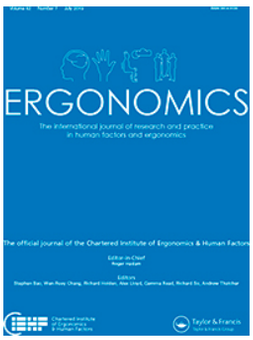

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Fighter pilots' teamwork: a descriptive study

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ABSTRACT

The execution of teamwork varies widely depending on the domain and task in question. Despite the considerable diversity of teams and their operation, researchers tend to aim for unified theories and models regardless of field. However, we argue that there is a need for translation and adaptation of the theoretical models to each specific domain. To this end, a case study was carried out on fighter pilots and it was investigated how teamwork is performed in this specialised and challenging environment, with a specific focus on the dependence on technology for these teams. The collaboration between the fighter pilots is described and analysed using a generic theoretical model for effective teamwork from the literature. The results show that domain-specific application and modification is needed in order for the model to capture fighter pilot's teamwork. The study provides deeper understanding of the working conditions for teams of pilots and gives design implications for how tactical support systems can enhance teamwork in the domain.

Practitioner summary: This article presents a qualitative interview study with fighter pilots based on a generic theoretical teamwork model applied to the fighter domain. The purpose is to understand the conditions under which teams of fighter pilots work and to provide guidance for the design of future technological aids.

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Teamwork; team effectiveness; fighter pilot; fighter aircraft

Introduction

Fighter pilots perform demanding and challenging missions in technologically advanced aircraft that require a range of special skills as well as years of training and practice. Moreover, the majority of fighter missions are performed by teams of aircraft, hence, teamwork is essential for the successful outcome of missions, and the importance of teamwork in the domain is acknowledged (Castor 2009; Helldin et al. 2010; Hierl, Neujahr, and Sandl 2012; Gozum 1995). However, a lack of understanding how teamwork among fighter pilots is carried out has been identified (Erlandsson et al. 2010).

There is an extensive amount of literature regarding teamwork in general, but the theoretical findings are difficult to apply in practice (Salas 2008; Wildman et al. 2012; Tannenbaum et al. 2012). Moreover, researchers may not specify and describe in enough detail the circumstances for the studied teams. For example, challenges faced by teams, such as time pressure, workload, complexity, and uncertainty are factors that, if unattended and undescribed, will add noise and variance to the results instead of increasing the knowledge regarding different contexts (Tannenbaum et al. 2012).

In the military fighter aircraft domain, there are several difficulties to overcome in order for a team to be efficient and successful. The situations are dynamic and stressful with high stakes, uncertain circumstances, and limited communication. Fighter pilots rely on *tactical support systems* for information retrieval and decision-making. A tactical support system has several functions including, for instance, the control and optimisation of on-board sensors, the fusion of data, as well as identification of targets and objects (RTO/NATO 2002). The capabilities of the aircraft and sensors, as well as the design of the tactical support system, including the graphical interfaces, will directly affect how pilots can perform the missions. Thus, the technology and the design at the same time enable and constrain the possible acting space, such that the tactics and plans for the missions will be a consequence of these factors

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(Woods 1998). Therefore, designers of cockpit interfaces and tactical support systems need to understand and consider this collaboration in order to build better and more capable systems for the future.

Teams of fighter pilots are performing their missions distributed in space, normally they cannot see each other, and therefore these teams depend on technological mediation for collaboration. The need for coordination drives the need for synchronous and tightly linked communication (MacMillan, Entin, and Serfaty 2004). Despite the large body of team research, it can be argued that there is a lack of attention towards different types of technology and artefacts that support team cognition (Fiore and Wiltshire 2016). The models mostly view psychological and organisational factors and leave out technology, which may play a greater part than the research community previously acknowledged (Goodman, Ravlin, and Schminke 1987; Fiore and Wiltshire 2016). Technology constrains and provides patterns for the team's activity, and technology shapes the structure of a team and how the team may perform its tasks (Salas, Cooke, and Rosen 2008). Performance of this type of distributed teams can be improved by better-designed technological aids (Ibid.), and already in 1987 Goodman, Ravlin and Schminke (1987) concluded that: 'Therefore, to understand group effectiveness, one needs to develop a model in the context of a specific technology, not in terms of groups in general' (p. 130). This is central to the study of teams of fighter pilots who are highly dependent on technology in order to fulfill their missions. This article presents a descriptive study of teamwork in the fighter aircraft domain. Previous studies are joined in order to present a comprehensive description of the conditions under which teams of fighter pilots work, extending the work presented in Ohlander et al. (2015), Ohlander et al. (2016a), and (Ohlander et al. 2016b). The results show how the teamwork factors from the investigated model manifest and relate to each other and how team effectiveness is achieved in the domain from a practical perspective. The main contribution of this article is that, based on these results, we present several implications for the design and development of future fighter tactical support systems.

