A Teamwork Model for Fighter Pilots

Ulrika Ohlander[1,2(✉)], Jens Alfredson[1], Maria Riveiro[2], and Göran Falkman[2]

[1] Saab Aeronautics, Saab AB, Linköping, Sweden
{ulrika.ohlander,jens.alfredson}@saabgroup.com
[2] University of Skövde, Skövde, Sweden
{maria.riveiro,goran.falkman}@his.se

Abstract. Fighter pilots depend on collaboration and teamwork to perform successful air missions. However, such collaboration is challenging due to limitations in communication and the amount of data that can be shared between aircraft. In order to design future support systems for fighter pilots, this paper aims at characterizing how pilots collaborate while performing real-world missions. Our starting point is the "Big Five" model for effective teamwork, put forth by Salas et al. [1]. Fighter pilots were interviewed about their teamwork, and how they prepare and perform missions in teams. The results from the interviews were used to describe how pilots collaborate in teams, and to suggest relationships between the teamwork elements of the "Big Five" model for fighter pilots performing missions. The results presented in this paper are intended to inform designers and developers of cockpit displays, data links and decision support systems for fighter aircraft.

Keywords: Team effectiveness · Teamwork · Fighter aircraft · Fighter pilots

1 Introduction

A majority of air missions are conducted by teams of aircraft, and effective teamwork among fighter pilots is a pre-requisite for a successful outcome of missions [2].

Team performance is the result of the teamwork, what the team accomplishes, and team effectiveness is about how the team members acts and interacts when performing the task. A team can perform well and even accomplish its goals, despite ineffective functioning. Hence, focusing only on the outcome and results of the teamwork will not give enough information about how the team reached its goals. In order to understand team effectiveness, it is necessary to investigate the internal processes of the team [1]. Teamwork is practiced in almost all kinds of settings, for example sports, management, product development, health care, as well as in the military. Research on teams is vast, and much of the previous literature focuses on human aspects related to teams, such as team building and leadership. The need for communication is often emphasized in the literature as a success factor, but in most other studied cases, the ability to communicate does not depend on technology as much as in the case between aircraft. The extreme conditions and circumstances, for example time pressure, high stakes, combined with this limited ability to communicate, make the teamwork for pilots challenging. In order

D. Harris (Ed.): EPCE 2016, LNAI 9736, pp. 221–230, 2016.
DOI: 10.1007/978-3-319-40030-3_23

to overcome the limitations associated to current support systems and design more effective systems for the future, this paper aims at investigating which factors make teamwork successful in this domain. To the best of our knowledge there is currently no such description in the literature.

The main contribution of this paper is the description of the teamwork in teams of fighter pilots. The aim is to describe how to these types of teams achieve effectiveness and successful outcomes of their missions. It has been shown that well-designed technology can improve team performance [3]. The teamwork elements that must be supported by technology in the studied environment are therefore of special interest. Since the teamwork between fighter pilots relies heavily on technological support, and there are certain limitations to which data can be distributed and displayed, the presented results are intended to guide in selecting the information that should be processed and presented to the pilots.

2 Teamwork Model

This section describes important theories and findings in team research and relates them to teams of fighter pilots.

A team of military fighter pilots typically consists of two or four aircraft, sometimes more. Since teamwork is present in many different settings, teams can be grouped depending on their characteristics such as team membership, work cycles and output. There are for example project teams, management teams and service teams. A team of fighter pilots can be classified as an *action team*. Other examples of action teams are response teams (medical, fire fighters), sports teams and aircrews. The classification is used to describe teams which are highly skilled specialist teams, cooperating in unpredictable circumstances [4]. Naturally, the task the team is formed to solve affects how the team works. There are mainly two categories of team tasks: collaborative and coordination tasks [1]. In a coordination task, team members depend on each other to perform subtasks in a certain priority, and perhaps there are specialized members for certain actions, for example in a medical team performing surgery. In a collaborative task, the team members are equally able to solve all the subtasks. The team task for a team of fighter pilots is in most cases collaborative. But there might be exceptions from this, for example when one of the team members is flying an aircraft with special equipment.

Many models for teamwork have been proposed in different areas. Salas et al. [1] made a review and found more than 138 relevant models of teamwork. They synthesized the factors that had been found to have an impact on team effectiveness and they named the model The “Big Five” of teamwork. The “Big Five” model contains five central factors and three coordinating mechanisms, thus in total eight elements, necessary for successful teamwork. The approach used when the model was created, and the general applicability, makes it a good starting point for team research. The Big Five model has been analyzed both in military team settings [5], as well as in general, office/school types of teams [6]. Moreover, it has been found to be relevant for teams of fighter pilots [7].

