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User Experiences and Expectations Towards Automation and Safety in Air Traffic Control

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ABSTRACT

Various forms of advanced automation in air traffic control are being developed to reduce air traffic controller (ATCO) workload, support performance, and increase safety. However, higher levels of automation can negatively affect the ATCO's performance, reduce situation awareness (SA), and the usage of automation also depends on user acceptance. Previous studies have shown that automation can be met with resistance from ATCOs, which might lead to disuse. Thus, this paper continues the exploration of ATCOs' expectations of automation to deeper understand ATCOs' fears and anticipations. Through a questionnaire, operational ATCOs answered questions regarding their current experiences and future expectations regarding automation extend, safety, SA, and workload. The quantitative analysis shows that automation and workload are expected to increase in the future compared with today and that safety and SA are expected to decrease. Even though the participants highlighted that they do not want to become the backup system to the automation, it is in that direction the development is heading. These are worrying results and something the air traffic management community should see as a wake-up call. A well-calibrated attitude towards automation seems crucial to ensure the best human-automation interplay.

Keywords: Air traffic control, Automation, Safety, Situation awareness, Workload, User experience, User acceptance

INTRODUCTION

The air traffic management/control (ATM/ATC) industry faces challenges such as higher efficiency demands and complex traffic situations while maintaining high safety. To meet such challenges, higher levels of automation (Endsley, 2018; Kaber, 2018; Sheridan, Verplank, & Brooks, 1978) is seen as one solution (SESAR, 2006, 2017). Various forms of automation are being developed to reduce operator load, support performance, and increase safety (SESAR, 2017). However, automation might also introduce risks for decreased safety, even though safety is a fundamental basis in ATM (SESAR, 2006). Higher levels of automation can negatively affect operator's performance since the operator could be removed from the control loop (Baxter, Rooksby, Wang, & Khajeh-Hosseini, 2012; Endsley & Kaber, 1999; Endsley & Kiris, 1995), resulting in loss of situation awareness (SA) (Endsley & Kaber, 1999) and out-of-the-loop problems (Kaber & Endsley, 1997). The usage

of automation (e.g., tools and functions) depends on user acceptance of the automation (Bekier, 2013; Hilburn & Flynn, 2001). However, automation can be met with resistance and scepticism from the operators (Borst, Westin, & Hilburn, 2012; Hilburn & Flynn, 2001; Svensson, Lundberg, Forsell, & Rönnberg, 2021), and several factors affect whether automation is accepted and used (Bekier, 2013; Eurocontrol, 2000, 2004; Lee & See, 2004; Mirchi et al., 2015; Nijhuis et al., 1999; Parasuraman, Duley, & Smoker, 1998; Thompson & Bailey, 2000). A recent study explored air traffic controllers' (ATCO) experience of current ATM systems and focused on teamwork between humans and automation (Svensson et al., 2021). However, few studies have addressed the ATCOs' fears and anticipations regarding the increase of automation in operational settings. This study presents ATCOs' expectations regarding automation, safety, situation awareness, and workload, explored through a questionnaire and workshops with operational ATCOs in Sweden.

BACKGROUND

A previous survey study showed that ATCOs believed that automation would increase in the future, that situation awareness (SA) and safety would decrease, and that workload will stay at the same level in the future compared with today (Svensson et al., 2021). Introducing automation that intrudes on the core tasks of maintaining SA (Endsley, 1995; Stanton, Salmon, Walker, Salas, & Hancock, 2017) and decision-making for ATCOs (Eurocontrol, 1996) changes the ATCO's role fundamentally. It can be difficult for many ATCOs to accept new automation concepts, even more so if the ATCOs cannot see its possible benefits (Eurocontrol, 2004). Experience has taught operators to be cautious (Hopkin & Wise, 1996). Hence, they can be reluctant to resign responsibility for decision-making or control to the automation (Hilburn, 2000). ATCOs may accept advisory automation, but only as long as the ATCO makes the decisions (Hilburn, 2000). Svensson et al. (2021) and Bekier, Molesworth, and Williamson (2011) found through survey studies that few respondents approved of a tool that involved shifting decision-making away from the operator. However, ATCOs can agree on automated tools that assist in organizing materials for decision-making (Bekier et al., 2011). Studies have shown that ATCOs also feared that future automation within ATM will include more monitoring tasks (Svensson et al., 2021) and, thereby, greater risks of fatigue (May & Baldwin, 2009) and mistakes when taking control if the automation fails (Hilburn, 2000). Thus, the willingness to accept automation appears to be task-dependent and dependent on the purpose of the automation (Bekier et al., 2011).

The present study explores ATCOs' fears and anticipations towards automation, what they think will happen in the future regarding automation, safety, SA, and workload, and positive and negative aspects of automation. By investigating ATCOs' experiences and expectations, automation could be developed to support the need of the ATCO and implemented in an acceptable and usable way.

