patterns was higher, as well as the average number of actor switches. Although these findings could not be supported significantly, they point in the direction of an increased complexity due to training. Significant support was found for the increase in multi-actor patterns, which also points to more complexity as more actors are involved within the communication. These findings suggest that training stimulates team members to contribute to the communication. This would be in line with previous research findings suggesting that training supports students' self-confidence (Lee & Park, 2015). Self-confidence could then have caused team members to feel more comfortable in contributing.

4.2 Practical implications

As the goal of CPR trainings would be to make teams perform well, so that patient outcomes can be improved, communicational differences between high and low performing teams (as explored in this study) could inform about what aspects of communication should get most attention during training. With the findings about flexibility and complexity of teams' communication in mind, several preliminary statements could be made concerning the improvement of the training curriculum.

The suggestion that there is no one-to-one link between high performing CPR teams and the flexibility of their communication, proposes that flexible communication over all possibly does not have to be an important point of attention within trainings. With the proposed mediating factor of leadership in mind, as mentioned by Shetty et al. (2009), precious training time can maybe be better spent on specific parameters of flexibility, such as flexibility in terms of leadership. Indeed, whereas previous studies underlined the importance of good communication in order to improve CPR performance, the team leader was mentioned to have an important guiding role in this (Andersen et al., 2010; Gabr, 2019). Given the many mandatory components that are already imposed within CPR training courses, more space is created, and other priorities can be set when knowing that communication's flexibility as comprehensive variable is probably not that important for performance (Greif et al., 2021).

Another important finding of this study, that could be researched more extensively in order to make optimal recommendations for trainings, is the discrepancy between what high performing teams showed in terms of complexity of their communication's structure and what was seen after training. Although high and low performing teams had no significant differences in complex communication structures, teams after training showed significantly less of this type of complexity compared to teams before training. This finding forms an important basis for doing more research into a possible cause and effect relationship between communication structure's complexity, team performance and the effect of training. When spuriousness could be ruled out and the training could indeed be found as causing less complex communication structures while high complexity (as suggested by this study's descriptive statistics) could be found as causing factor for high performance, it could then be important to adjust the training so that it does no longer result in less complex communication structures within the teams. Indeed, as it was previously proposed by e.g. Orasanu (1994) that less complexity could cause ambiguity, which could be detrimental within action teams, it is important to gain clarity about whether the development towards less complex structures is a desirable consequence of trainings.

The unexpected finding that post-training teams showed more complex communication with regards to involved actors also provides an important basis for researchers so that training developers could be informed. If the bigger complexity could indeed be found to be caused by the current training, training developers could wonder whether such an outcome of the training is a desirable development for performance. More research is thus needed about involved actors within communication and its effect on CPR performance. Then, with the findings of the current study in mind, training developers can be conscience about the effect of current trainings on actor related complexity of communication and thus can make thoughtful considerations about what is needed in the training curriculum to pursue high performance.

4.3 Limitations and future research

Having seen the potential implications of this research, it is important to note some limitations that could have influenced the research outcomes. First, the lack of significant support for certain findings might have been the result of the small sample size (that was used because of time constraints for this study and limitations in the access to other teams' data). As Snyder and Lawson (1993) showed for studies with a small sample size, just one extra participant could make the difference between significant and non-significant outcomes (without changing effect sizes). Thus, in order to make more firm statements about the hypotheses, this exploratory study could be extended by using a larger sample size. The found effect sizes, that often showed more than 'small' magnitudes of effect, also provide ground for doing more research with a larger sample. Even for the parameters with smaller effect sizes, research with a bigger sample could provide useful insights for the training curriculum, since effect sizes that were indicated as being 'small' ($d = 0.2$) were found to still be of policy interest when based on measures of academic achievement (Hedges & Hedberg, 2007). Further, the limitations of the small sample size are also reflected by the fact that the within-team differences were based on data of only two teams. Deviating data from only one team could thus have greatly influenced research outcomes. For example, it is important to note that, while meetings were on average around 20 minutes, the duration of one of the pre-training meetings was very much below this average. With a duration of only 13 minutes, findings from this meeting could have been different from findings in other meetings for example because less communication took place due to the shorter time frame or because this shorter timeframe hindered the minimum occurrence of 3 for pattern detection. A bigger sample would enable a correction of such differences in meeting duration (since a correction in the form of cutting all comparisons down to the same meeting time wouldn't be appropriate within a non-linear action team context).