In this work, when we are exploring the meaning of the elements in this specific context, we choose not to differ between the five factors and the three coordinating mechanisms. Instead, we label all eight components teamwork *elements*. The "Big Five" elements and their definitions as given by Salas et al. are listed in Table 1. An adapted illustration of the model with relationships between the elements as suggested by Salas et al. is shown in Fig. 1.

Table 1. The "Big Five"of effective teamwork and their definitions, after Salas et al. (2005)

Big Five Element	Definition
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 organize, and establish a positive atmosphere
Mutual performance monitoring	The ability to develop common understandings of the team environment and apply appropriate task strategies to accurately monitor teammate performance
Backup behavior	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
Adaptability	Ability to adjust strategies based on information gathered from the environment through the use of backup behavior and reallocation of intrateam resources. Altering a course of action or team repertoire in response to changing conditions (internal or external)
Team orientation	Propensity to take other's behavior into account during group interaction and the belief in the importance of team goals over individual members' goals
Shared mental models	An organizing knowledge structure of the relationships among the task the team is engaged in and how the team members will interact
Mutual trust	The shared belief that team members will perform their roles and protect the interests of their teammates
Closed-loop communication	The exchange of information between a sender and a receiver irrespective of the medium

Teamwork is a dynamic activity. The team is formed, the task assigned, planned, performed, finished and evaluated. The cycle of task performance is vital to investigate in order to understand the teamwork as also pointed out by Salas et al. [1]. Teams perform in episodes, and these processes have been investigated and described in [8]. A suggested task performance cycle with the "Big Five" elements for a team of fighter pilots is shown in Fig. 2 [9].

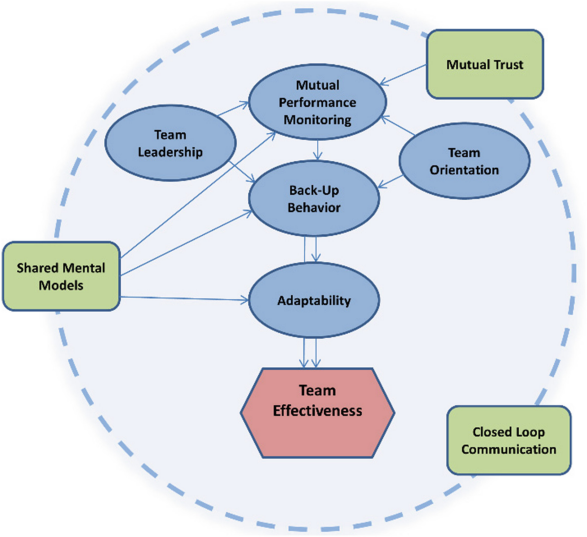

Fig. 1. The "Big Five" for team effectiveness, after Salas et al. [1]. The "Big Five" factors are represented by ovals while supporting mechanisms are shown as squares. The arrows represent propositions by Salas et al. for how the elements relate to each other.

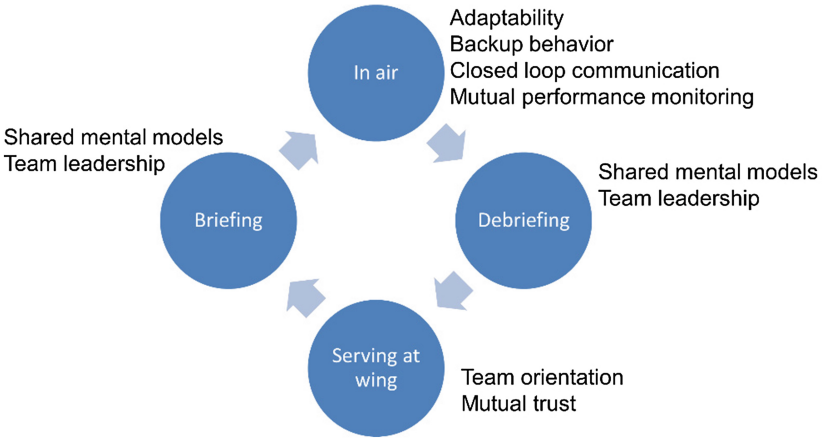

Fig. 2. Task performance cycle for fighter pilots with the "Big Five" elements [9]

3 Method

A qualitative research approach was applied and interviewing was selected as the most suitable method, since the aim of this work was to characterize how pilots collaborate while performing real-world missions. The interviews were conducted as described below following general guidelines for qualitative research [10].

