2011

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Increased utilisation of automation is seen as a potential, if not the most likely solution to cope with the forecasted increase in air traffic (SESAR, 2006; FAA, 2010). However, Air Traffic Controller Operators (ATCOs) are very selective about forms of automated assistance (EUROCONTROL, 2000). Automation acceptance is considered crucial for the successful implementation of any new technology within air traffic management and therefore is one of the largest challenges the industry faces (Hilburn & Flynn, 2001). Since traditional predictors of automation acceptance such as trust and job satisfaction appear to be diminishing (Bekier, Molesworth & Williamson, in press), the main aim of the present research was to identify the factors that help to explain ATCOs willingness to accept more mature forms of automated assistance. The results revealed that ATCOs value automation that is user-friendly, removes ‘boring’ and ‘standardized’ tasks, and importantly keeps them cognitively challenged in their role.

Air service providers are under pressure to modernisation their Air Traffic Management (ATM) systems in order to deliver the required capacity gains for the forecasted increase in air traffic movements. While it has been acknowledged that this is long overdue (Metzger, 2001), how exactly it is to occur remains a contentious issue. According to Parasuraman and Rovira (2010), one solution is to reduce the size of the traffic sectors controllers are required to manage. However this has a potential negative flow-on effect for the controller in terms of understanding the scheme of traffic and its relationship to the adjoining sectors. Metzger and Parasuraman (2005) propose an alternate which involves sharing the decision-making responsibility between pilots and air traffic controllers. In contrast, Odoni (1999) believes a congestion-based pricing would be the most effective means of delivering the required capacity gains, through a better distribution of the traffic movements. Hilburn (1996) sees technology in the form of automation as a solution to the problem. Specifically, Hilburn contends that efficiency gains are best achieved through increasing the role of automation within the system. It is the latter of these suggestions that appears to have received the most attention (Kirwan, 2001; Agogino & Tumer, 2009), simply because it is viewed that automation currently employed in many Air Traffic Management (ATM) systems is underutilized.

The utilization of automation in many present ATM systems focuses largely on low level cognitive tasks such as data gathering and storage, data compilation, the computation and presentation of summaries of data, the retrieval and updating of data, as well as data synthesis (Hopkin, 1999). However, it is envisaged with the proposed increase in automation utilization (SESAR, 2006; FAA, 2010) tasks other than those involving low level cognition will be considered (e.g., decision-making). Key to the success of these changes is air traffic controllers’ acceptance or willingness to use any increase in automated technology.

According to EUROCONTROL, (2000) air traffic controllers as a whole are very selective about forms of computer assistance. History is littered with examples where users’ reluctance to embrace new technological advances have seen the implementation of a new system or tool fail. In a simulated study with unmanned air vehicles and various levels of automated decision-aids, Ruff and colleagues found that as the accuracy of the decision-aid decreased and users detected the errors produced, acceptance of the system, in terms of trust dramatically decreased (Ruff, Narayanan, & Draper, 2002). This study also found that as the level of automation increased, performance deteriorated. Similar results have been identified elsewhere (Wickens, Mavor, & McGee, 1997;

Wiener, 1988). For designers of automation, these results are the opposite of what they intended to achieve. According to Ruff et al., (2002) automation does more than replace the task performed by the human; it changes the operational function requirement and as a result often imposes a greater level of demand on the operator. For the end user, this adds to their level of scepticism regarding any new implementation of technology. Nonetheless, since increased utilisation of automation is seen as a viable option to facilitate the forecasted increase of traffic within ATM, the present study sought to determine what factors predict user acceptance within this domain.

Previous research has demonstrated that trust in automation (automated system continually performing its duties; Muir & Moray, 1996; Lee & See, 2003) and job satisfaction – both past and present (Hopkins, 1991; Lee, Rhee, & Dunham, 2009) are significant predictors of automation acceptance. Within air traffic management, Bekier and colleagues have found similar results, in addition to a number of other factors such as age and automation experience (Bekier, Molesworth & Williamson, in press). However, the variance in automation acceptance accounted for by these variables was very low. Therefore, future work is needed to examine other factors that predict automation acceptance. Hence, the main aim of the present study was to investigate the predictors of automation acceptance with air traffic controller operators. Specifically, the research sought to answer the following question.

Research Question

If the traditional predictors of automation acceptance such as trust and job satisfaction explain only a small portion of air traffic controllers' willingness to accept/use automated technology, what other factors account for the variation across controllers?

Method

Participants

20 (16 males) professional air traffic control operators from one centrally located air navigation service provider volunteered for the research. The mean age of participants was 37.70 (SD = 8.36) years. On average the participants had been working as an air traffic controller for 15.4 (SD = 8.07) years. All procedures in this study were approved in advance by the University of New South Wales ethics panel.