Second, practical realities provoked that the used sample consisted of a fairly homogenous group of students from the University of Twente only. This logically has consequences for the extent to which found effects are generalizable and, with that, probably also for the extent to which effects could be statistically significant. This makes it interesting for future researchers to investigate with a larger sample size, containing student teams from other educational settings as well, whether differences that could now be seen within the descriptives of the sample, also could be proven to be significant.

Another limitation could have been caused by the fact that, although the hypotheses are about real CPR teams, the intention of the observed training was not to train resuscitation teams, but to provide students with insight in medical technologies and procedures relevant to CPR. This is a slightly different approach than would be pursued when training actual resuscitation teams to, for example, provide any certifications. The fact that no certifications could be acquired by taking part in the observed training could have impacted team members motivation. This could have influenced research outcomes since motivation affects the extent to which there is cooperation within a team (Abbas & Nawaz, 2019). Communication is an important dynamic within such cooperation and could thus probably also be affected by motivation (Eisenberg et al., 2005). Further, despite the hypotheses being about real CPR teams, this study looked at *student* CPR teams and could thus have resulted in slightly other outcomes than when observing real resuscitation teams, as experience within the work field (that students possibly have less of) changes the way in which team members communicate (Jones & Peters, 2019).

Lastly, because of technical problems with the THEME software, two options within the program couldn't be used. These included; (1) the number of T-markers that were present within teams' communication and (2) visual representations of communication patterns' appearance throughout a simulation. T-markers represent a predictor or retrodictor of coming or preceding patterns. Thus, since this parameter indicates predictability within communication, it would have been useful for specifying flexibility. Next to t-markers, the visual representations of patterns' distribution would have provided insight in complexity during different moments of the task. For example, through making pattern lengths visible, this option would have made it possible to make statements about whether complex patterns are, in this respect, more prominently present during the beginning or the end of a simulation setting.

Interesting for future research would be investigating the effect of total training length on the found effects pre- and after training. Within the current training, five simulations took place within a time period of two months. However, research shows that for skill mastery a minimal of seven repetitions of practice is needed (Bälter, Zimmaro, & Thille, 2018). This could have influenced the differences between pre- and post-training teams within the current study. Thus, it would be interesting to investigate whether expending the number of simulation practices, either by extending the duration of the training or by providing more practices within the current time span, would influence outcomes on communication's flexibility and complexity pre- and post-training. This could give insights for training development about the number of practices that is needed to achieve desired results.

Also interesting for future research would be to investigate whether the found significant differences between pre- and after training teams would also be apparent when teams are consisting of different members throughout the training. Indeed, Kanki and Foushee (1989) found that communication within teams that had recently worked together was more effective than within teams that had not. By also taking newly composed teams after training into account, it could thus be explored whether the found differences indeed are the result of training, or that they could be caused by the effect of team members getting used to each other and being better able to anticipate.

Lastly, linking content of communication to the found patterns could deepen insights in the findings regarding complexity. By doing so, future studies could investigate whether the proposed effect of complex communication on memory overload indeed holds true in general sense, or that more specific statements could be made when looking at the content that may or may not be shared in a complex way. For example, statements could be made about whether or not a redundancy effect occurs within certain patterns, as studying content reveals whether communication was actually necessary in the given situation.

4.4 Conclusion

Having studied the differences in flexibility and complexity of communication between high and low performing CPR teams and before and after training, several key points emerged;

1. High performing teams' communication does not differ from low performing teams in terms flexibility. More research needs to be done to determine whether this absence of any difference is characteristic for a CPR context specifically or that other variables, such as leadership, serve as mediator.
2. Training significantly increased flexibility of teams' communication. This could possibly be explained by a greater anticipation between team members as they worked together more often throughout the training. Also, the development towards more flexibility could arise without specific attention being paid to this within the training.
3. Differences in terms of complexity in communication between high and low performing teams could not be supported significantly. However, descriptives seemed to suggest that higher performing teams showed more complex communication patterns, especially with regards to structural aspects of complexity.
4. Complexity in structure of teams' communication decreased after training. In terms of involved actors, complexity increased after training. More research is needed in order to find out whether these findings could be the result of individual level training consequences (such as increased self-confidence of team members), or that a team level explanation can be given.