Teamwork theories and models

Since teamwork is pursued in many different settings and for different purposes, there are many types of teams. Military teams, such as a teams of fighter pilots, can be defined as 'small formal units that use lethal force (or the threat of it) to accomplish a variety of tasks associated with maintaining domestic order and ensuring national security' (Devine 2002, p. 303). The military team is facing active resistance, is highly dependent on specific hardware systems, and the team members are exposed to substantial hazards. The military team is embedded in a hierarchical organisation and has to comply with more or less detailed orders. However, due to chaotic and unpredictable circumstances, the military team has high demands on communication and flexibility in leadership. Therefore, the team's processes, which have an impact on the team effectiveness, are not necessarily the same as for any other type of team.

Teams are formed in an organisation and they perform their activities in cycles, so-called episodes, where there are shifts between action phases and transition phases (Marks, Mathieu, and Zaccaro 2001). Episodes are marked by periods of action and transition phases between actions, and are most easily identified by the goals the team is trying to accomplish. Action phases are the periods of time when teams are engaged in the acts that contribute directly to goal accomplishment. Action processes are monitoring of resources and progress, communication, and coordination of actions. During transition phases, teams evaluate past episodes and plan for the coming, and hence, transition processes are planning activities, strategy, and goal specification. Consequently, it is important to identify the performance episodes in order to understand when the different team processes are most salient.

The vast literature on teamwork is fragmented and has been judged as nearly impossible to either use for guiding research or to use practically (Salas, Sims, and Burke 2005). Salas et al. reviewed the literature and identified 138 models that attempted to describe effective teams and disclose the 'black box' of team processes for effectiveness that dominates the most common input-output models (for a discussion about issues with these models see for example Kozlowski (2015)). The main factors in the resulting teamwork model (see Figure 1) suggested by Salas, Sims, and Burke (2005) are leadership, mutual performance monitoring, backup behaviour, adaptability, and team orientation. Furthermore, three coordinating mechanisms were added to support the factors: shared mental models, mutual trust, and closed-loop communication. There is no apparent difference between what constitutes a core factor or a coordinating mechanism, and in a later article Salas et al. state that they all collectively form teamwork (Salas et al.

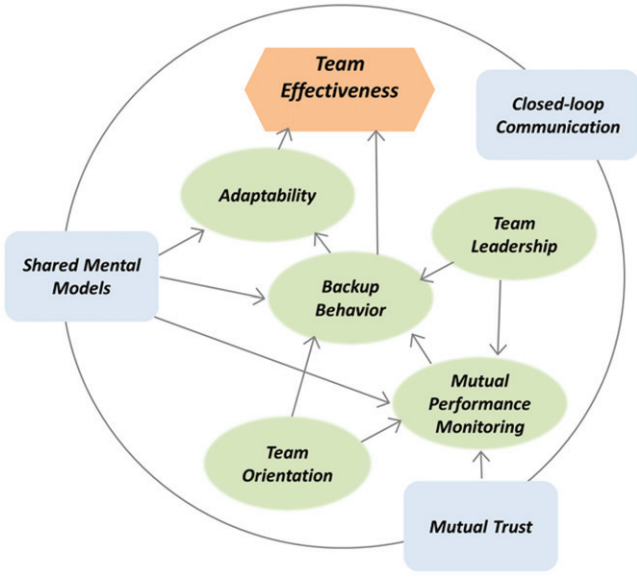

Figure 1. The model for team effectiveness, after Salas et al. (2005). The five core factors are represented by ovals and the three supporting mechanisms are represented by rectangles on the surrounding circle. The arrows represent propositions for how the factor affects each other and contribute to team effectiveness.

