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Understanding Student Pilot Mental Workload in Recreational Aircraft Training

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Abstract**—**The increase in air travel worldwide has resulted in a pilot shortage. To increase student pilot capacity and lower costs, flight schools have increased the use of recreational aircraft (RA) with technological advanced cockpits in flight schools. The impact of RA based training compared to general aviation (GA) aircraft training on student mental workload is not well understood. This research investigated student pilot (N = 17) awareness of mental workload between technologically advanced cockpit equipped RA training with analogue gauge equipped GA training. The results showed a significantly higher rating of mental workload across subscales of mental and physical demand on the NASA-TLX in recreational aviation aircraft training compared to GA aircraft. Similarly, thematic content analysis of follow-up questions identified that mental workload of the student pilots flying the RA was perceived to be more than the GA aircraft.

Keywords**—**Glass cockpit, flight training, mental workload, student pilot.

I. Introduction

ACCESS to affordable flights has led to an increase in air travel across the globe. This has resulted in the aviation industry being on the cusp of history's largest increase in air travel worldwide. Air travel is predicted to grow at an unprecedented rate of 5.8% a year over the next 20 years and by 2038 will require 645,000 new commercial airline pilots worldwide [1], [8]. To meet the demands of growth and to lower training costs, flight training schools have increased the use of RA to train new pilots. RA aircraft are smaller, lighter (under 600 kilograms), and frequently built with advanced materials to lower weight and improve performance. The operating and fuel costs of operating RA aircraft can be up to 60% less than GA aircraft with most RA aircraft having option of technological advanced cockpits referred to as 'glass cockpits.

The training the student pilot receives on one system may be ineffective or unsafe when used with other manufacturer's system [17]. The configuration differences result in an interface that is presented in a different format with multi-layers of information. The new technology interface of the glass cockpit in light aircraft has created unfamiliar and distinct human factors challenges [11], [13], [16].

In comparison, analogue gauge aircraft have remained consistent in both design and operation across the developmental stages of engineering within aviation. The standard design is typically focused on the six basic instruments. The standardization of instruments has the effect of making all analogue cockpit training relative to safe operation in most aircraft. This continuity enables training and knowledge transfer to different types of analogue aircraft. However, the differences between aircrafts in cockpit configuration and design can impact the mental workload of the pilot, and their awareness within flight [5], [22]. Research suggests that high mental workload and high stress levels are responsible for over half of flying incidents and accidents [20]. Aviation's number one priority is safety therefore it is important to explore the impact of flight training on safe flight operations [10], [19]. Currently, to our knowledge, little attention has been devoted to the perceived mental workload of trainee pilots during their flight training in different aircraft cockpit configurations.

II. Mental Workload

Mental workload is recognized as a critical component to human-machine interface success, and a significant factor of operations design and practice [7]. Measurements of mental workload are an estimation of the effort required to perform a task or a sequence of tasks based on an individual's perception and judgement. An increase in mental workload could result in high levels of cognitive and emotional processing that exceeds the capability of the pilot resulting in an inability to work efficiently, complete tasks, manage systems, and loss of situational awareness and ultimately affect the safe operation of the aircraft.

Research in military and civilian transport aircraft has shown that differences in cockpit configuration relate to differences in mental workload and may negatively affect the operation of the aircraft [14]. National Aeronautics and Space Administration (NASA) and Casner conducted a 52 item survey to explore pilots' attitudes toward advanced cockpit systems suggesting: "pilots' beliefs and attitudes about advanced cockpit systems can sometimes be powerful determinants of pilot behavior and performance in the cockpit" [2]. Further, research into pilot perceptions of glass cockpits, assessed by survey and open response questions revealed pilots perceive glass cockpits to be stressful and may negatively impact on pilot mental workload. In particular, from the 245 male pilots and 17 female pilots who responded to the survey, there were three major areas of concern identified, stress and workload caused by learning the technology, the view that technology could improve the

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workload, and beliefs that complacency and overreliance of the glass cockpit could compromise safety especially with young pilots in training. In addition, further survey of perceptions of glass cockpit systems in pilots [11] identified a perception that glass cockpits were easy to use, glass cockpits increased situational awareness, more training was needed, and a concern of loss of flying skills by becoming too dependent on the glass cockpit systems.

