Understanding the effect of team familiarity on Shared Spatial Situational Awareness

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SUMMARY

The study investigates the relationship between team familiarity (both professional and personal) and Shared Spatial Situational Awareness (SSSA) during a flight simulation task. The findings suggest that team familiarity, and specifically personal familiarity, is important for both SSSA accuracy and the percentage of unknown lost SSSA state instances. Interestingly, professional familiarity was not found to be significant.

KEYWORDS

Teams, Situational Awareness, Aviation

Introduction

Situational Awareness (SA) is being aware of your surroundings, interpreting information and anticipating what it means for future states. SA is one of the most critical human factors topics in aviation safety. Indeed, Kharoufah et al. (2018) and Kalagher et al. (2021) analysed numerous aviation accidents and found SA to be the most significant contributory factor. Kalagher et al. (2021) who reviewed 94 general aviation accidents for which situational awareness was cited as being an antecedent, found that the consequence was most often fatal for accidents occurring during the cruise phase in which the crew also had spatial or geographical disorientation. The maintenance of SA is critical for effective decision-making in many domains.

The loss of SA is a problem not exclusive to aerospace, with the loss of SA being identified as a considerable antecedent in many industries' accidents, such as aviation (Kalagher et al., 2021), medical (Al-Moteri, 2022) and maritime (Gommosani et al., 2021).

Much of the accident data attributing a cause of SA tends to relate to teams rather than individuals, such as a flight deck crew, operating theatre, or a control room. A review of the literature however demonstrates a vastly reduced quantity of research relating to team or shared SA, which may therefore fail to acknowledge that cockpits and control rooms are made up of more than one individual; it fails to consider SA within the team (Graafland et al., 2014). To this end, this research investigates the relationship between team familiarity and Shared Situational Awareness (SSA). To evaluate and measure this, the research specifically focuses on the spatial element of SSA, herein identified as Shared Spatial Situational Awareness (SSSA).

Situational Awareness

There are many definitions and theories of SA, including that by Smith and Hancock (1995), but perhaps the most prevalent definition is that by Endsley (1995), which defines SA 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's model suggests three hierarchical stages: level 1 SA - perception of the elements in the

environment, level 2 SA – comprehension of the current situation, and level 3 SA – projection of future status.

There are many factors which influence SA according to Endsley (1999), including processing limitations such as attention and working memory limitations, as well as coping mechanisms such as mental models and automaticity. Mental models and schema for example are used as coping mechanisms to allow pilots to speed up decision-making in the higher levels of SA.

Endsley (1995) further suggests that there can be sub-categories of SA, such as spatial or geographical SA, which includes requirements across each of the three levels of SA of her model. Her paper goes on to state that SA has often been observed to be highly spatial, and that this spatial element is valuable in establishing the importance of elements of the environment, and therefore which elements to prioritise at a given time. For this reason, this paper focuses on spatial/geographical SA, referred to as 'spatial' from this point forward.

Shared Situational Awareness

Endsley (1995) defines Team SA as "the degree to which every team member possesses the SA required for his or her responsibilities". She and Li (2017) conducted a literature review which included Ensley's work and summarised the definition of team SA as "a multidimensional construct" which "contains the SA related to the individual's own roles, the SA of other team members, and the SA of the overall team." It is important to understand that these definitions support the notion that there are elements of a person's SA within a team that are shared and elements which are not. It is only necessary for a subset of information to be shared across a team (Endsley, 1995). Shared Situational Awareness (SSA) is therefore a sub-component of team SA and is defined by Endsley and Jones (1997) as "the degree to which team members possess the same SA on shared SA requirements." Endsley (1995) suggests it is the overlapped elements (shared SA), which require a large proportion of the team's coordination, which could be done via many means including verbal communication or duplicated display information.

Endsley (1999) suggests to develop team SA, much of the team's coordination activities are based on information-sharing. This will include level 1 SA information such as data from visual displays, as well as information pertaining to levels 2 and 3 so that the team can benefit from the varying experiences of the individual team members. It is less likely that the higher levels of SA will be achieved via displays, making team SA more important to achieve levels 2 and 3. This may for example be done via communication and a Shared Mental Model (SMM) between team members.

