Safety Science 103 (2018) 280–286

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

Pilot performance comparison between electronic and paper instrument approach charts

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ARTICLE INFO

Keywords:
Electronic flight bags
NASA TLX
Workload
Flight performance
Skill degradation

ABSTRACT

Electronic flight bags (EFB's) have become common in the era of technologically advanced aircraft (TAA) and glass cockpits. However, many pilots still rely on paper charts as backups in case of electronic failures. The purpose of this study was to examine pilot performance differences when using electronic and paper instrument approach charts. Twenty-nine participants from a large university completed the study in a fixed-based flight-training device (FTD). While completing a flight between two major cities, the participants were asked to answer questions on instrument approach charts using an electronic flight bag. Halfway through the questions, the electronic flight bag was said to have failed, and participants were provided with paper charts. The findings indicate that participants' response time was significantly lower using electronic charts over paper ones. Flight performance, as observed via video footage, indicated far worse control of altitude and course when using paper charts than when electronic charts were used. In a post-test instrument, participants' poorly estimated the their average response time to questions in both conditions. Finally, participants' indicated that they felt the use of electronic charts reduced their workload as measured by the NASA TLX. The paper discusses the practical applications of these findings.

1. Introduction and review of literature

Before airplane cockpits became significantly more automated, many pilots controlled the airplane via manual inputs and calculations, which they determined using control panels and instrument displays (i.e. air speed, altitude, compass, etc.) However, as technology has advanced, many tools that pilots use have become increasingly automated, which has helped reduce workload, minimize errors, and support safer airline operations (Ebbatson, Harris, Huddlestone, & Sears, 2010; German & Rhodes, 2016). Unfortunately, a negative side effect from increasing automation in the cockpit is that pilots may become complacent and suffer from skill degradation (Farr, 1987; Waldock, 2017; Weiner & Curry, 1980;). Skill degradation typically occurs when a skill is learned or knowledge is acquired but then that skill or knowledge is not used for an extended period of time and the person either forgets the skill or takes a longer time to recall the appropriate information (Farr, 1987; Winfred, Bennett, Stanush, & McNelly, 1998). For example, pilots previously used paper charts when calculating airplane performance data, fuel calculations, etc.; however, most pilots now use electronic flight bags (EFB) as their main source of information and calculations. It may not seem like a major issue if a person takes longer to perform a task due to skill degradation; however, if that person is overestimating their performance (illusory superiority) then there could be severe consequences. For workers in a high-stakes job they should have an accurate awareness of their own capabilities so they can perform their job to the best of their ability. The purpose of this study will be to examine pilot performance differences when using electronic and paper instrument approach charts. Additionally, participants will be asked to complete the NASA TLX to estimate their workload in both conditions, and finally, pilots will estimate their response time to questions. A background is provided on electronic flight bags, skill degradation, and the theoretical foundations of this study.

1.1. Electronic flights bags

In a traditional cockpit environment, all pertinent flight information that the pilot required was found in paper charts, which helped pilots determine flight path, calculate performance data, perform fuel calculations, etc. (Fitzsimmons, 2002; U.S. Department of Transportation, 2014). However, as automation in the cockpit increased, pilots' tools

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https://doi.org/10.1016/j.ssci.2017.12.016
Received 24 June 2017; Received in revised form 24 October 2017; Accepted 13 December 2017
0925-7535/

have become more automated as well. Currently, most commercial and general aviation (GA) pilots use electronic flight bags (EFB), which can be comprised of a smartphone, tablet (most typical), laptop, etc. and helps the pilot perform flight management tasks more easily and efficiently, often with less, or no, paper (Chandra, Yeh, Riley, & Mangold, 2003; Johnstone, 2013). EFBs ensure that aircrew no longer have to fly with missing or out of date documentation and they help reduce weight and monetary costs because pilots are no longer carrying several paper charts (Fitzsimmons, 2002).

Furthermore, EFBs increase safety because they provide more accurate information such as takeoff performance information using real-time data rather than data that has been rounded to the nearest 100 kgs (typical of paper charts because it is easier for humans to make these types of calculations) (U.S. Department of Transportation, 2014; Johnstone, 2013). EFBs also allows flight crew members on the ground to receive a notification when a crew member has opened an important flight crew notice and obtain a notice that the crew member has read and understood its contents (Johnstone, 2013). Electronic flight bags are more cost effective, safer, and user-friendly; however, they do carry the potential danger of failing, crashing, and leaving the pilot scrambling to recall how to perform calculations manually. It is recommended that most pilots carry back up chargers, cords, etc. but not everyone carries back up iPads, laptops, or smartphones (U.S. Department of Transportation, 2014). Therefore, if their EFB is to completely fail, the pilot may have to rely on their own ability to manually perform these functions, and if their skills are not at a proficient level there could be severe consequences.