With these findings, a starting point for future research is provided by this exploratory study, so that informed recommendations can be made for the improvement of CPR trainings. Suggestions for such future research are for example that research is done with a bigger sample size, that cause-and effect relationships and substantive aspects of communication within the patterns are linked to current findings and that other parameters within flexibility and complexity as such (for example leadership or change in team membership) are taken into account.

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Appendix A
Consent form

UNIVERSITY OF TWENTE.
FACULTY BMS

201486 REQUEST FOR ETHICAL REVIEW

Request nr:	201486
Researcher:	Muller, A.W.
Supervisor:	David, L.Z.
Reviewer:	Leemkuil, H.H.
Status:	Approved by commission
Version:	2

1. START

A. TITLE AND CONTEXT OF THE RESEARCH PROJECT

1. What is the title of the research project? (max. 100 characters)

   Recurring communication patterns of medical teams as they practice cardiopulmonary resuscitation

2. In which context will you conduct this research?

   Master's Thesis

3. Date of the application

   04-12-2020

5. Is this research project closely connected to a research project previously assessed by the BMS Ethics Committee?

   Yes

please provide the ethic request number(s) for the research project(s):

   201161

B. CONTACT INFORMATION

6. Contact information for the lead researcher

   6a. Initials:

   A.W.

   6b. Surname:

   Muller

   6c. Education/Department (if applicable):

   M-EST

   6d. Staff or Student number:

   2214423

2020-12-14 11:13:32 1/5

6e. Email address:

a.w.muller@student.utwente.nl

6f. Telephone number (during the research project):

+31612721219

6g. If additional researchers (students and/or staff) will be involved in carrying out this research, please name them:

-

6h. Have you completed a PhD degree?

No

7. Contact information for the BMS Supervisor

7a. Initials:

L.Z.

7b. Surname:

David

7c. Department:

BMS-OWK

7d. Email address:

l.david@utwente.nl

7e. Telephone number (during the research project):

+31534898294

8. Is one of the ethics committee reviewers involved in your research? Note: not everyone is a reviewer.

No

C. RESEARCH PROJECT DESCRIPTION

9a. Please provide a brief description (150 words max.) of the background and aim(s) of your research project in non-expert language.

This study will look at differences in (complexity and consistency of) communication patterns between high and low performing student cardiopulmonary resuscitation teams and how these patterns evolve over time (during training, thus what effect training had). This will be done by transcribing video recordings of student teams' first and last CPR training session. Performance scores of these teams are available, so that a comparison can be made between low/high performing teams. For the (oftentimes still poor) CPR outcomes to improve, research needs to pay attention to CPR team performance and how training can play a role in enhancing this. Study results could give insights in training needs. As well, within this context, focussing on patterns instead of substantive aspects of communication fills a gap of currently existing literature and ensures that the process of communication is seen as a continuous process (rooted in its context) instead of being something static.

9b. Approximate starting date/end date of data collection:

Starting date: 2020-12-11

End date: 2021-04-29

9c. If applicable: indicate which external organization(s) has/have commissioned and/or provided funding for your research.

Commissioning organization(s):

Not applicable

Funding organization(s):

Not applicable

2. TYPE OF STUDY

Please select the type of study you plan to conduct:

I will be using only existing (secondary) data pertaining to individuals, groups or organizations.

3. RESEARCH INVOLVING EXISTING DATA OR DOCUMENTS

A. WHICH DATA AND/OR DOCUMENTS WILL BE ACCESSED AND HOW?

10. Please provide a brief description of the data or documents that you plan to use (max. 2000 characters, including spaces).

-Video recordings of UT technical medicine student teams (following the advanced life support master course) performing simulated cardiopulmonary resuscitation. Video recordings of each team's first and last session will be used. -Performance scores of these teams, as provided by their teachers.

11. Please indicate whether the data/documents you will use are:

- Private

11d. Please indicate the purpose for which these data were originally collected (max. 2000 characters, including spaces):

Previous research (2018, under guidance of Hoogeboom and Groenier)

11e. How will you obtain access to these private data, and what are the conditions for use?