The Role of Shared Mental Models and Communication

Shared Mental Models and communication elevate themselves as being key themes within the literature for the achievement of Levels 2 and 3 SA, with Endsley and Jones (2004) stating that higher team performance was found in teams that had SMMs in comparison to those that did not. Indeed, in an analysis of accident data, Jones and Endsley (1996) found 13.8% of the accidents reviewed to be attributable in some way to mental models.

Team members' mental models need to be the same to come to the same conclusion and therefore share the same SSA (Endsley & Jones, 1997). This is supported by Cannon-Bowers et al., 1993, as cited in Endsley, 1999, suggesting that the sharing of SA between the team members is enriched by SMMs "which provide a common frame of reference for crew member actions and allow team members to predict each other's behaviours". Stout et al. (2017) further suggest that SMMs are "a prerequisite for achieving team situational awareness" and are critical for performance.

Endsley (1999) suggests that by having similar mental models, the team are better able to communicate with each other as they can predict each other's actions, therefore enhancing SA.

Orasanu and Salas (1993, as cited in Endsley & Jones, 2004), state that one of the key advantages of SMMs is that "they can provide important interaction patterns and standardized speech and communications allowing crew members to interact in predictable ways".

However, Endsley and Jones (1997) suggest that higher levels can be achieved by the team if they possess the same mental models without the need for extra communication. This is supported by Mosier and Chidester (1991, as cited in Endsley, 1999) who found there to be less communication between better-performing teams.

Shared Situational Awareness States

Endsley and Jones (2004) define team SSA states into three categories; both correct, both incorrect, and different. If both team members have the same understanding and are correct, this is the most preferred state. Alternatively, they may have differing views with either only one of the team being correct, or them both being incorrect (in different ways or both having the same incorrect understanding).

Losing SA however, does not necessarily lead to poor performance and therefore risk of danger. In a tactical fighter mission study, Endsley (1990) found that if they realised they had lost SA it was not necessarily linked to poor performance when they could modify their behaviour. If the crew do not know they have lost SA, i.e. neither pilot has an understanding that SA has been lost, it carries the greatest safety risk (Jentsch et al., 1997, as cited in Endsley & Jones, 1997). To this end, the method used when understanding unknown lost SSSA will focus on occurrences where both participants are unaware rather than only one.

Shared Spatial Situational Awareness

There is little research available specifically looking at the spatial element of SSA. One such study by Prebot et al. (2019), investigated the assessment of SSA within complex decision-making via the assessment of the spatial element of SSA. The experiment provided verification of the method used to test SSSA, stating that "using distances (spatiality) as an evaluation metric of Shared SA, allowed us to quantify more precisely the situation awareness, giving levels to in the end qualify teams performance." For this reason, a similar method will be used in our research.

Familiarity

Familiarity has been defined as a multidimensional construct consisting of both professional and personal familiarity by Hanft (2002, as cited in Maynard et al., 2018). There have been many studies conducted that show team familiarity to have a positive outcome on performance, despite Barker et al. (1996) claiming no difference. A study by Kurmann et al. (2014) compared surgical outcomes of patients who had been operated on by newly formed teams, against patient outcomes when the teams were in the last month of a six-month partnership. They found improved team performance, including higher concentration scores, and reduced morbidity in the teams that had been partnered for longer, suggesting team familiarity to be beneficial. Muskat et al. (2022), who conducted a systematic literature review on team familiarity across many domains, supported this, finding that team familiarity resulted in positive performance, higher team cognition, higher efficiency, increased output quality, increased team productivity, error reduction and higher safety.

The National Transportation Safety Board (NTSB) (1994) conducted a review of major accidents and incidents of U.S. air carriers from 1978-1990 that involved flight crew and found 73% of the incidents occurred on the first day of a pairing, with 44% being on the crew's first flight. Similarly, a review of U.S. air carrier accident data between 1991 and 2010 by Boss et al. (2013) looked at the accident rates of Captains and First officers with team familiarity, including measuring this via whether they were on their first day of the pairing. They found a "negative effect on accident rates"

with higher accident rates amongst those with lower crew familiarity. This is supported by Endsley and Jones (2004) who suggest that teams that have not previously worked together might be at a disadvantage, as those that have, are able to understand each other, their roles etc, which in turn helps promote effective communication and anticipate actions. This is also supported by Orasanu and Salas (1993, as cited in Endsley, 1997) who suggest that the familiarity between the crew and shared experiences allow the development of the SMMs. This in turn is important in allowing the crew to reach levels 2 and 3 SA (Endsley, 1995), and therefore allowing good team performance.