2007). Throughout this study, the eight factors were treated and evaluated equally, and in the following, they will all be referred to as teamwork factors.

The factors, coordinating mechanisms and corresponding behavioural markers that promote effective teamwork according to the framework are listed in Table 1 (Salas, Sims, and Burke 2005). Behavioural markers are examples of how the teamwork factors can be expressed during the course of action.

In the article, Salas, Sims, and Burke (2005) gave propositions for how the factors affect each other to achieve effective teamwork. These relationships are illustrated in Figure 1.

The article by Salas, Sims, and Burke (2005) about the suggested model for effective teamwork has been widely cited in the literature. However, there is not much work done regarding the practical implications and the applicability of the model to real-world problems, even though this was the authors' intention with the model (Salas, Sims, and Burke 2005). A longitudinal study of Dutch army peace-keeping teams that gave support for the model was pursued by Duel (2010).

Method

In order to investigate teamwork among fighter pilots, which is difficult to study due to the restricted environment and limited options to observe real teams in action, an interview study with participants with extensive experience from military air operations was selected as a feasible method. Ten active fighter pilots were recruited for interviews about their views on teamwork during missions. The criteria for inclusion in the study were substantial experience of execution of tactical air missions. The pilots' average age was 38 years (29–46). Their experience of flying fighter jets ranged from 500 to 3000 h, with an average of 1500 h. The interviews lasted between 40 min up to 2 h depending on the subject's availability. The interviews were all performed in Swedish, however, the teamwork factors, definitions and the behavioural markers were presented in English, as given in Table 1.

The relatively small number of interviewees (10) is motivated by the fact that the total number of fighter pilots is small and as a group they are relatively homogenous. Fighter pilots are recruited according to specific selection criteria and extensively trained in a common environment. In qualitative research, where specific themes are investigated, every respondent contributes and adds depth to the picture (Crouch and McKenzie 2006). Fighter aircraft technologies differ substantially between aircraft, and current aircraft design benefit from ongoing technology development trends. The pilot experience from modern fighter aircraft was in focus for this study. To be representative for modern fighter aircraft the investigation was carried out on currently active pilots flying a state-of-the-art fighter system and the interviewed pilots were asked to relate to an air-to-air mission in their answers.

During the interviews, the pilots were first asked about their experiences and views on teamwork as fighter pilots in general. Then they were presented with the teamwork factors printed on separate paper slips. The pilots were provided with the definition of

Table 1. The identified factors for effective teamwork, their definitions and behavioural markers after Salas et al. (2005).

Teamwork effectivenes factors	Definition	Behavioural markers
Team leadership	Ability to direct and coordinate the activities of other team members, assess team performance, assign tasks, develop team knowledge, skills, and abilities, motivate team members, plan and organise, and establish a positive atmosphere.	(a) Facilitate team problem solving (b) Provide performance expectations and acceptable interaction patterns (c) Synchronise and combine individual team member contributions (d) Seek and evaluate information that affects team functioning (e) Clarify team member roles (f) Engage in preparatory meetings and feedback sessions with the team
Mutual performance monitoring	The ability to develop common understandings of the team environment and apply appropriate task strategies to accurately monitor team-mate performance.	(g) Identifying mistakes and lapses in other team members' actions (h) Providing feedback regarding team member actions to facilitate self-correction
Backup behaviour	Ability to anticipate other team members' needs through accurate knowledge about their responsibilities. This includes the ability to shift workload among members to achieve balance during high periods of workload or pressure.	(i) Recognition by potential backup providers that there is a workload distribution problem in their team (j) Shifting of work responsibilities to underutilised team members (k) Completion of the whole task or parts of tasks by other team members
Adaptability	Ability to adjust strategies based on information gathered from the environment through the use of backup behaviour and reallocation of intra-team resources. Altering a course of action or team repertoire in response to changing conditions (internal or external).	(l) Identify cues that a change has occurred, assign meaning to that change, and develop a new plan to deal with changes (m) Identify opportunities for improvement and innovation for habitual or routine practices (n) Remain vigilant to changes in the internal and external environment of the team
Team orientation	Propensity to take other's behaviour into account during group interaction and the belief in the importance of team goals over individual members' goals.	(o) Taking into account alternative solutions provided by teammates and appraising that input to determine what is most correct (p) Increased task involvement, information sharing, strategizing and participatory goal setting
Shared mental models	An organising knowledge structure of the relationships among the task the team is engaged in and how the team members will interact.	(q) Anticipating and predicting each other's needs (r) Identify changes in the team, task or team mates and implicitly adjusting strategies as needed
Mutual trust	The shared belief that team members will perform their roles and protect the interests of their team-mates.	(s) Information sharing (t) Willingness to admit mistakes and accept feedback
Closed-loop communication	The exchange of information between a sender and a receiver irrespective of the medium.	(u) Following up with team members to ensure message was received (v) Acknowledging that a message was received (x) Clarifying with the sender of the message that the message received is the same as the intended message