My thesis supervisor will provide access for me. Conditions for use are that they will only be used for the purpose of this research.

11f. Have the individuals/organizations to whom these data pertain provided consent for additional, later use of the data?

Yes

B. CONFIDENTIALITY AND ANONYMITY

12. Does the dataset contain information (or a combination of information) that can be traced back to

specific individuals/organizations?

Yes

If yes, will you take steps to protect the privacy and other legitimate interests of individuals, groups or organizations involved (both in the dataset and in publication of results)?

The student number of involved students is linked to the data, but has been encrypted and protected. As well, all video recordings will be deleted as soon as these are transcribed. As well, within the transcriptions, pseudonyms will be used. The key to this will be stored in a separate secure file. Within this key, only a number is used that can be linked back to the original video and thus to the consent forms.

5. DATA MANAGEMENT

- I have read the UT Data policy.
- I am aware of my responsibilities for the proper handling of data, regarding working with personal data, storage of data, sharing and presentation/publication of data.

6. OTHER POTENTIAL ETHICAL ISSUES/CONFLICTS OF INTEREST

40. Do you anticipate any other ethical issues/conflicts of interest in your research project that have not been previously noted in this application? Please state any issues and explain how you propose to deal with them. Additionally, if known indicate the purpose your results have (i.e. the results are used for e.g. policy, management, strategic or societal purposes).

The results will be used for theoretical purposes

7. ATTACHMENTS

-

8. COMMENTS

David, L.Z. (10-12-2020 17:38):

Dear Henny, thank you for your comments and apologies for the confusion. Indeed, the answer to both 11f and 12 is yes. This project is directly connected to the dataset and data handling of 201161. The individuals to whom these data pertain have provided consent for additional, later use of the data (11f). Also, the dataset contains information that can be traced back to individuals (12). The video material is linked to the student number of each participant, that has been encrypted and protected from when it was first collected. To protect the privacy and other legitimate interests of individuals involved, after the data is transcribed, all videos will be deleted and the transcriptions will use pseudonyms whose key will be stored in a separate secure file. the key will only contain a number that can be linked back to the original video and thus to the consent forms.

Muller, A.W. (10-12-2020 16:19):

These were indeed questions I was doubting about. I thought that te form would first go to my supervisor (L. David), of which I knew she would know whether consent for later use was provided and whether the information couls trace back to specific individuals/organizations. The answerd given in request 201161 are leading, so this means that I filled in the form wrong with regards to the to mentioned questions. The individuals to which the data pertain DO have provided consent for additional use and information COULD be traced back to specific individuals/organizations.

Leemkuil, H.H. (10-12-2020 11:08):

At 11f you indicate that the individuals/organizations to whom these data pertain don't have provided consent for additional, later use of the data. This would mean that it's not ethical to use the data. Furthermore this is contradictory to the information provided in request 201161 to which your research is related. Another contradictory element is in 12. You state that the dataset doesn't contain information (or a combination of information) that can be traced back to specific individuals/organizations. Please clarify these issues.

9. CONCLUSION

Status: Approved by commission

The ethical committee has assessed the ethical aspects of your research project. On the basis of the information you provided, the committee does not have any ethical concerns regarding this research project. It is your responsibility to ensure that the research is carried out in line with the information provided in the application you submitted for ethical review. If you make changes to the proposal that affect the approach to research on humans, you must resubmit the changed project or grant agreement to the ethical committee with these changes highlighted.

Moreover, novel ethical issues may emerge while carrying out your research. It is important that you re-consider and discuss the ethical aspects and implications of your research regularly, and that you proceed as a responsible scientist.

Finally, your research is subject to regulations such as the EU General Data Protection Regulation (GDPR), the Code of Conduct for the use of personal data in Scientific Research by VSNU (the Association of Universities in the Netherlands), further codes of conduct that are applicable in your field, and the obligation to report a security incident (data breach or otherwise) at the UT.