The Measurement of Team Familiarity

The systematic review by Muskat et al. (2022) suggests that there are several antecedents to team familiarity, with the key antecedent being cited as time. This includes the amount of time working together, the number of shared experiences, and the amount of friendship. They do not however state the amount of time necessary to be categorised as a familiar team, or the types of activities, depth etc of the experiences to achieve this.

Maynard et al. (2018) measured personal and professional familiarity using a Likert scale questionnaire based on the work by Hanft (2002, as cited in Maynard et al., 2018). They found that professional familiarity was significantly positively related to their task of information elaboration but that personal familiarity was not. In turn, information elaboration was significantly related to team effectiveness.

Professional and Personal Team Familiarity

There is little research available with respect to how professional and personal team familiarity might affect SA; however, theoretical underpinnings suggest a difference.

When considering professional familiarity, SMMs and Endsley's SA theory (1995) would suggest that shared work experiences allow the building of professional information, such as an understanding of the knowledge bases of teammates and the expertise that can be relied upon. This would allow for more effective communications and therefore anticipation of each other's actions (SMM). This in turn allows higher levels of SA to be achieved within the team (Endsley & Jones, 2004). This is supported by Roberston and Endsley (1995, as cited in Endsley, 1999) who suggest that Crew Resource Management (CRM) training can impact the development of SMMs and individual SA.

There is however far less written about how personal familiarity might lead to better performance. One explanation however is offered by Maynard et al. (2018), who suggest that increased familiarity means that members "are more likely to suggest and use the ideas of others based on their levels of interpersonal comfort, which reduces fear of ridicule or exclusion". Communication and information elaboration are social phenomena requiring the free exchange of information, integration, and decision-making. Edmondson (1999) suggests that this is more likely if there is psychological safety and comfort with their teammates. As more effective communication is suggested to be linked to better SMMs, it could be suggested that personal familiarity would result in better SSSA. This is supported by Jehn and Shah (1997), who found significantly better performance from friendship groups compared to acquaintance groups regarding decision-making due to greater commitment and cooperation.

Method

This study investigates the relationship between team familiarity (professional and personal) and SSSA. It was hypothesised that there would be a difference in the team's SSSA accuracy based on team familiarity, as well as a difference in the 'unknown lost SSSA state' shown, where the teams incorrectly think that they are marking the same location as their teammate. This study conducted

an experiment with 74 participants, and the study design includes pre-experiment, experiment and post-experiment phases.

In the pre-experiment phase, participants were voluntarily assigned to either the navigator or pilot role at the start of each session after collecting informed consent. Then participants' subjective evaluation of team familiarity, including personal and professional elements, was recorded via a seven-point Likert scale (based on Hanft, 2002, and Maynard et al., 2018). The Qualtrics questionnaire also captured demographic and background information. The experiment was then explained and instruments (for example, a map and recording sheet, as well as the target for the navigator) were introduced to the participants. The pilot then had a practice flight for three minutes, whilst the navigator was invited to watch for the practice only to gain an understanding of the visuals their teammate would be experiencing.

In the experiment phase, the pilot performed an online flight simulation game based on Bing maps (provided by geo-fs.com (Geo-FS, 2023) in HD) using a Thrustmaster USB joystick set with a 0.3 sensitivity, whilst the navigator verbally guided the pilot to a target known only to themselves (Hayward executive airport). They were allowed to verbally communicate freely to ascertain location, but the navigator was instructed not to directly give the target location (for example, 'top right of the map'). The participants had no previous knowledge of where they would be flying (San Francisco) and were separated by a barrier so that no line of sight was possible. Each participant was given an A3 piece of paper with a map of the San Francisco area printed on it, taken from Bing maps. All participants started at the same point and were already in the air. The starting location and direction were indicated on the map, with due North at the top of the paper as convention would dictate. Participants could choose any route. No coordinates, grid or scale indications were given.

Every 45 seconds, the simulation would be paused, and participants were asked to mark down where they thought the aircraft was located on their paper map. This is referred to as the Position Evaluation Point herein (PEP). They were also asked whether they thought they had marked the same approximate location as their teammate. The participants were asked not to communicate during this time, and the actual location was recorded. This was repeated until the aircraft landed or until they had been flying for 20 minutes, at which point the simulation was ended.