the factors as proposed by Salas, Sims, and Burke (2005), and they were asked to rank the eight factors, starting with the most important factor during an air-to-air mission. In addition, they were further interviewed regarding the teamwork factors. The pilots were asked to discuss and reflect on each factor and to describe the factor in the context of a group of fighter pilots during the execution of an air-to-air mission. A simple example was given to illustrate a possible scenario, which included two aircraft cooperating in an interception against a group of enemies.

Results

In this section, we first show how the interviewees ranked the teamwork factors due to importance, followed by a detailed description of each factor. Then, a description of the identified task performance cycle is provided and finally, an adapted teamwork model for fighter pilots with the factors and identified relationships is presented.

Ranking of teamwork factors

All participants' rankings of the teamwork factors were added and the resulting list with the most important factor on top is shown in Table 2.

Descriptions of the teamwork factors

The interviews provided descriptions of the characteristics of the teamwork factors in the context of military

Table 2. The resulting ranking of the eight teamwork factors. All participants included.

Rank	Teamwork factor
1	Mutual performance monitoring
2	Closed loop communication
3	Shared mental models
4	Adaptability
5	Mutual trust
6	Team orientation
7	Team leadership
8	Backup behaviour

fighter missions. The factors are here presented in the order they were ranked by the pilots.

Mutual performance monitoring

Knowing where the others are, their status, and what they are doing is fundamental to a successful mission. However, the pilots stressed the importance of not checking on each other for mistakes. During the execution of a mission, the monitoring depends on technical solutions, such as sensors, data links and cockpit displays. The fast-paced situations make it difficult to rely on the information; it might be updated too slowly to be useful. However, not only is the current status of interest, information about what the team mates are planning to do is also highly desirable. Furthermore, in many cases it is not suitable to communicate status and intentions via voice radio, making the information shared via data links and on the displays crucial.

Closed-Loop communication

Closed-loop communication is also considered important during the missions. In general, the discipline concerning the closed loop was not regarded as a problem, since there are clear procedures for communication via radio, with call signs and acknowledgements. However, as long as the original plan is followed, the need for a closed loop is considered less important, or as one respondent said: 'I can see that he is doing what we planned.' It was suggested that the information transferred via data link can help in keeping the closed loop by sending acknowledgements via data link. If the information is available on the displays, there is no need to talk about it. The absence of acknowledgements generally adds workload to the team leader since he or she cannot move on with the planned actions until he or she knows that the message has been received. The safety aspect of closed-loop communication was also articulated, especially when the plan is changed, as one respondent noted 'It is crucial to know whether everybody understands, otherwise the situation may become dangerous.'

Shared mental models

Shared mental models are interpreted by the pilots as emerging from the tactics and standard procedures. Before the mission, the team members plan and discuss the mission and the goals during the briefing session. The pilots considered it very important that everybody shares the same understanding about the mission. The tactics and plans for a mission are to a large extent based on standard procedures that every pilot must know. The standardised procedures ensure common grounds and predictability. 'If we all have the same mental models, I can count on that most people will make the same decisions', was one notable statement. It was also recognised that the better the shared mental models are the less talk on the radio during the mission is needed.