Apparatus and Stimuli

Two questionnaires comprised the material, namely a demographics question (e.g., age, gender, experience) and an air traffic control questionnaire. The air traffic control questionnaire consisted of six 'open-ended' questions. The questionnaire was divided into three parts. The first part contained two questions which were specifically designed to examine the tasks and/or components of an ATCOs' role they considered to be most motivating and important in their daily ATC work. Specifically question one read '*Which tasks or aspect of your daily ATC work are the most motivating for you? Give examples of these which you rate positively and negatively*'. Question two read *'what would you describe as the most important task in your role as an ATCO and why?'*

The second part of the questionnaire was designed to determine which existing ATM tools are presently used and ATCOs' view on the characteristics of these tools, both positive and negative. Specifically question three read '*Of all the support tools at your disposal, which features do you rate the most positive and why?'* Question four was similar to question three except it was concerned with which features ATCOs did not like. It read '*Of all the support tools at your disposal, which features do you rate the most negative and why?'*

The third part of the questionnaire was designed to elicit the characteristics of an ideal futuristic support tool, as seen by the ATCO and to obtain insight into the views of ATCOs about the limitations and capabilities of ATM automation. Hence, question five read *'If an automated system was to be introduced in your role, hence to assist you – what design features would you insist on?'*

The final question (question six) read ‘*Do you believe that the core ATC tasks (as stated in response to question 2) can today be performed by automation in a way that is superior to human performance?’*

A tape recorder (Sony IC Recorder, ICD-8500) was used to record all interviews.

Procedure

One central European based air navigation service provider was selected for the research primarily because of the automation-supported environment of its operations and the availability of different ATCO groups (ACC, APP/DEP, TWR) on location. An email providing background information of the research was sent to the workforce of the air navigation service provider seeking voluntary participation in the research. Potential participants expressed interest in the research through email where they were provided additional information in the form of an information sheet. Upon confirmation to assist with the research, a mutually suitable time was arranged to conduct the research/interview. All the interviews were recorded and on average each interview took 30 minutes. At the conclusion of the research participants were thanked for their time.

Results

Data Reduction

In order to analyze participants’ responses to Part 2 and 3 of the questionnaire, the data were grouped into common categories. In total, three categories were formed and were titled: User-Friendliness, Functionality and Quality. These categories were created based on a word or phrase used by participants, which were attributed to the object under examination (i.e., adjectives). Definitions for the following categories were:

- User-friendliness **-** refers to the design of the machine/user interface and its impact on human performance (e.g. ergonomic, easy to use, and well arranged).
- Functionality – refers to the quality of being suited to serve a purpose (e.g. supportive, facilitating work and useless).
- Quality – refers to the degree of excellence including output of the software and future use (e.g. robust, missing accuracy and producing false alarms).

Following this and to ensure reliability of coding, two industry specialists were asked to code the data independently. In total, 52 independent words or phrases were identified and coded. Agreement rate amongst the three raters was 96%.

Questionnaire

The responses to the six questions were summarized and are described below. Remember the format of the study involved open-ended questions with the objective of obtaining as much information as possible from the viewpoint of the ATCO. This often resulted in the ATCOs providing more than one response to each question. As a result, the below summary includes all responses presented as a percentage. Total responses to each question are reported at the conclusion of each summary.

Part 1 – Motivating in present role. In response to the first question, the majority of the ATCOs mentioned at least one task or component/function of their role which they rated positively in their daily ATC work. In this context, radar and related work was reported to be the most motivating aspect of the daily work (38.5%), with ‘radar work’ cited by 23.1% and ‘conflict detection and resolution’ cited by (15.4%). The second most frequently cited term was ‘challenge’ (23.1%), followed by ‘radio contact with pilots’ or ‘interaction with pilots’ (10.3%). Further mentioned terms were ‘teamwork’ (7.7%), ‘efficiency’ (7.7%), ‘customer service’ (5.1%) and ‘all task’ (5.1%). Safety as a holist construct was only reported once (2.5%). Total stated 39.

The most frequently cited negative aspect of ATM was ‘no traffic’ (37.5%). This was closely followed by ‘nil’ or no aspect is negative (25%). Further mentioned tasks/aspects included ‘regulations’ or ‘restrictions’ (16.7%), ‘monotonous and repetitive tasks’ (8.3%), ‘unnecessary and diverting tasks’ (8.3%) as well as ‘cooperation with military’ (4.2%). Total stated 24.

When asked what would you describe as the most important task/component in the role as an ATCO (question 2), the term ‘separation/safety’ featured highest (65.5%). This was followed by ‘efficiency’ (26.9%), ‘customer service’ (3.8%) and ‘to stay calm’ (3.8%). Total stated 26.

It appears that ATCO find their daily tasks to be motivating, particularly the ATC core tasks such as conflict detection and solution or the radio communication with the pilots. Boredom and monotony on the other hand are very much disliked. Not surprisingly safety and efficiency are seen as the most important ATC functions.

Part 2 – Characteristics of existing tools. Based on the grouping of participants’ responses into the three categories (e.g., user-friendliness, functionality and quality), the majority (58.1%) of responses related to the positive experiences with automation based on the ‘functionality’ of the automation (e.g., practical, supportive) followed by its ‘user-friendliness’ (37.2%; e.g., usable, ergonomic). The remaining (4.7%) responses related to ‘quality’ aspects of the automation such as reliable and fast. Total stated 43.

When asked about the negative features of support tools at their disposal, ‘user-friendliness’ rated highest (45.1%) followed by ‘functionality’ (35.5%) and ‘quality’ (19.4%). Total stated 31.

