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SUMMARY

The need for sustainable aviation has accelerated the development of electric aircraft and propulsion systems. These systems generate less noise when compared to conventional piston engines (Moshov & Toropylina, 2022) and in the event of a failure provide limited cues to the pilot. If pilots fail to recognise the situation and take prompt recovery action, powerplant failure is often followed by an aerodynamic stall and loss of control in flight (Smith & Bromfield, 2022). The aim of this research is to investigate the effects of multimodal presentation of the propulsion system status to improve pilot response times in the event of an electric propulsion systems failure. A human centred design approach was used to develop multimodal presentation of data using visual, auditory and visual/auditory feedback in combination. Simulated flights were conducted in a fixed-base flight simulator with control and experimental groups of student pilots (n=8). Results indicate that pilot response times are reduced when using a combination of visual/auditory presentation.

KEYWORDS

Electric Aircraft, Multimodal Presentation, Response Time, Workload, Propulsion System Usability

Introduction

Safety is paramount in aviation and the presentation of essential, contextual information for the management of an electric or hybrid aircraft's propulsion system is relatively new. The aim of this research is to investigate the effects of multimodal presentation of the propulsion system status to improve pilot response times in the event of an electric propulsion systems failure. The objectives of this research are to design multimodal presentation of essential data to enhance detection of engine failure, to reduce the workload of a pilot during emergencies and to determine the usability of different information presentations. This will inform future design of propulsion system monitoring and alerting systems for use in electric aircraft.

Methodology

Auditory presentation (A) was developed using a sound effects engine comprising a tone sinewave for sonification (Kramer, et al., 1999) with frequency proportional to the aircraft propulsion system revolutions per minute (RPM). A separate sound file, featuring a female voice aural alert annunciating "Engine failure" was created for engine failure events. The visual presentation (V) used a simulated Head Up Display (HUD), created using a game engine, and was positioned to the left of the pilot's forward field-of-view in the cockpit on the central visuals display of the simulator. A red warning cross ("X") with the caption "Engine Failure" was also presented during an engine failure. The multimodal presentation (VA) was the combination of the visual (V) and auditory (A) presentations, in addition to the conventional cockpit instrument displays (N). A fixed-base engineering flight simulator was used to simulate flights and propulsion system failures. Eight student pilots (mean age: 20.6, mean real aircraft flying hours: 11.5) were divided equally into control and experimental groups. A between-groups experimental mixed design was used with participants performing four simulated flight scenarios (normal take-off, normal approach, take-off with engine failure, glide approach (base to finals with engine failure), with presentation (experimental group) or without presentation (control group). To avoid learning effects, the scenario sequence was pseudo-randomised and balanced for each group. Engine failure was also pseudo-randomised and manually triggered using the Flight Instructor/Operator Station at approximately 400 ft above ground level (AGL) for take-off and 750 ft AGL for the approach. Participants were instructed to press a button on the control yoke in the event of an engine failure, enabling response times to be captured. System usability was assesses using the System Usability Scale (Brooke, 1996) and workload using NASA-TLX (Hart & Staveland, 1988) after completion of each scenario.

Preliminary Results Analysis and Discussion

Preliminary results comparing Control vs Experimental Groups showed that, during take-off with engine failure, multimodal presentation (VA) response times were 1.27s faster than no presentation (N) response times. For the glide approach, multimodal presentation (VA) response times were 1.29s faster than no presentation (N). The multimodal (VA) results are consistent with previous research findings of Spence & Santangelo (Spence & Santangelo, 2007), where response times during high perceived load were improved using audio-visual cueing Some participants commented that they used RPM sonification and the aural alert, as their primary source of information on system status. Some participants primarily used the appearance of the red cross as an indication of propulsion system failure. Visual presentation (V) ranked the highest for usability, however this may have been influenced by participants' preferred feedback styles (Chui, et al., 2020). SUS is normally used for the assessment of display design, using terminology more associated with displays and this may have also influenced feedback. During system failures, a minority of participants, were (task) fixated on establishing the appropriate glide speed and this delayed pressing the confirmation button or in one case forgetting to press the button at all.

Conclusions

Preliminary results with respect to response times for different presentation are encouraging. Subjective feedback regarding multimodal (VA) presentation was positive. Further analysis of the simulated flight data (including pilot control inputs) is needed to investigate response times more comprehensively. The experiment will be repeated with more participants, results consolidated and a full statistical analysis completed on all measures. This research will inform human-centred, future electric aircraft cockpit and HUD design. It has the potential to contribute to the prevention of loss of control in-flight accidents for electric/hybrid propulsion due to system failure.

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