Appendix B
List of performance scales

Teameffectiviteit

en prestatieschalen

voor docenten

Groep: ______
Datum: ___ /___
Tijd blok ______
scenario nummer ______
Shock/non-shock: ______
beoordelaar: ___

INSTRUCTIEZO
INVULLEN:NIET ZO:

Team effectiviteit

Erg inaccuraat — Erg accuraat

	1	2	3	4	5	6	7
1. Dit team is steeds een goed presterend team.	○	○	○	○	○	○	○
2. Dit team is effectief.	○	○	○	○	○	○	○
3. Dit team maakt weinig fouten.	○	○	○	○	○	○	○
4. Dit team verzet kwalitatief hoog werk.	○	○	○	○	○	○	○

ALS effectiviteit
1 = onvoldoende, 5 = uitstekend

	- -	-	+/-	+	+ +
	1	2	3	4	5
5. ALS-protocol	○	○	○	○	○
6. Uitvoering handelingen	○	○	○	○	○
7. Diagnostiek en klinisch redeneren	○	○	○	○	○
8. Therapeutisch plan	○	○	○	○	○
9. Werkwijze	○	○	○	○	○

Appendix C

Codebook derived from Hoogeboom & Wilderom (2020)

Coded behaviour	Definition	Examples
Providing negative feedback	Criticizing the behavior or actions of other team members	“I do not think that this is a good solution” “In August I’ve send an e-mail with amendments, and I find it regrettable that at least half of the attendees does not know the content of this e-mail”
Task monitoring	Asking team members for clarification and confirmation about (the progress on) their tasks	“How is the project progressing” “Do you also have a specific role in that process, since there might be possibilities for a follow-up project”
Correcting	Imposing of disciplinary actions; Presenting team members with a “fait accompli”	“Yes, but that is the wrong decision” “Now you are talking about a failure fine, however this is a different type of fine”
Individualized consideration	Paying attention to each individual’s need for achievement and growth by acting as a coach or mentor and creating a supportive climate	“We offer a training course in August, which might be helpful for your career planning” “You can make a note of that request, I am willing to help you with it”
Intellectual stimulation	Asking for ideas, stimulating team members to critically think about team tasks, opportunities, and so on, including the questioning of assumptions; thinking about old situations in new ways	“Yes, if you have any ideas put them together and discuss it with me or Jan”
Idealized influence behavior/Inspirational motivation	Talking about an important collective sense of vision; Talking about important values and beliefs	“I find it important that we all work in unison towards this shared objective” “Until Vision 2020 is more clearly specified we will be

		operating under these standards; it is important to follow this agreed line”
Showing disinterest	Not taking any action (when expected)	Not listening actively
Defending one’s own position	Emphasizing one’s leadership position; Emphasizing self-importance	“I am the manager within this organization” “We do it my way, because I am the manager”
Interrupting	Interfering or disturbing when other team members are talking	Disrupting other team members when they did not finish their sentence
Directing	Dividing tasks among team members (without enforcing them); Determining the current direction	“John, I’d like you to take care of that” “Jack, I want you to…”
Informing	Giving factual information	“The budget for this project is…” “The sick-leave figure is relatively low”
Structuring	Structuring the meeting; Changing the topic; Shifting toward the next agenda point	“We will end this meeting at 2pm” “Maybe, we need to discuss this point after you are finished”
Providing positive feedback	Positively evaluating and rewarding the behavior and actions of team members	“How you approach the project is much better than 3 months ago” “I am delighted to see that you did not passively waited, but rather pro-actively came with a proposal”
Giving own opinion	Giving one’s own opinion about what course of action needs to be followed for the organization, department, or the team	“We already discussed this, let’s talk especially about how we can avoid these things in the future” “In my opinion, we should…”
Agreeing	Agreeing with something; consenting with something	“This also reflects how I personally think about the matter” “Yes, I agree with you”

Disagreeing	Contradicting with team members	"That is not correct" "I have to disagree with you on this point"
Humor	Making jokes or funny statements	Often jokes are made within the context of the interaction. When three or more members laugh, the code "humor" is assigned.
Giving personal information	Sharing personal information (e.g., about the family situation)	"We had a lovely holiday" "My mother is doing better now, thank you"