Adaptability

Adaptability was interpreted as the ability to change plans and adapt to new situations and it was considered vital since the conditions during a mission may change rapidly. Even if the mission is planned and discussed and the tactics are selected according to the standard procedures before take-off, some contingency will always remain, and unexpected events may occur. However, there are difficulties with being adaptive in this environment with its limitations regarding communication. The result may be that not everybody in the team receives or understands the new plan correctly. The risk of failure due to communication difficulties must always be judged against the possible gains that can be achieved by the changes. In many cases, it is best to 'stick to the plan', as one pilot said.

Mutual trust

The team members trust that their colleagues will do what is expected of them during the mission. Mutual trust was very much considered a direct result of team leadership. The team leader was considered responsible for the trust in the team. The team members, on their part, allow the leader to act as their team leader during the mission. This is important since team leadership is a role that shifts between members during different missions.

Team orientation

Team orientation is an attitude, in contrast to the other factors that are behavioural. Pilots are trained and disciplined to work in teams and team orientation was taken for granted by the interviewed pilots. The importance of team orientation is emphasised by the organisation and the pilots assume that someone who has passed recruitment and training can be trusted. One practical aspect of team orientation that was mentioned was that during stressful situations, it is easy to lose situation awareness regarding the team as a whole. The pilot can become so focussed on his own situation that he 'forgets' about the rest of the team and does not realise that perhaps some other team member is better positioned to take action at the moment.

Team leadership

Team leadership plays a salient role in the understanding of the task and affects how the team is going to perform the mission. The interviewed pilots argued that a good team leader does the main part of the job before the mission; during the mission, team leadership was considered less important. A good team leader listens to the team and lets everybody take part in the discussions when the tactics are decided. With good leadership, team members already understand the goal and the expectations, without the need for detailed orders from the leader during mission execution. It was considered important for the pilots to take active part in the preparations and to have the opportunity to discuss alternatives. However, when the discussion is finished and the tactics are decided, team members must respect the decision of the team leader. 'No problem-solving regarding tactics in the air, it must be clear who decides', one pilot said. Further, when unforeseen events occur in the air, the leader is expected to take control and give clear instructions on how to proceed.

Backup behaviour

When roles shift because someone is out of weapons, low in fuel, or has to leave the group, it was considered as examples of backup behaviour, and if the team leader is forced to leave the group for some reason, there is always a deputy appointed to step in. Since the team task largely is collaborative and, in most cases, all participants are equally able to perform the subtasks of the mission, backup behaviour might be difficult to distinguish from adaptability. Both these factors are essentially equal to flexibility. The priority for the team is to get the job done—who actually does what seems to be of less importance. This could explain why the ranking of backup behaviour is low; the pilots did not really regard it as backup if someone else got in the position to use the radar or fire a shot, for example.

Task performance cycle

As previously noted, teams are formed in an organisation but perform their activities in cycles, so-called 'episodes', and there is a shift between action phases and transition phases (Marks, Mathieu, and Zaccaro 2001). Salas, Sims, and Burke (2005) also suggest that, depending on the task in question, the teamwork factors will vary in importance during the different phases of the execution of a task. The interviews gave insight into the task performance cycle of an air mission, and the phases where the teamwork factors were found to be more salient are shown in Figure 2. The cycle starts with the organisation, the air force wing, from which the members of the team are selected for each mission. The leader is appointed and the team is given their task. The group gathers for a briefing to prepare and plan for the mission, then the mission is performed. Afterwards, there is a debriefing where the mission is discussed, and the team members can give feedback to each other and reflect on their performance. After the debriefing, the team is dissolved and the members are ready for their next mission.

The factors vary in importance during the different phases of the cycle. At the briefing, before the mission, shared mental models are established according to the findings in the interviews. Afterwards, at the debriefing, differences in the pilots' conceptions about the performance may be identified and, hence, the shared mental models are updated. Team leadership is reported as being most important before the mission and the team leader is also essential to ensure that the debriefing and feedback sessions are performed with trust and mutual respect. Team orientation and mutual trust are factors that the air force organisation addresses and cultivates in the transition phases between the performance episodes.