For training purposes, a system that is perceived to have less mental workload for learners may enhance the learning experience of student pilots. Importantly, the improvements in cockpit displays and aircraft design are exposing novice pilots to advancements in technology that historically were only available to fighter pilots and civilian transport pilots [12], [15]. Research of 62 university students with no previous flight training experience were flown in glass and analogue cockpit non-motion simulators [22]. The results showed that the glass cockpit altimeter may have contributed to participants' fixation on one piece of information. This resulted in important information being neglected and affecting situational awareness of the participant from focusing on the display of information. The research highlighted some concerns over the amount of content and how much time is spent looking at the glass cockpit information. Kristovics et al. argue that rather than relying on intuition and proficiency as used in analogue gauge cockpit, glass cockpits require thorough, logical thought processes [12]. With the cockpit information presented in different formats, systems that may require more cognitive demand that could expose the pilot-trainee to too much mental workload and possibly overload their capacity to manage the tasks of flight training.

It is important to examine mental workload (MWL) in RA aircraft as there is limited research of MWL in RA aircraft. Studies have explored MWL in military and civilian aircraft with results showing that MWL can affect the safety of flight operations [4], [6], [14], [19], [21]. Therefore, if MWL is important in the safe operation of an aircraft, identifying the amount student pilots are experience flying RA is equally important. Given the relationship between MWL and safe flight, it is feasible to assume that identifying the amount of MWL inflight may depict a reasonable approach to determine the effectiveness of the pilot flying the aircraft. Therefore, it is important to measure trainee pilot MWL as an important part of recognizing the complexity of flight training. To ensure there is effective training for differences in cockpit displays between RA and GA aircraft on student pilot flight training, this study examined the perceived MWL of pilot-trainees in real-time flight training with analogue and glass cockpit aircraft.

III. Participants

17 novice university aviation flight course students (11 men and 6 women), with a mean age of 27.1 years (SD = 13.7) participated in the study. Student pilots were eligible if that had completed at least one hour minimum of flight training and had completed an Aviation Theory course. The training flight represents a standard training circuit of the flight training curriculum. Participants registered their interest in completing the study by contacting the researcher. No additional academic credit was given and there was no academic consequence if they did not choose to participate in the research recruitment. Participants were given a $30.00 gift voucher for food and beverage as an acknowledgement of their contribution to the research. Ethical approval was obtained from the Central Queensland University Human Research Ethics Committee and all research data were collected and stored in line with the national standards for research with human participants. The participants had limited flight experience hours (M = 24.33, SD = 21.58) prior to this study.

IV. Procedure

A. Flight Training

For each training flight, participants completed a briefing and instruction on the circuit, the NASA-TLX pre and post flight, and post-flight follow up questions. A circuit flight consists of takeoff, crosswind, downwind, base, final (landing) segments of flight (Fig. 1). Circuits are a typical path that aircraft are required to travel to avoid other air traffic at an airport and are primarily used during flight training to practice take-off and landing. Circuits also provide structure and situational awareness at airfields. The participant flew two separate flights with an instructor, one in a RA and the other in a GA registered aircraft. Participants flew with the same instructor on both RA and GA flights. After each flight, participants completed a NASA-TLX form and a post flight and follow up.

B. Aircraft

RA

RA are small light aircrafts that have a maximum weight limit of 600 kilograms, typically equipped with a small engine (80-120 horsepower/60-90 kilowatts, and many are equipped with glass cockpits. RA aircraft can be used to train recreational pilots with the ability to log some hours towards a GA pilot license [3]. The RA flight trainer used in this research is a low wing, two seat, tricycle landing gear, 2015 Sling 2. The aircraft is equipped with a MGL Avionics electronic flight instrument system (glass cockpit).

GA

GA aircrafts have a maximum take-off weight MTOW of approximately 1100 kilograms, carry four people, and have a cruise speed of 110 knots. The GA aircraft flight trainer used in this research is a 1974 Cessna 172N, a high wing, four seat, and tricycle gear aircraft flown under GA rules. The aircraft is typical age of a GA training aircraft and is equipped with the standard six analogue gauge configuration.

C. NASA-TLX

The NASA-TLX is a six subscale tool that has been widely used for the assessment of MWL completing a task for pilots [9]. This widely used tool consists of a questionnaire containing six subscales. The participants complete 6 scales: Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort, and Frustration and these scales are used to obtain an overall average workload rating. Participants indicate on a scale from 0 to 100 how much MWL they experience after completing a task. The re-test reliability coefficients indicated the NASA-TLX and Cronbach's alpha coefficient were more than 0.80, the correlation coefficients between its items score and total score were all more than 0.751 ($p < 0.01$) except the item of performance [18].

D. Post-Flight Follow Up

An interview question was used to explore the perceived most and least MWL phases of flight, namely "*what is the most amount of mental workload phase of flight?*", and "*what is the least amount of mental workload phase of flight?*".

The purpose of the interview questions was to provide additional context and feedback of the MWL perceived in-flight. The follow-up provided participants the chance to expand on the amount of MWL experienced during phases of flight and reflect on performance.

