

Evaluation of Levels of Automation for Non-Normal Event Resolution

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ABSTRACT

Increasing the automation in a flight deck has not always led to benefits to the pilot; instead it is often found that inappropriate implementation of automation can cause a variety of issues including loss of situation awareness, poorer performance, and a perceived increase in workload. It is important to determine in what context a pilot might benefit the most from the inclusion of automation and then to determine the appropriate level at which that automation is implemented.

The objective of this study was to evaluate what level of automation is most appropriate for supporting the pilots in the performance of non-normal event resolution tasks. Pilots were given a series of scenarios where the level of automation for performing tasks was varied from no automation to full automation. A related objective was to determine whether the use of a voice interface is effective in providing sufficient feedback to support the pilots' situation awareness. In the scenarios, the number of computer-generated voice messages was varied to provide more or less information about the automation's performance.

Subjective workload ratings indicated a solid trend for lower workload ratings for those conditions where the pilot had significant support from automation (i.e. when automation performed the tasks). When given the opportunity to design the automation for themselves, almost all pilots specified that the automation should perform the tasks. The pilots also requested to keep the voice messages for some, if not all, tasks and were evenly split over whether the automation should request permission or not before performing the tasks. The results of this research suggest that in order for increased automation to be an effective aid to the pilot, it needs to be

implemented in such a way that the pilot has insight into, and some degree of control over, the system's actions.

INTRODUCTION

Non-normal events are those situations where a system or operating context is functioning outside normal parameters and can potentially impact safe flight operations. They are accompanied by a set of risks including high workload and time pressure which can have a negative effect on working memory and higher cognitive functions¹. Typically, these issues have been addressed by providing the pilots with non-normal checklists (paper and/or electronic) which outline the tasks needed to be performed in order to correct or compensate for a system malfunction². By referring to a checklist to determine what tasks are needed to be performed, the pilots are not necessarily required to recall information from memory or to perform complex problem-solving or trouble-shooting in order to determine what to do about the situation.

However there are a few circumstances that require the pilots to perform actions from memory in a time-critical manner. For example, when an engine fire is suspected, pilots are trained to perform the first five steps of the associated non-normal checklist from memory (so-called "memory items") before referring to the physical checklist.

In this and similar scenarios involving challenge-response checklists, both pilots work together to perform the checklist items with one pilot initiating the tasks and the other pilot confirming or verifying them³. While this allows the pilots to share the workload as well as provides an error-trapping function, it also potentially takes the attention of both pilots off of other important responsibilities, such as monitoring other flight systems and performing aviating and navigating

tasks. Furthermore, a recent review⁴ of accidents related to checklists and monitoring failures indicates that these checklist techniques still have some vulnerabilities.

One way to mitigate these issues is to use automation to help manage pilot workload in resolving non-normal events. Potential benefits of introducing automation into the resolution process include increased consistency of task performance, reducing overall pilot workload, and freeing one or both of the pilots to deal with other responsibilities. However, it is particularly important to consider how automation can be introduced to reduce the safety challenges of an emergency situation without introducing new challenges due to the nature of the automation itself⁵.

As automation is increasingly implemented on flight decks, pilots find that it offers benefits (relieving them of various formerly time-consuming manual and/or cognitive tasks) but also introduces a wide range of potential problems. A review of the literature⁵ shows that automation, when it is not carefully designed, can lead to confusion about its functions and a perception of increased workload as pilots try to compensate for that confusion by second-guessing or working around or against the automation. Mode control issues are a commonly cited example of where automation obscures the inner workings of the system and leaves the pilots to guess what is happening⁶.

Another potentially risky impact of automation is that it can foster complacency^{7,8}, resulting in a loss of vigilance as well as situation awareness. Too much trust in the automation leads to slower reactions if the automation fails, and loss of situation awareness could result in incomplete understanding of the situation.

Finally, automation effectively removes pilots from their previously close relationship with the aircraft systems and subsystems and, especially in situations where little or no feedback is available to the pilots, can result in the pilot being out of the loop and lacking system knowledge^{9,10}. A loss of system knowledge is particularly problematic if the pilots are trying to figure out why a system has failed or what effects that system failure may have on other related systems.

These three risk factors of increased workload, decreased situation awareness, and loss of system knowledge can significantly impair the level of safety in the flight deck in general, and may be exacerbated should a non-normal, or emergency, situation arise. Non-normal situations, therefore, provide an excellent context for investigating an effective way to implement automation to better support the pilots during their resolution activities.

Research^{5,10} suggests that workload was reduced, and situation awareness improved, when automation was applied to the implementation of actions (compared to automating higher-level functions). For this study, the memory-item tasks involved in resolving the non-normal situation were automated to varying degrees (from no automated tasks to all automated tasks). This was expected to relieve the pilot of the effort of task recall as well as the physical procedures of performing the tasks and result in lower perceived workload.

To address the feedback issue, the literature^{7,11} supports the use of a technique of “callouts” or verbalizing information about the state of the systems and the automation. In this study, verbal information was provided in the form of a simulated voice interface which provided a varying number of voice messages reporting the automation's behavior (from minimal callouts to callouts for every action and state change). It was expected that pilots would prefer more callouts in those scenarios that involved more automated tasks.

METHODS

PARTICIPANTS

Ten experienced test and engineering pilots were recruited for this study. The average age of the pilots was 48.6 yrs (range of 34 - 66), and average total flight hours was 7935 (range of 3,700 to 17,000).

APPARATUS

A medium-fidelity, 787-style virtual flight deck was presented on several 24" diagonal monitors, and provided pilots with sufficient instrumentation for the approach tasks. Virtual throttles and engine fire controls were simulated on a touch-screen display located in the center console area. The out-the-window view was projected on a large curved screen mounted approximately nine feet in front of the simulator. Pilots manually controlled the flight using a Precision Flight Controls yoke and column system. The automated non-normal event responses were simulated by a confederate seated at a remote console. The voice messages were pre-recorded in a computer-generated female voice (Cepstral software, standard American accent) for consistency across subjects.

SCENARIOS

This study consisted of six experimental trials. In each scenario, pilots were to perform the first five memory items of the Engine Fire non-normal checklist. The experimenter described the level of automation and type of interaction that the pilot would be presented with before each trial began. The scenarios were presented in quasi-random order from five “scripts” representing different levels of automation. The scripts specified whether the pilot or the automation would