METHOD

An online questionnaire was distributed through ATM managers to operational ATCOs in Sweden, including ATC sites such as area control, approach control, and tower control. The questionnaire was voluntary and could be done during work hours. A total of $n = 113$ licensed ATCOs (68 male and 41 female, 4 choose not to disclose gender) responded to the online questionnaire. The respondents' mean experience was $M = 20.9$ years (SD = 7.6), ranging between 2 and 35 years. Age was divided into four groups: 30 years old or younger ($n = 1$), between 30 and 39 years ($n = 21$), between 40 and 49 years ($n = 51$), and 50 years or older ($n = 40$).

The questionnaire was developed explicitly for this study and consisted of 50 questions and statements split into four sections. The questions asked about ATCOs' experiences and expectations of current and future ATM systems, teamwork between the ATCO and current and future automated systems, and demography. Likert scales (Fink, 2013) ranging from 1 = 'very low' or 'very much disagree' to 5 = 'very high' or 'very much agree' were used and free-text sections. Respondents were free to move back and forth between questionnaire sections and change their responses.

To discuss the results from the questionnaire study and ask follow-up questions on a qualitative level, semi-structured group interview workshops with operational ATCOs were conducted. Nine workshops were held, with three to five ATCOs in each workshop; a total of $n = 35$ operational ATCOs participated in the workshops. The work experience of the participants in the workshop varied from 1 year to 25 years and a mix of male ($n = 16$) and female ($n = 19$) participants. The outcome of the workshops and the free-text answers from the questionnaire were analysed with a thematic analysis (Creswell, 2009).

RESULTS

Even though the questionnaire consisted of 50 questions and statements, for this paper, the teamwork questions from the questionnaire are not quantitative analysed and reported. Instead, this paper focuses on automation, safety, situation awareness, and workload from the questionnaire and the workshops. Quotations from the respondents in the questionnaire and workshops, translated from Swedish, are given as illustrations.

Quantitative results: For statistical analysis, SPSS Statistics Version 26 (IBM Cooperation, USA) was used. Paired-samples *t*-test were carried out to investigate the difference between participants' experiences of current ATM system and expectations for future ATM systems. The results show significantly differences between current and future automation amount, ($t(112) = -10.31$, $p < .001$), safety ($t(112) = 11.82$, $p < .001$), situation awareness ($t(112) = -16.31$, $p < .001$), and workload ($t(112) = -4.86$, $p < .001$). See figure 1.

Qualitative results: Responses from the questionnaire and workshops indicate that the ATCOs think there are many positive aspects of automation in ATC. For example, the respondents from both the questionnaire and

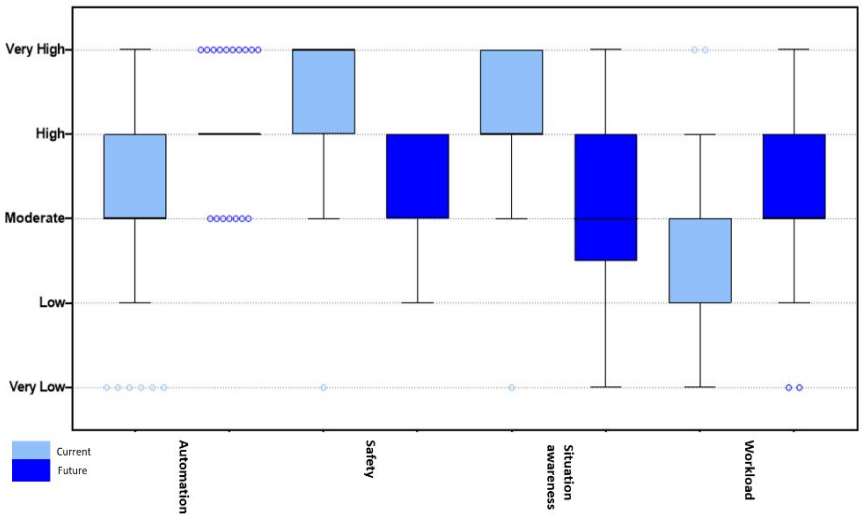

Figure 1: Compared with today, the participants believed that the grade of automation will be higher, that safety and SA will decrease, and that workload will increase in the future. Error bars indicate standard deviation, and dots represent outliers.