Appendix D
Codebook second round of coding

Coded behavior	Definition	Examples	Notes
Providing negative feedback	Criticizing the behaviour or actions of other team members	"That one isn't attached correctly"	
Task monitoring	Asking team members for clarification and confirmation about (the progress on) their tasks	"Uhh were you already almost done with the intubation?" "Did you keep an eye on the time, since the last shock?"	Also coded for when time (to do a check) is asked for. When time is mentioned as a fact, this is coded as structuring.
Correcting	Imposing of disciplinary actions; presenting team members with a "fait accompli"	"No, let's do a history and physical examination first" "I just would do on the half minute, that is what we just did as well"	
Individualized consideration	Paying attention to each individual's need for achievement and growth by acting as a coach or mentor and creating a supportive climate	"Should we help?" "Yes indeed, that can be attached again, maybe the other way around?"	
Intellectual stimulation	Asking for ideas, stimulating team members to critically think about team tasks, opportunities, and so on, including the questioning of assumptions; thinkin g about old situations in new ways	"Everybody agrees?" "And why a suspicion of pregnancy, is there a reason for that?"	

		“I see a change in rhythm, is that right?”	
Interrupting	Interfering or disturbing when other team members are talking	“Uhm sorry, just for a second, I do 10 milliliters and administer adrenalin” “You have to wait with administering that!”	Unit of analysis is first second of a communicated word/sentence wit h which is interrupted
Directing	Dividing tasks among team members (without enforcing them); determining the current direction	“Do you want to feel her pulse” “Switch” “Rhythm check” “So, we are going to add a shock”	
Informing	Giving factual information	“We think madam has a myocardial infarction” “Eighteen minutes ago now” “Yes, he is loaded”	Only code for informing when information is given upon request or directed towards a specific team member
Structuring	Structuring the meetings; changing the topic; shifting toward the next agenda point	“That means we are going to the shock protocol” “And then we are going to intubate after the next thirty compressions” “After fifteen seconds we are	“after 5 seconds, we are going to do a rhythm check” is coded as structuring, but “we are going to do a rhythm check” (now) is coded as directing

		going to do a rhythm check"	
Providing positive feedback	Positively evaluating and rewarding the behavior and actions of team members	"Good job that you pay attention" "Great that you mention that" "Good idea"	
Disagreeing	Contradicting with team members	"No, we are already too late with that now"	
Humor	Making jokes or funny statements		
Action-related talking to the room	Includes comments on the performance of own current behaviour	"Shock added" "Bed free" "I administer 1 milligram adrenalin" "Respirated two times"	Coded for when it is talked to the room at large, not to a specific person "bed free" is coded as action-related talking to the room when it is a reaction on a direction. When it is a reaction on a question, it is coded as informing.
Information related talking to the room	Coded if a team member appeared to address a communication not to a specific team member but to the room at large	"This looks like uhh" "But she also had problems with her upper airways I understood and stuffiness" "Rhythm increases"	Coded for when the information is provided without request "I don't feel pulse" is coded as information related talking to the room, unless it is a reaction to a question like "do you have pulse?", then it is coded as informing
Inquiry	Request for information	"Bed free?"	Not coded for when it is about

		"Do you have pulse?" "What is the capillary refill?"	questioning of assumptions, this is coded as intellectual stimulation
Suggestion	Recommendation for action	"Shall we switch?" "Apply an IV?" "Shall we do a lab request?"	
Acknowledgement	Agreeing with something or acknowledging that a preceding statement was heard	"Yes that's fine" "I think so too" "Okay"	

Appendix E
Definitive codebook

Coded behavior	Definition	Examples	Notes
Providing negative feedback	Criticizing the behaviour or actions of other team members	"That one isn't attached correctly"	
Task monitoring	Asking team members for clarification and confirmation about (the progress on) their tasks	"Uhh were you already almost done with the intubation?" "Did you keep an eye on the time, since the last shock?"	Also coded for when time (to do a check) is asked for. When time is mentioned as a fact, this is coded as structuring.
Correcting	Imposing of disciplinary actions; presenting team members with a "fait accompli"	"No, let's do a history and physical examination first" "I just would do on the half minute, that is what we just did as well"	
Individualized consideration	Paying attention to each individual's need for achievement and growth by acting as a coach or mentor and creating a supportive climate	"Should we help?" "Yes indeed, that can be attached again, maybe the other way around?"	
Intellectual stimulation	Asking for ideas, stimulating team members to critically think about team tasks, opportunities, and so on, including the questioning of assumptions; thinkin g about old situations in new ways	"Everybody agrees?" "And why a suspicion of pregnancy, is there a reason for that?"	