Relationships between the teamwork factors

The descriptions of the teamwork factors and the task performance cycle are used to identify how the teamwork factors relate to each other and lead to team effectiveness in the studied case. Figure 3 shows the

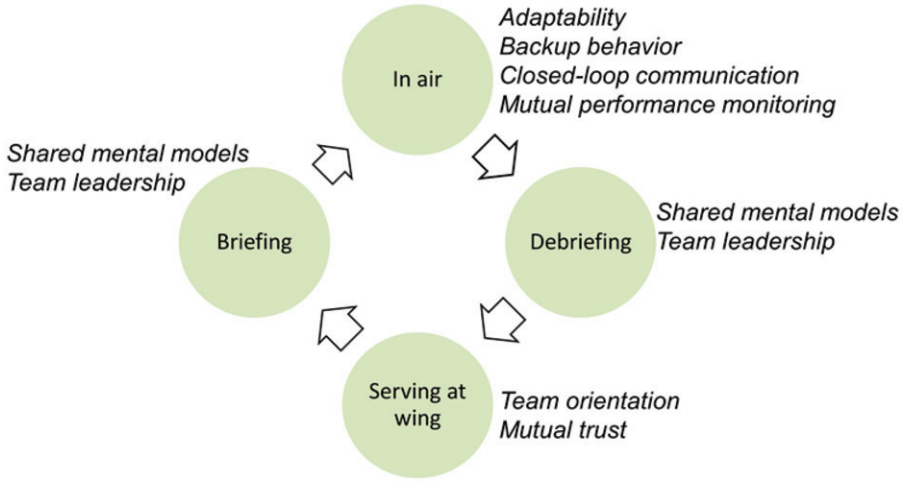

Figure 2. Task performance cycle, which shows the different phases fighter pilots prepare and perform missions in. The teamwork factors are distributed between the different phases of missions depending on how they vary in importance during the phases.

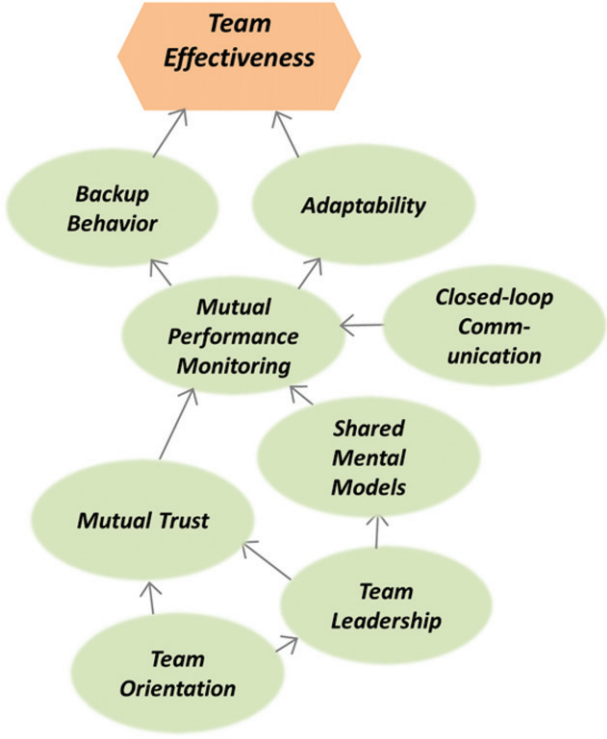

Figure 3. The identified relationships between the factors for effective teamwork for teams of fighter pilots.

studied teamwork factors adapted with the identified relationships from the investigation. The model shows how team effectiveness is achieved by fighter pilots during an air-to-air mission.

The process towards team effectiveness originates with team orientation, which affects team leadership and mutual trust. Team orientation is a natural starting point, since it is an attitude, something the team members bring to the teamwork, and not a behaviour as the rest of the factors (Salas, Sims, and Burke 2005).