3.1 Conducted Interviews

Open-ended interviews were conducted with ten experienced active fighter pilots. The participants were all male and their average age was 38 years (29–45). Their average flying time on fighter jets was 1500 h (500–3000). The interviews lasted between 40 min up to 2 h depending on the subject's availability. During the interviews, the subjects were first asked in general about their experiences and views on teamwork as fighter pilots. Then, they were presented with the teamwork elements printed on loose paper slips, a total of eight pieces. They were informed about the definitions of the elements as proposed by Salas et al. [1], and they were asked to rank the eight paper slips and to put the most important element during the performing of a mission on top. In addition, the pilots were asked to discuss and reflect on the teamwork elements and to explain what they thought the elements could mean for a group of fighter pilots during a mission. The interviews were recorded and transcribed afterwards for analysis.

4 Results

4.1 Ranking of Teamwork Elements

The average ranking of the most important teamwork elements during mission execution between all interviewees was calculated. The resulting list, with the mean value of the ranking in parenthesis, is presented below:

1. Mutual performance monitoring (3.4)
2. Closed loop communication (4.0)
3. Shared mental models (4.1)
4. Adaptability (4.3)
5. Mutual trust (4.4)
6. Team orientation (4.8)
7. Team leadership (5.0)
8. Back-up behavior (6.1)

4.2 Description of the Teamwork Elements

In this section, each element in the teamwork model is described in the context of a team of fighter pilots. The descriptions are the results of the interviews.

Mutual Performance Monitoring. Mutual performance monitoring was ranked among the pilots as the most important teamwork element in the air. Without knowing where the others are, their status and what they are doing, it is almost impossible to perform a mission. However, the importance of not checking on each other for mistakes was stressed. The monitoring depends on technical solutions, such as data links and cockpit displays. Since the aircraft are moving very fast, it is sometimes difficult to rely on the information on the displays; it might be updated too slowly to be useful in some cases. If, for example, someone is making a sharp turn it takes too long before this is

visible on the others' screens. But, not only is the current status of interest, information about what the teammates are planning to do is also highly desirable. Also, in many cases it is not suitable to communicate status and intentions on the radio. If a pilot feels he cannot ask about this information he is left guessing from the teammate's behavior in the air. And as one pilot said: "If I don´t know, I might have to shoot myself, and then perhaps we will waste a missile."

Closed Loop Communication. Closed loop communication was also considered important during the mission; it was ranked as number two by the pilots. In general, the discipline concerning the closed loop was not regarded as a problem, since there are clear procedures that determine how communication via radio is carried out, with call signs and acknowledgements. And in the cases where people might skip the routines, the pilots concluded that they know each other so well that they know how each person usually manages the radio. As long as the original plan is followed, the need for a closed loop was considered less important, "I can see that he is doing what we planned". This element should probably in this context be regarded as not only referring to the necessity of a closed loop, but the capability and occurrence of communication between the team members at all. However, the information transferred via data link can help in keeping the closed loop. The utility of clear acknowledgements via data link was expressed. If the information is on the displays, there is no need to ask. Also, the absence of a closed loop would sometimes be taken as a sign of cognitive overload. If someone remains silent on the radio, perhaps he/she is too busy with something else and was not able to hear to the message. The absence of acknowledgements generally adds workload also to the team leader since he/she cannot move on with the planned actions until he/she knows that the message has been received. The safety aspect of closed loop communication was also articulated, especially when the plan is changed, "It is crucial to know whether everybody understand, or the situation may become dangerous."

Shared Mental Models. The element shared mental models was interpreted by the pilots as originating from the tactics and standard procedures that the team complies to. Before the mission, the team members plan and discuss the mission and the goals during the briefing session. The pilots considered it to be very important that everybody share the same understanding about the mission. The standardized procedures ensure common grounds and predictability. "If we all have the same mental models, I can count on that most people will take the same decisions." It was also recognized that the better the shared mental models are, the less talk is needed.

Adaptability. Adaptability was interpreted as the ability to change plans and adapt to new situations. It was considered as an important factor since it is impossible to plan a mission in every detail. Some contingency will always remain, and unexpected events may occur. However, there are difficulties with being adaptive in this environment with the limited communication. The possible gains must always be judged against the risk of a failure due to communication difficulties and misunderstandings. In many cases it is best to "stick to the plan".