1.2. Sill degradation

Technological advances in the glass cockpit enables the pilot to program flight modes, including autopilot takeoff, climb, cruise, descent, and landing, all of which do not require manual control inputs (Casner, Geven, Recker, & Schooler, 2014; Young, Fanjoy, & Suckow, 2006). However, this high level of automation in the cockpit has created concern that pilots may suffer from skill degradation or loss of manual flying skills, which could have severe consequences if there is an automation failure and the pilot must respond quickly (Bridges, Neal-Smith, & Mills, 2016; Casner et al., 2014; Ebbatson et al., 2010). Skill degradation is the “loss or decay of trained or acquired skills (or knowledge) after periods of non-use” (Winfred et al., 1998, p. 58). Pilots are particularly susceptible to manual skill degradation because they learn the necessary skills in flight school but then they may never have to use those skills again (depending on the level of automation in their aircraft) (Ebbatson et al., 2010) although the U.S. Department of Transportation does encourage pilots to manually fly the aircraft when conditions permit (2017).

Skill degradation is a major issue because if there is an automation failure or an emergency, the pilot must be able to recognize, correctly diagnose, and respond to the problem in an appropriate amount of time. Unfortunately, history has shown that pilots may experience mind wandering due to cockpit automation (Smallwood & Schooler, 2006) and if their skills are not proficient, then they may not recall the appropriate solution in time. For example, in 2009, Air France Flight 447 crashed into the Atlantic Ocean because ice crystals had formed, which caused the autopilot to disconnect. The flight crew reacted incorrectly to the problem causing the plane to go into an unrecoverable stall and eventually crashing (Waldock, 2017). While pilots do receive training for emergency procedures, the opportunity to continuously practice and maintain these skills is limited due to the high amount of automation in the cockpit (Milner et al., 2017).

An earlier study (Milner et al., 2017) compared pilots’ response times when answering questions with an iPad or with a paper chart. Twenty-seven student pilots answered a series of thirty questions related to instrument approach procedures on a desktop display. The participants were allowed to use an electronic chart display (EFB) for the first fifteen questions then they had to use a paper chart for the final fifteen questions. Participants were timed on how quickly they were able to locate and identify the correct answer. Participants answered questions significantly faster with the electronic charts than with the paper charts. It was hypothesized that response time increased with the paper charts due to skill degradation and as a result, their flight performance may suffer.

Without refresher training or a consistent recurrent practice schedule, these skills can degrade over time and may contribute to an accident if there is an automation failure during an emergency. The consequences of skill degradation may be severe, if not fatal, if the person is overestimating their ability. The current study continues on this earlier study and increases fidelity through use of a flight simulator for the experiment.

1.3. Theoretical foundations for the study

1.3.1. Capacity to manage tasks

A capacity theory of attention was found to be underlying concept, where a human is limited by capacity on performing mental work. Kahneman (1973) posits that humans lack the ability to process more than one input at a time. A capacity theory exerts that how humans pay attention to objects and acts. There are two ways to describe the process of information-transfer among humans. First, if a human is having a difficulty to identify any momentary variation in a task, their actions will reflect the variations in their arousal level. Second, several mental activities can be performed concurrently, where some of them demands the requirement to perform in isolation. Kahneman (1973) illustrated with an example of a driver, who interrupted his/her conversation fails to make a turn.

Any mental activity among humans requires two types of inputs: information input specific to corresponding structure and non-specific input, which may be termed differently as “effort”, “capacity”, or “attention”. An underlying assumption of capacity theory is that the ability of humans to perform multiple activities is limited by total amount of attention, associated with them (Kahneman, 1973). While investigating mental activities with different demands on the limited capacity, there is a likelihood of failing activity due to insufficient capacity on meeting its demands or the processing channels are allocated to other activities. The central tenets of capacity theory were built on three questions: “What makes an activity more or less demanding? What factors control the total amount of capacity available at any time? What are the rules of the allocation policy?” (Kahneman, 1973, p. 10).

A capacity model of attention consists of two central elements, which are allocation policy and the evaluation of demands on the limited capacity. There are four factors to control the allocation policy, such as enduring dispositions to reflect any involuntary attention like allocating capacity to any novel signal, momentary intentions, evaluation of demands, and effects of arousal (Kahneman, 1973). There is likelihood for interference to occur when demands of two activities are beyond available capacity. Kahneman (1973) posits that there is a possibility to undergo more than one task at one instant, but it needs skills specific to that task. Furthermore, capacity theory of attention enables us with the knowledge on limited amount of attention and its relation to allocation policy of tasks.

1.3.2. Prediction of participant response time

Link (1978) proposed relative judgment theory to compare a presented stimulus and a mental psychophysical standard. This sequential theory of judgment helps to predict response probability (RP), response time (RT), and relationship between both. The central tenets of relative judgment theory postulate that mental standard is initiated by experience, such as training or pre-exposure. Link (1978) postulated that if experimenter is presented with stimulus, then there is a comparison between the psychological value of the stimulus and mental standard. In single trail, there is an accumulation of differences over time, until