Team leadership and mutual trust are found to be important during the initial phase of the task performance cycle, i.e. the briefing, and the pilots consider the team leader to be responsible for the mutual trust in the team. Since the communication is limited during the mission, it is extremely important to have detailed plans and alternatives set beforehand. The team leader is responsible for how the team plans for the mission and how well the team actually will develop shared mental models. According to the pilots, the most important factors during missions are mutual performance monitoring and it is found at the core of the adapted teamwork model, see Figure 3. Closed-loop communication is a prerequisite for maintaining mutual performance monitoring. Finally, adaptability and backup behaviour are resulting from the mutual performance monitoring.

Design implications

Based on the study presented, in what way can the tactical support systems and graphical interfaces be improved to better support teamwork? The study has shed light on the components that make up effective teamwork, and how fighter pilots perceive these components during the pursuit of a mission. But how can this knowledge be used in the design of future tactical support systems? Mutual performance monitoring was found to be the most important factor in this distributed environment, but the challenge regarding how to convey useful information without overloading the system or the users still remains. Mutual performance monitoring can be understood as a component of *situation awareness*), which is commonly defined as 'the perception of the elements in the environment within

a volume of time and space, the comprehension of their meaning and the projection of their status in the near future' (Endsley 1988). Some work has been done to understand what fighter pilots need to maintain their situation awareness. Endsley performed a survey on what information fighter pilots needed in an air-to-air scenario and listed 143 important items and 86 fairly important items (Endsley 1993). This regarded entities on the opponent side as well as teammates, and it is notable that the information needs were claimed to be almost the same regardless of the type of object. The situation awareness concept treats the entire outside world in one big scoop, ('elements in the environment') when actually there could be advantages to try to present the team view to the pilots and highlight team information more significantly. As it was noted during the interviews, pilots may lose the team view due to stress, and perform suboptimal actions instead of letting the best-positioned pilot act. Other more specific design suggestions include the automatic sharing of system information between team-members. This is already available today to some degree, but more details about the system as well as pilot status could be shared. The possibility for pilots to send pre-defined text messages to each other is also something to consider and develop more. The acknowledgement of messages adds workload and one design solution could be to automate this in order to make the closed-loop communication less demanding. Finally, the fear of not being able to deliver messages regarding changing plans correctly restrains the pilots from being adaptive. This inherent weakness could be improved by supporting the ability to share intentions within the team, for example by highlighting items and areas of interest for each other on the map.

Discussion

To rate and rank the teamwork factors was considered difficult by the pilots. Generally, their first reaction to the task was that all factors are valuable and important, making it nearly impossible to choose one over the other. It should be noted here that the purpose of this study is not to emphasise one aspect over the other, but rather to highlight and describe how the factors for effective teamwork appear during the cycle of performance of an air-to-air mission. However, Salas, Sims, and Burke (2005) do propose that the importance of the factors in the model will differ depending on the task and team composition. By asking the pilots to rank the factors, they were forced to evaluate each factor and decide on its importance in relation to the other factors. As discussed earlier, it was also clearly stated during the interviews that the pilots were asked to consider an air-to-air mission scenario in order to assure they all had the same mind-set, and that the results reflect what is most important during the execution of similar missions.

Mutual performance monitoring was ranked as the most important factor during a mission. Without the ability to monitor each other on displays, no teamwork can practically exist in the domain. In other settings, where team members are co-located, the monitoring is more direct and can often be pursued without significant effort. As a comparison, Duel (2010) found that for army teams, mutual performance monitoring was of less importance, and other factors such as team orientation were considered to contribute more to the teamwork effectiveness in that context.

Closed-loop communication is related to flight safety. There is an awareness about this among pilots and communication via radio follows a protocol. Messages need to be acknowledged, and the absence of acknowledgements may lead to increased workload and perhaps a delay of actions, especially for the team leader.

It can also be noted that closed-loop communication and mutual performance monitoring need technology to occur, since no monitoring of teammates or communication between them can take place in the environment in question without technological aids.

The pilots express the importance of having shared mental models and missions are planned with possible backups in case of deviations from the original plan. The operation of a fighter aircraft is built on many rules and procedures that need to be followed, and the behaviour is regulated so that in many cases there are standard procedures, that everybody needs to know and adhere to. This supports the ability for implicit coordination according to Mac Millan, Entin, and Serfaty. (2004). Effective teams have a high degree of implicit coordination where team members are able to act together without further communication, based on their shared understanding of the situation. The pilots also discuss the shared mental models during the debriefing after the mission, and this is important for future missions. Feedback and reflective practices are found to be important factors that enable coordination in teams that operate in extreme environments according to Godé and Lebraty (2015).