		“I see a change in rhythm, is that right?”	
Interrupting	Interfering or disturbing when other team members are talking	“Uhm sorry, just for a second, I do 10 milliliters and administer adrenalin” “You have to wait with administering that!”	Unit of analysis is first second of a communicated word/sentence wit h which is interrupted
Directing	Dividing tasks among team members (without enforcing them); determining the current direction	“Do you want to feel her pulse” “Switch” “Rhythm check” “So, we are going to add a shock”	
Informing	Giving factual information	“We think madam has a myocardial infarction” “Eighteen minutes ago now” “Yes, he is loaded”	Only code for informing when information is given upon request or directed towards a specific team member
Structuring	Structuring the meetings; changing the topic; shifting toward the next agenda point	“That means we are going to the shock protocol” “And then we are going to intubate after the next thirty compressions” “After fifteen seconds we are	“after 5 seconds, we are going to do a rhythm check” is coded as structuring, but “we are going to do a rhythm check” (now) is coded as directing

		going to do a rhythm check”	
Providing positive feedback	Positively evaluating and rewarding the behavior and actions of team members	“Good job that you pay attention” “Great that you mention that” “Good idea”	
Disagreeing	Contradicting with team members	“No, we are already too late with that now”	
Humor	Making jokes or funny statements		
Action-related talking to the room	Includes comments on the performance of own current behaviour	“Shock added” “Bed free” “I administer 1 milligram adrenalin” “Respirated two times”	Coded for when it is talked to the room at large, not to a specific person “bed free” is coded as action-related talking to the room when it is a reaction on a direction. When it is a reaction on a question, it is coded as informing.
Information related talking to the room	Coded if a team member appeared to address a communication not to a specific team member but to the room at large	“This looks like uhh” “But she also had problems with her upper airways I understood and stuffiness” “Rhythm increases”	Coded for when the information is provided without request “I don’t feel pulse” is coded as information related talking to the room, unless it is a reaction to a question like “do you have pulse?”, then it is coded as informing
Inquiry	Request for information	“Bed free?”	Not coded for when it is about

		"Do you have pulse?" "What is the capillary refill?"	questioning of assumptions, this is coded as intellectual stimulation
Suggestion	Recommendation for action	"Shall we switch?" "Apply an IV?" "Shall we do a lab request?"	
Acknowledgement	Agreeing with something or acknowledging that a preceding statement was heard	"Yes that's fine" "I think so too" "Okay"	
Environmental cue	Communication not provided by actual team members	"oh god oh god, this isn't Mieke right? What is happening?" "I'm the intensivist. I heard there was a reanimation setting?" "Hi, yes I'm the co-assistant. I had a question, can I ask something?"	

Appendix F
vvt file

```
actors
 actorone
 actortwo
 actorthree
 actorfour
 actorfive
 actorsix

b_e
 b
 e

communicationtype
 acknowledgement
 actionrelatedtalkingtotheroom
 agreeing
 correcting
 defendingonesownposition
 directing
 disagreeing
 environmentalcue
 givingownopinion
 givingpersonalinformation
 humor
 idealizedinfluencebehavior
 individualizedconsideration
 informationrelatedtalkingto
 informing
 inquiry
 intellectualstimulation
 interrupting
 providingnegativefeedback
 providingpositivefeedback
 showingdisinterest
 structuring
 suggestion
 taskmonitoring
```

Appendix G
Overview of used parameters and their labels within THEME

Overview of used parameters and their labels in the overview table within THEME

Parameters	*Label*
Number of different patterns	PatDiff
Number of pattern occurrences	PatOcc
Mean number of pattern occurrences	n_mean
Pattern length	EtsinPats
Mean of pattern length	length_mean
Mean number of pattern levels	level_mean
Number of loops	Hasloop
Mean number of actors	nactors_mean
Mean number of actor switches	nswitches_mean
Number of single-actor patterns	MonoDiff
Number of multi-actor patterns	InterDiff

Appendix H
Descriptive statistics of all separate teams' communication pattern characteristics

Table 7

Descriptive statistics of all separate teams' communication pattern characteristics