the workshops mentioned tools such as MTCD (medium-term conflict detection) and STCA (short-term conflict alert) as assisting the ATCO in detecting conflicts, contributing to the ATCO saving time for other tasks, and enhancing safety. In addition, existing automation (e.g., conflict detection tools and communication tools) makes the work a little more efficient for the ATCO and, hence, lowers the ATCO's workload. One response from the questionnaire: "*In most parts very positive. Makes the total workload lower compared to less automation but with the same amount of traffic*." According to the responses, automation also removes monotonous tasks such as basic communication tasks, in today's system performed by the technical system instead of the ATCO. The ATCO can also handle a higher capacity and a more extensive traffic volume with more automated tools. One response from the questionnaire: "*Today's tools are not too advanced and often simpler automation. This makes it relatively easy to use and does not interfere with the work in position. The tools we have today are supportive of the operator, but you are still the one who makes the final decision*". Many participants saw automation as a safety net, and that the system hinders the ATCO from making errors. One response from the questionnaire: "*Creating more time for the most important things, to control flights and flight safety*". Several participants requested an automated tool to assist them with inbound clearance (for en-route sectors), which takes unnecessary time and capacity from the ATCO and needs to be done for every inbound aircraft. One response from the questionnaire: "*I would like to be able to focus on more complex tasks and letting the system handle routine stuff, like giving inbound clearance*".

Even though the participants believed there are many benefits with automation, they also thought there are (and will be) many issues with it as well. During the workshops, many participants were sceptical towards more

automation and believed that automation often failed them in their current work. One response from the workshops: "*It seems to work, but in reality, we make it work*", meaning that even though the automation is there to support them, there are many malfunctions the ATCOs need to handle as well. If malfunctions occur today, there are safety procedures to follow, which also will be the case for future automation. One response from the questionnaire: "*When it comes to CPDLC (controller pilot datalink communication), it could be more reliable. Sometimes it works, sometimes it does not*." Many participants also believed that today's conflict detection tools are helpful but not always trustable. The participants in the workshops discussed that false alerts sometimes are so frequent that they "numb" the ATCOs in reacting to the warnings. Another aspect that the participants highlighted is that they could trust the system too much. One response from the questionnaire: "*Easy to get 'blind' and trust the systems too much*." In addition, the ATCO often double-checks information provided from the system, increasing the workload, which was also a fear for future automated systems. However, the participants found it concerning to increase traffic volumes along with complex automation. This is due to today's complexity of closing down sectors and moving traffic, especially if SA is decreased (figure 1) due to automation taking many tasks. Decreased SA was one of the major concerns regarding implementing more automation, seen in both the quantitative and qualitative results. One response from the questionnaire: "*I don't think we are there just yet, but we might lose control and situational awareness with more automation*." Decreased SA might jeopardize the ATCO's ability to stay in the loop, control the situation, take control from the system if necessary, and, thus, contribute to a decreased safety level.

There was a big concern about what would happen if the automation would, for any reason, fail. Can the ATCO handle a transition after a sudden or unexpected degradation of automation level, or when the automation completely stops working? According to the quantitative results, the participants believed workload will increase in the future compared with today due to increased automation that is imperfect. If automation is introduced and used more frequently, the participants stated that they need to know that it works in all situations. The ATCOs need to understand when and why the automation might degrade in automation level and know that they can handle the situation without the automation. There were many concerns regarding increasing the amount of automation; for example, one response from the questionnaire: "*Balancing the amount of automation so that the controller still remains in the loop*". Keeping the human operator in the loop is essential to maintain safety when the levels of automation increase. According to the participants, this will require more training, education, and information about the automation that will be implemented.

CONCLUSION

Some of the major reasons for introducing higher automation levels in ATC are to increase capacity, cost efficiency, and safety. Automation is introduced

as a safety net support to improve safety performance. However, if the automation fails, the ATCO is supposed to take control of the situation (e.g., with a higher and more complex traffic volume than today), making the ATCO a backup system to the automation, something the participants from this study and previous studies (Svensson et al., 2021) fear. The results also indicate a concern regarding the expected increase of workload and automation in the future, while safety and SA are expected to decrease. However, balancing workload and automation is difficult in today's ATC environments due to automation, e.g., MTCD, giving "false alerts" (due to parameter settings in the system that cannot be changed easily). These results align with previous results (Svensson, 2014, 2015). In addition, according to the results, trust towards automation should be well-calibrated since it can easily be eroded due to automation failures. The ATCOs should be involved in all early stages of automation development, from idea development based on previous research and experience to discussion groups, workshops, development prototypes, etc. This is particularly important when the automation can malfunction, and the ATCO needs to be the backup system. The expectations highlighted from this study must be understood and managed through change management, communication, and dialogues between research, development, and end-users. The ATCO needs to know the benefits of the automation, how it works, why it performs in specific ways, why it malfunctions, and what happens when it does. This calls for better integration of human capabilities and transparency of the system functionalities. Extensive automation training is necessary for the ATCO to keep safety at a high level. In addition, follow-up studies with updated questionnaires are important to capture existing concerns, fears, and anticipations amongst the end-users (in this case ATCOs).

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