During the experiment phase, SSSA accuracy was recorded by measuring the distance between the PEP and the actual aircraft location for each participant (mm). The actual location was ascertained from a screen recording of the flight. In addition, team awareness of SSSA state was measured when asked if they had marked the same approximate location as their teammate (yes/no). The percentage of instances where both participants responded 'yes' but were more than 10mm apart determined the unknown lost SSSA score.

In the post-experiment phase, participants were debriefed and thanked for their participation.

Results

74 participants (52 Male, 20 Female and two declined to answer) ranging from 18 to 69 years old (M= 33.08) were recruited on an availability basis at their workplace to complete this study. Among the 37 tested teams, 10 did not reach the target. Six teams landed at an incorrect location and four failed to land within 20 minutes. Of the successful teams, three sets had incomplete data, and so the data relating to these were removed, along with those that did not reach the target.

The findings suggest that overall team familiarity ($p = -.478$, $p < 0.05$) and especially personal familiarity ($r = -.499$, $p < 0.05$) are important for SSSA accuracy. It was also found that overall team familiarity ($p = -.424$, $p < 0.05$) and especially personal familiarity ($r = -.473$, $p < 0.05$) are important for the percentage of unknown lost SSSA state instances. This suggests that higher overall team familiarity and personal familiarity scores are related to lower team accuracy scores,

i.e., more accurate results within the team and a lower number of instances of unknown lost SSSA. Interestingly, professional familiarity was not significantly correlated.

Discussion

The relationship between team familiarity (professional and personal) and SSSA has been explored using a correlational study design in which teams directed each other to a target in an online flight simulation game to understand their SSSA accuracy and SSSA state.

The results of this study confirmed prior theory and research indicating there to be a positive relationship between team familiarity and performance. Whilst there was little research available to consider the effect of SSSA specifically, it could be hypothesised that there would be an effect on SSSA accuracy, as well as instances of unknown lost SSSA states, as a result of overall team familiarity, professional familiarity, and personal familiarity based on Endsley's work of SA and team SA/shared SA (1995). The literature suggests that team familiarity was found to be positively correlated with shared experiences, with an emphasis on work-related experiences, which allow team members to build an accurate SMM and therefore communicate more effectively (Endsley, 1999). This in turn allows them to act in more predictable ways (Orasanu & Salas, 1993, as cited in Endsley & Jones, 2004). In addition, the literature suggests that personal familiarity is positively correlated as communication is enhanced by friendship and personal familiarity due in part to the more likely free exchange of information (Edmondson, 1999). One participant stated, "Because we knew each other, I could tell when she wasn't sure or if something was going wrong because of her tone of voice". This would support shared experiences being important for effective communication within the team, as suggested to be important for the development of SMMs and therefore reaching levels 2 and 3 SA by Endsley (1999).

There was however a lack of support with regard to the relationship specifically between professional team familiarity and SSSA with respect to both accuracy and unknown lost SSSA states. This was in contrast, however, to the work by Maynard et al. (2018) who found that professional rather than personal familiarity led to better information elaboration. One possible explanation for this is related to the fact that participants weren't familiar with this task type. Endsley (1999) states that novice pilots have limitations due to working memory limitations. The cockpit is a complex environment that can exceed attention and working memory capacities, suggesting that SA can be lost if the information that needs to be perceived isn't attended to whilst attending to other sources. Whilst participants were given practice time in the pre-experiment phase, they were still novices with regard to the task type. The practice session would not have been enough to reduce the demands on their attention significantly. This would support the need for further assessment with a representative flight deck crew and a representative task, which was not possible here due to the limitations with regard to resources on a student project. However, this study provides valuable insight into the relationship as it is one of the first studies to consider the relationship between SSSA and team familiarity, but it is acknowledged that the findings should be validated by flight crew and representative flight tasks.

Key Takeaways/Applications

There are numerous practical implications that can be proposed due to this research. As the results suggest personal familiarity is beneficial when considering SSSA, managers may want to consider adding personal familiarity as an element of their decision-making criteria when deciding on crew rosters. Whilst there will be many other factors to be considered with varying levels of importance and risk, such as working time regulations, if there is existent personal familiarity between potential crews, it may be of benefit to roster them together as this could provide less risk relating to SSSA as a result.