		Team 6 (low performing)		Team 10 (low performing)		Team 15 (low performing)		Team 2 (high performing		Team 8 (high performing)		Team 1 (high performing)		Team 1 pre-training		Team 5 (high performing)		Team 5 pre-training	
		N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Characteristics concerning	*Parameters*																		
Flexibility	Number of different patterns	1299	23.06	2661	26.75	840	24.53	1002	25.17	718	21.49	3346	27.39	604	24.85	3538	28.26	205	17.95
	Number of pattern occurrences	5632		9946		3424		3981		3341		12216		2431		12518		1142	
Complexity (structure)	Pattern length	58		78		60		68		70		72		58		76		43	
	Average number of pattern levels	3.91		4.61		3.68		3.42		3.13		4.22		3.45		5.09		2.35	
	Number of loops	628		1552		328		207		274		1924		269		2218		46	
Complexity (involved actors)	Average number of actors	3.10		3.12		2.61		2.61		2.53		3.09		2.78		3.42		1.80	
	Average number of actor switches	3.06		3.55		2.15		2.51		1.90		2.82		2.14		4.33		1.09	
	Number of single-actor patterns	69	5.31	140	5.26	94	11.19	96	9.58	81	11.28	141	4.21	71	11.75	99	2.80	63	30.73

Number of multi-actor patterns	1230	94.69	2521	94.74	746	88.81	906	90.42	637	88.72	3205	95.79	533	15.93	3439	97.20	142	69.27

Appendix I
Overview of frequencies of codes per team type

Table 8

Overview of frequencies of all codes (after training) and frequencies per low and high performing teams

	Frequency low performing teams (after training, *N=3)*	Frequency high performing teams (after training, *N=4)*	Total frequency
Code			
Providing negative feedback	1	1	2
Task monitoring	19	42	61
Correcting	21	17	38
Individualized consideration	2	1	3
Intellectual stimulation	46	39	85
Interrupting	15	23	38
Directing	111	153	264
Informing	117	153	270
Structuring	81	111	192
Providing positive feedback	6	3	9
Disagreeing	1	1	2
Humor	4	11	15
Action-related talking to the room	89	163	252
Information related talking to the room	186	307	493
Inquiry	104	126	230
Suggestion	68	117	185
Acknowledgement	404	529	933
Environmental cue	239	215	454
Total number of codes	1514	2012	3526

Table 9

Overview of frequencies of codes per pre- and after training teams

	Frequency pre-training teams (*N=2)*	Frequency after training teams (*N=2)*	Total frequency
Code			
Providing negative feedback	0	1	1
Task monitoring	11	27	38
Correcting	9	11	20
Individualized consideration	3	1	4
Intellectual stimulation	3	25	28
Interrupting	6	10	16
Directing	54	99	153
Informing	53	90	143
Structuring	15	52	67
Providing positive feedback	1	2	3
Disagreeing	3	0	3
Humor	2	4	6
Action-related talking to the room	103	89	192
Information related talking to the room	49	151	200
Inquiry	39	73	112
Suggestion	25	51	76
Acknowledgement	107	284	391
Environmental cue	83	118	201
Total number of codes	566	1088	1654

Appendix J
Overview of learning objectives within the Advanced Life Support course

1. The student can describe the underlying principles of therapies that are commonly used in a resuscitation setting.
2. The student can describe the possibilities and limitations of diagnostic technologies that are commonly used in a resuscitation setting.
3. The student is able to relate information derived from the anamnesis, physical examination, arterial blood gas values, venous laboratory values, echography, X-thorax and the patient monitor to an individual patient case.
4. The student can perform resuscitation in a team according to the protocol of shockable and non-shockable rhythms in a simulated resuscitation setting.
5. The student can adequately perform chest compressions, non-invasive ventilation techniques, medication administration, and electrical therapies that are part of the resuscitation protocol in a simulated resuscitation setting.
6. The student can adequately communicate and collaborate in a team in a simulated resuscitation setting.
7. The student can handover patients in a structured way according to the SBAR methodology.
8. The student can analyze a patient in a structured way according to the ABCDE methodology.
9. The student can propose an adequate diagnostic and therapeutic strategy based on the available clinical and contextual information of a patient case.