Part 3 – Ideal futuristic tool. In relation to participants’ responses to the hypothetical question regarding the design features they would insist on with a new automated system, 24 terms were used. Interestingly 52.9% of these related to ‘user-friendliness’ such as ‘easy to use’ or ‘ergonomic’, followed equally by ‘quality’ (25.5%) and ‘functionality’ (21.5%). Total stated 51.

Finally, ATCOs were provided the opportunity to reflect on whether advanced technology could perform the core tasks they personally indentified in the role. The participants responded unanimously on this question with all answering in the negative. In other words, 100% of participants felt that the core ATC tasks could not be performed by automation in a way superior to the human. The limitations to this question are discussed below.

Discussion

Increased utilization of automation within the ATM system is seen as a real and viable solution to the forecasted increase in air traffic movements (FAA, 2010; SESAR 2006). Crucial to the success of such a change is operators’ acceptance of the automation. Since traditional predictors of automation acceptance such as trust and job satisfaction explain only a small portion of user acceptance (Bekier et al., in press), the aim of the present study was to investigate the main drivers that may better account for this acceptance. The results from part 1 of the study revealed that the core-task of conflict detection and resolution is liked and motivating for ATCOs. Similarly, it was clear that ATCOs dislike the monotony aspects of their tasks. This was most evident by the high citations rate of terms such as ‘no traffic’, ‘boredom’ and ‘monotonous and repetitive tasks’. It is noteworthy that a quarter of all the participants were unable to report a ‘negative (most)’ aspect of their work, which can be a good indication that overall ATCOs enjoy their daily tasks, as they exist today. By extension, this may translate into a reluctance to support fundamental changes such as an increase in automation in their work environment. This conclusion is supported by existing literature (Hopkin, 1995; Eurocontrol, 2000) that describes ATCOs as ‘conservative’ and ‘selective’ about forms of computer assistance. In the context of automation implementation, these results suggest that from an end users’ (ATCO) point of view it is probably easier to automate non-core tasks such as ‘flight data management and standardized coordination’s’ and/or ‘hand-offs’ rather than core tasks such as ‘conflict resolution’, since it is precisely these tasks that ATCOs find most motivating and key drivers.

The results from part 2 of the questionnaire that was concerned with the benefits and shortcomings of existing automation and the expectations towards future automation revealed a consistent theme across all three questions. Specifically, 'user-friendliness'- referring to the design of the machine/user interface and its impact on the human performance featured highly in participants' response in all questions (37.2%, 45.1% and 52.9% respectively). A similar, although not as prominent trend was evident (58.1%, 35.5% and 21.5% respectively) with 'functionality' - quality of being suited to serve a purpose. In contrast, quality – the degree of excellence including output of the software and future use featured the least across two questions (4.7%, 19.4% and 25.5% respectively).

When asked about the positive aspects of today's automation, 'functionality' featured highest (58.1%) followed by 'user-friendliness' (37.2%) and 'quality' (4.7%). However, when asked why automation is not liked, the distinction between 'functionality' and 'quality' is less, 35.5% and 19.4% respectively, while 'user-friendliness' increased to 45.1%. When questioned about expectations towards future ATM automation, both 'functionality' and 'quality' were of almost equal importance, while 'user-friendliness remained relatively the same. In other words, existing ATM automation is 'liked' because it is intuitive to use and suited to the purpose. In this sense, it appears that software stability, reliability and accuracy are almost taken for granted. However, when existing automation is not liked, it is predominately due to its lack of lack of user-friendliness (45.1%) and to a lesser degree because of its functionality or quality. This distribution is similar with future automation that is expected to be user-friendly and to a lesser but equally similar degree functional and quality. To put it simple, ATCO enjoy automation because it supports them to do their task and is easy to use, hence allowing them to focus on their core task/s. However, where automation is not liked it is mainly because it is not user-friendly and the handling of the automation is distractive from executing their core tasks.

Limitations and Future Research

The results from the present study need to be interpreted within the context of the research. Specifically, the present study surveyed 20 ATCOs. Due to this relatively small number of participants, caution should be taken to ensure the appropriate weight is applied to the percentages discussed. A caveat should also be noted with the sample. Specifically, participants were all recruited from one air navigation provider, albeit a large and prominent provider. Finally, it could be argued that the results from question six are somewhat expected due to the leading nature of the question. This being the case, future research should focus on investigating if this scepticism surrounding automated technology performing controllers' core task is as prominent as reported in this study.

Conclusion

In summary, the results from the present study suggest that if air navigation service providers are planning to increase the use of automation within the ATM system, they need to choose carefully the tasks they elect to automate if they wish to obtain user support. In addition, they need to ensure that the automation is well designed from a usability perspective as well from a reliability perspective, although the latter appears to occur already. Importantly, any new automation should ensure the ATCOs are cognitively engaged in the task, hence sufficiently challenged in their role. Most importantly, ATCOs would like to see new automation remove the 'boring' and 'standardized' tasks in their role, thereby allowing them to focus on the core task of radar work namely conflict detection and resolution.

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