E. Design

The research study was a repeated measures mixed method design with the independent variables being the different aircraft and aircraft displays, and the dependent variable being the students MWL from both interview and scaled measurement.

F. Analyses

The data were analysed using SPSS and a series of paired sample t-tests were performed to examine whether there were significant differences between ratings given to both pre and post-flight measurements, and between each aircraft type (RA vs. GA) over each of the 6 subscales of the NASA-TLX. Only post-flight comparisons between flights are reported below. Background characteristics of the sample including age, gender and hours of flight experience were reviewed in pair sample t-tests to explore the impact on overall MWL differences between flight types. The post flight and follow up was analyzed with Leximancer®, a text analytics tool.

V. Results

A. MWL

Overall MWL showed that RA flight MWL (M = 44.1, SD = 19.8) was perceived to be significantly higher than the GA flight (M = 35.5, SD = 14.3), t (16) = 2.094, p = 0.053. Data are represented in Fig. 1.

To better understand the role of background characteristics on overall MWL, the impact of gender and flight experience were analysed.

B. Gender

For men, MWL overall scores were higher for RA aircraft (M = 48.3, SD = 18.8) than GA aircraft (M = 41.9, SD = 11.5). Similarly, for women, MWL overall scores were higher for RA when compared to flying GA aircraft, however when compared to men's scores, women scored much less overall MWL for RA aircraft (M = 33.8, SD = 24.9) and GA aircraft (M = 24.9, SD = 12.8). A one-way ANOVA for gender showed no significance in the RA flight overall ($F(1,16) = 2.789$, $p = .116$) although the GA flight overall showed significance between genders on MWL levels ($F(1,16) = 7.125$, $p = .018$).

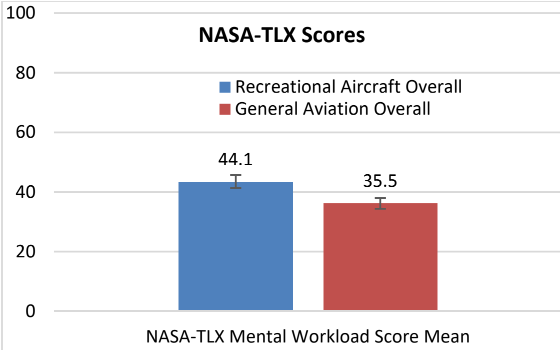

Fig. 1 NASA-TLX Overall Flight Score

C. Flight Experience

Flight experience in hours (M = 24.2, SD = 21.9) showed no significance for RA flight overall ($F(4,12) = 1.08$, $p = .518$, although the GA flight overall displayed significance between group means ($F(4,12) = 6.86$, $p = .039$. For GA flights, there was significant difference between hours of flight experience with an $F(1,15) = 9.03$), $p = .009$). The post-flight follow up questions revealed the landing as the most MWL phase of flight for both aircraft types. However, participants flying the glass cockpit equipped RA scored the landing phase of flight substantially more (72%) than the analogue gauged GA aircraft (44%) compared to the other phases of flight.

VI. Discussion

This study aimed to examine MWL levels in glass cockpit equipped RA and analogue gauge equipped GA aircraft during a circuit training flight. The overall MWL of flight training participants was higher in the RA glass-cockpit equipped aircraft when compared to the GA analogue gauge equipped aircraft. The scores of the MWL before flight were similarly low for both types of aircraft. This provided a baseline to gauge the increase in MWL. The post-flight follow up questions revealed the landing phase as the most MWL phase of flight. Over two thirds of participants identified the landing phase as the most MWL phase of flight. This compares to under half of the participants identifying the landing phase of the GA aircraft as the most MWL phase of flight.

VII. Strength and Limitations

This research measured MWL "in the field" within the flight training environment utilizing the aircraft used for flight training. It measured MWL in two aircraft types with 17 students from a university flight training program.

The main findings of this study revealed a difference in

MWL between RA and GA by student pilots. The participants scored the RA higher for overall MWL when compared to the GA aircraft during a circuit training flight. Flight experience and gender were varying factors in the amount of MWL reported. The post-flight follow up provided individual reports on MWL, cockpit configuration, and performance.

VIII. Summary and Conclusion

Student pilots perceive that MWL experiences are different between RA and GA flights training experiences. The scores of each aircraft type showed that students experience the flight training in significantly different workloads.

Further research should consider in depth investigations in to the differences of perceptions of MWL and reported MWL. Eye-movement, electro dermal (skin conductance), and heart rate could provide richer data to evaluate MWL on student pilots in various training scenarios. Instructor or third party evaluation of performance could be added to provide further interpretation of the impact the aircraft, phase of flight, and student perceptions on their performance. Future research should investigate further corroborative data to verifying the perception of MWL.

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