If it is not possible to take advantage of existent personal familiarity when rostering, it may be beneficial to take steps to enhance the organisational culture to encourage personal familiarity within their staffing. This may for example be via team-building days that do not solely focus on work-related tasks or encouraging social interactions such as sports clubs and team lunches. Indeed, Maynard and Gilson (2021) suggested several methods to improve personal familiarity, including arriving at meetings early to initiate organic personal conversations. This could easily be adopted by flight deck crew arriving slightly early rather than getting straight down to business.

Additionally, although not as much weight should be given compared to personal familiarity, it would be worth using existing professional familiarity as a selection criterion when considering rosters. This is because team familiarity, which included both personal and professional elements, was found to be significant. Again, if not already existing, techniques could be employed to enhance it.

It is recommended that awareness be raised on the benefits of team familiarity, especially personal familiarity, for any high-risk industry in which SSSA is critical. The implementation of specific training to counter this may be of use.

Limitations

Based on the literature review conducted, this is one of the first studies to consider the relationship between SSSA and team familiarity, even without further consideration for the sub-type of familiarity. Whilst the results suggest the saliency of personal familiarity, future research is needed to address some research limitations.

This research was conducted in a laboratory setting with a sample of volunteer participants who were not pilots. Future research should aim to validate findings using pilots in a representative environment, which was impossible due to limited access to resources on a student project. The correlational design of this research has allowed the identification of a potential relationship between team familiarity and SSSA. However, an experimental design should be adopted for follow-up investigations to establish causation and build upon this evidence. Anecdotally, this difference in crew team familiarity already naturally exists within the differences between commercial and military operations. Military crews are more likely to be flying with familiar teammates as there are generally a smaller number of pilots trained to fly each aircraft type hence higher levels of professional familiarity, but they are also more likely to know each other personally due to living on military bases. Accurate SSSA as well as accurately perceived SSSA is extremely important when flying to avoid the likes of Controlled Flight Into Terrain and Mid-Air Collisions, but it is even more important for military aircraft in potential combat situations due to increased dangers. It is unfortunate that SSSA cannot be isolated and naturally measured, for example via accident data analysis, as a result of the existing differences. Due to many interacting variables, such as the level of training received and the nature of the tasks being undertaken, SSSA accident data relating to team familiarity would be difficult to decipher as being purely a result of team familiarity. To that end, experimental data should be gathered to explore the correlation further and validate findings.

Future work could be conducted to understand whether there was anything significant about the data relating to teams that did not successfully complete the task. It may be that SSSA contributed to these teams being unsuccessful in completing the task, suggesting that any team familiarity effect would be even more informative.

Additionally, practical implications such as those made above, should not be considered in isolation. Whilst team familiarity has been shown to positively affect SSSA within this research, it does not consider any other variables that could potentially have a negative effect. If a third variable

was negatively affected by team familiarity, a safety management systems approach might be conducive to understanding the risk associated with any proposed approach to ensure the safest route is taken for operations. Future research might consider further understanding performance factors, including workload, in terms of personal and professional familiarity to aid in quantitatively assessing appropriate pairings for rosters.

A final limitation of this research is that it only considered a two-person cockpit team. In reality, flying aircraft involves many people in different roles as acknowledged by ICAO who identify Air Traffic Controllers, cabin crew and aircraft dispatchers as "essential participants in an effective CRM process" (ICAO, n.d.). To this end, future research should consider whether there is also an impact on SSSA due to team familiarities between these extended teams, such as between the flight deck crew and ATCs, which would allow the implementation of practical recommendations to be benefited from more widely. Certainly, Maynard et al. (2018) and Maynard and Gilson (2021) found that information elaboration is related to professional familiarity more saliently than personal in virtual teams, with virtuality moderating the relationship. The relationship between the flight deck and ATC may be considered 'virtual' and therefore potentially result in a different impact on SSSA compared to a face-to-face relationship.

Conclusion

Whilst much of the literature suggests that shared work and task-related experiences are important to build role understanding and a knowledge base of teammates (professional familiarity) in order to gain a better mental model and therefore better SA, it seems that this research found the personal element of shared experiences to be more pertinent to the development of SSSA. This element is seldom discussed in the literature to date. It is hoped that this research can bridge the gap in the literature relating to personal, professional, and overall team familiarity, as well as SSSA.

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