Mutual Trust. The team members trust that their colleagues will do what is expected of them during the mission. Mutual trust was argued to be the result of good team

leadership. The leader was considered to be responsible for the trust among the team members. The team members on their hand trust the team leader to act during the mission. During missions, pilots with different ranks can be mixed in one team. It is not uncommon that a pilot with a lower rank is trusted to act as the team leader over a higher ranked colleague.

Team Orientation. Pilots are trained and disciplined to work in teams; not many types of missions are performed by single pilots. Team orientation was considered to be fairly unproblematic and a natural trait among the interviewed pilots, something they assume always to be present among their teammates. The pilots expressed it as "the team above self." However, this does not mean that it can be taken for granted. The importance of team orientation is fostered and emphasized by the organization. One aspect of team orientation that was mentioned was that during stressful situations it is easy to lose awareness about the whole situation and what the others are doing. The pilot can get so focused on his own situation that he "forgets" about the rest of the team and does not realize that perhaps some other team member is better positioned and can step in and take over.

Team Leadership. During the actual execution of the mission, team leadership was ranked as less important. The interviewed pilots argued that a good team leader does the main part of the job at the briefing before the mission. 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 agree and understand the tactics, and they know what is expected of them without the need of detailed orders during mission execution. It was considered important for the pilots to be an active part of 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." Further, when unforeseen events occur in the air, the leader is expected to take control and give clear instructions on how to proceed.

Backup Behavior. The respondents agreed that the need for backup behavior is something they are aware of and try to build into the system. If, for example, 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 to a large extent is collaborative, and in most cases all participants are equally able to perform the subtasks of the mission, backup behavior might be difficult to distinguish from adaptability. Both these elements 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 is low; the pilots did not really regard is at a back-up behavior if someone else got in the position to use the radar or fire a shot. Only when someone was out of weapons, low in fuel or had to leave the group, it was considered as a backup behavior.

Relationship Between the Teamwork Elements. For establishing the relations between the teamwork elements we use the performance cycle presented in Sect. 2. This cycle suggests where each teamwork element comes into play.

The elements team orientation, team leadership and mutual trust were previously identified as prerequisites for a mission, and are mainly established and manifested on ground [9]. Team leadership was considered to be central for the mutual trust and in the establishing of shared mental models during briefings before the mission. The element shared mental models was found to be a prerequisite for mutual performance monitoring. The elements the pilots ranked as most important for a successful mission were mutual performance monitoring and closed loop communication. These are also the two elements where the pilots need technology, such as radio, data links and displays to perform. Backup behavior and adaptability are the elements that are central during mission performance, which are dependent on mutual performance monitoring and closed loop communication to be present before they can be accomplished.

Based on these findings, a suggested relationship between the eight teamwork elements, and how team effectiveness is built up during a mission, is shown in Fig. 3.

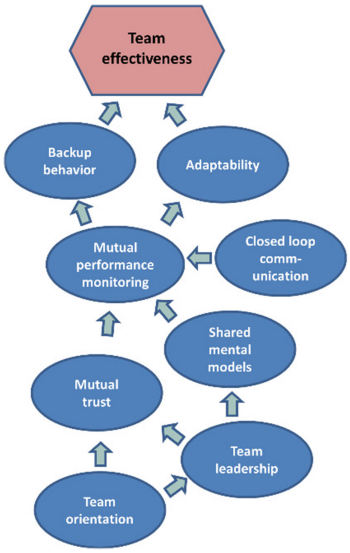

Fig. 3. The found relationships between the "Big Five" elements for effective teamwork for teams of fighter pilots.

5 Discussion

The "Big Five" model for effective teamwork was found to be relevant and well suited as a starting point for research of teams in the military fighter domain. The model has previously been used for research on peace keeping army teams where it was also found to be applicable [5]. Team orientation is described by Salas et al. as an attitude in contrast to the other elements that are behavioral. This makes team orientation a natural starting point for the chain of relationships. According to the propositions by Salas et al. team leadership would influence the team's ability to engage in mutual performance

monitoring and backup behavior. However, in this context it was found that the team leadership was considered to be central for the mutual trust and in the establishing of shared mental models during briefings before the mission. Shared mental models was in accordance to the propositions by Salas et al. found to be a fundamental prerequisite for mutual performance monitoring, adaptability, and back-up behavior. In the original model by Salas et al. the element closed loop communication is a coordinating mechanism without connections to the other elements. However, there are propositions given, but not incorporated in the model, regarding how closed loop communication may connect to mutual performance monitoring, back-up behavior and adaptability. During the performing of an air mission closed loop communication was found to be a prerequisite to mutual performance monitoring, and is therefore put in the model in this place. The need for the pilots to communicate does not only occur during the actual mission, but also during briefing and debriefing, but then there are no technical limitations.