Shared mental models are, in accordance with the propositions by Salas et al., found to be a prerequisite for mutual performance monitoring, adaptability, and backup behaviour. In the original model pictured by

Salas et al., the factor closed-loop communication is a coordinating mechanism and no connections to the other factors are shown. However, there are propositions given in the paper (Salas, Sims, and Burke 2005), not pictured in the model, regarding how closed-loop communication may affect mutual performance monitoring, backup behaviour, and adaptability. These propositions are in line with the findings of this study, namely that during the performance of an air mission, closed-loop communication is a prerequisite to mutual performance monitoring.

Regarding adaptability, the potential benefits of changing plans need to be balanced with the risk that the new plan is not received and understood by the whole team. This limited acting space, i.e. lack of adaptability, should be expected to improve with better communication and enhanced mutual performance monitoring.

According to Salas, Sims, and Burke (2005), team leadership would influence the team's ability to engage in mutual performance monitoring and backup behaviour. However, in the researched context it is found that team leadership rather is considered central for the mutual trust, and in the establishment of shared mental models during briefings before the mission.

Validity

The characteristics of teamwork in the fighter pilot domain are distributed teams who work under time pressure and stress. The limited ability to communicate and share information is the main constraint. Even though different aircraft may have different sources of information (sensors) and different means of information sharing (data links) the major difficulties remain the same and the given descriptions of how teamwork is pursued should be valid for a variety of fighter aircraft types. However, the detailed design solutions may, of course, be different depending on the available technology. The culture of the organisation may also affect how for example, team leadership is expressed either as directive control (more freedom to solve the task on lower command levels) or command guidance (following detailed orders).

Conclusions and future work

A model for effective teamwork, which is claimed to capture the essential teamwork processes, by Salas, Sims, and Burke (2005), was selected as the entry point to the studies of teamwork in the fighter aircraft domain. According to Salas, Sims, and Burke (2005), the manifestation of the eight described team processes will differ between teams depending on the team tasks and therefore, in order to understand how effectiveness is achieved in a particular team, the team processes need to be described and analysed in the specific context. Our investigation confirms the notion that teamwork is a vital capability in the domain, and the eight factors are found to be relevant and important for the pilots. The results from the interviews presented here provide more elaborated descriptions of each of the factors during air-to-air missions. The findings result in a suggestion of how the factors of the teamwork model relate to each other, how team effectiveness is achieved in the domain, and how the design of tactical support systems can further support the teamwork.

The mutual performance monitoring is found to be central during missions and consists mainly of the information on displays where the team members can see each other's positions on a map. The distributed information about the team members should be analysed in more detail from the teamwork perspective and additional data, which enhance the ability for team members to monitor each other, should be considered to be included. Another aspect being the fact that today the available information is focussing on the current situation, and there is more to be done to help the pilots to predict their teammates' actions and possible future states, especially with short notice and in very dynamic situations.

The capability to be adaptive and change plans relies largely on the communication ability. If the ability to communicate and pursue mutual performance monitoring is improved, the team will be able to adapt to developing situations.

Future work

The findings presented here about the investigated teamwork factors need to be further processed in order to identify the most important pieces of information in certain situations in order to support team effectiveness. Each pilot builds his or her awareness of the situation through mutual performance monitoring and closed-loop communication and the team of pilots depends on technology during their missions, as has been discussed earlier. Future work includes for example investigating further the difficult task to maintain both one's own situation and keep track of the whole team at the same time.

A way to support this process of approaching detailed design regarding team factors, such as mutual

performance monitoring, is to use the gained insights regarding pilots' teamwork as input during workshops with experienced designers and developers of cockpit interfaces. The teamwork model and the descriptions of the teamwork factors can be assumed to add a new and valuable perspective to the design work. Design propositions based on these findings could be tested and evaluated in order to establish guidelines for the design of pilot interfaces in fighter aircraft for enhanced team collaboration.

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