6 Conclusions

The aim of this paper was to describe how fighter pilots work in teams and what factors they think are central for achieving effective and successful missions. To this end ten fighter pilots were interviewed about their experiences from team work. The findings regarding each teamwork element inform how teamwork is viewed by the interviewed subjects in this specific domain. The findings resulted in a suggested relationship between the elements of the "Big Five" model by Salas et al. (2005), adapted to the domain.

Team leadership was considered to be central for the mutual trust and in the establishing of shared mental models during briefings before the mission. Shared mental models was in accordance to the propositions by Salas et al. found to be a fundamental prerequisite for mutual performance monitoring, adaptability, and back-up behavior. The elements the pilots ranked as most important for a successful mission were mutual performance monitoring and closed loop communication.

7 Future Work

Each pilot builds his awareness of the situation through mutual performance monitoring and closed loop communication. Since the pilots are separated, and many times they do not even see each other's aircraft, the teamwork is depending on technology during missions. There are several identified issues that could be further explored in order to better support the team with technology:

- The task to maintain both one's own situation and keep track of the whole team at the same time is difficult. There is a risk that a pilot gets so engaged in his own situation that he forgets to check whether someone else can help out or even perform the whole task instead.

- As of today, the potential benefits of changing plans needs to be balanced with the risk that the new plan is not received and understood by the whole team. The limited acting space, i.e. the team's adaptability, should be expected to improve with better communication and mutual performance monitoring.
- The ability to communicate and understand each other's intentions, especially with very short notice could be further explored and developed in order to support the teamwork.

Other domains might also benefit from our findings in the area of teamwork and effective team collaboration. The proposed elaborated model, adapted for teamwork of fighter pilots, together with a deeper understanding of how these high-performing and mature teams collaborate can hopefully inform and inspire how teams with similar characteristics can accomplish effective teamwork.

Acknowledgements. This research was funded by NFFP (National Aviation Research Programme, NFFP6-2013-01201), which is founded by VINNOVA (Swedish Governmental Agency for Innovation Systems), the Swedish Armed Forces and the Swedish Defence Material Administration. The authors also like to thank Saab AB and the University of Skövde for supporting the project.

References

1. Salas, E., Sims, D., Burke, S.: Is there a "Big Five" in teamwork? Small Group Res. **36**(5), 555–599 (2005)
2. Castor, M.: The use of structural equation modelling to describe the effect of operator functional state on air-to-air engagement outcomes. Doctoral thesis, Linköping University (2009)
3. Salas, E., Cooke, N.J., Rosen, M.A.: On teams, teamwork, and team performance: discoveries and developments. Hum. Factors **50**(3), 540–547 (2008)
4. Sundstrom, E., De Meuse, K.P., Futrell, D.: Work teams: application and effectiveness. Am. Psychol. **45**(2), 120–133 (1990)
5. Duel, J.: Teamwork in action: military teams preparing for, and conducting peace support operations, Tilburg University (2010)
6. Moen van Rosmalen, T.: The development of a questionnaire on the subjective experience of teamwork, based on Salas, Sims and Burke's "the big five of teamwork" and Hackman's understanding of team effectiveness'. Master thesis, The Norwegian University of Science and Technology (2012)
7. Ohlander, U., Alfredson, J., Riveiro, M., Falkman, G.: Understanding team effectiveness in a tactical air unit, In: Harris, D. (ed.) Engineering Psychology and Cognitive Ergonomics. LNCS, vol. 9174, pp. 472–479. Springer, Switzerland (2015)
8. Marks, M.A., Mathieu, J.E., Zaccaro, S.J.: A temporally based framework and taxonomy of team processes. Acad. Manage. Rev. **26**(3), 356–376 (2001)
9. Ohlander, U., Alfredson, J., Riveiro, M., Falkman, G.: Elements of team effectiveness: a qualitative study with pilots. In: Proceedings of CogSIMA, San Diego, CA (2016)
10. Patton, M.Q.: Qualitative Research & Evaluation Methods: Integrating Theory and Practice, 4th edn. SAGE Publications Inc, Thousand Oaks (2015)