Journal of Modern Technology and Engineering
Special Issue | IECHCI2022, 2023, pp.14-20

Jomard Publishing

AIRCRAFT MAINTENANCE ACTIVITIES WITH EYE TRACKING

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Abstract. Aircraft maintenance activities are a process performed by aircraft maintenance personnel to ensure that aircraft performance continues in a sustainable manner. The performance of aircraft maintenance technicians is critical in aviation operations. Innovative technologies and methods should be developed and used to reduce human error and sustain acceptable human performance. Recent advances in technology have made it possible to analyze visual searches using metrics other than performance metrics. Eye tracking technology has been shown to provide objective measurements of human behavior. Eye movement tracking basically aims to detect exactly where people are looking at certain time periods. In this study, a literature review was conducted on the use of eye tracking technology in aircraft maintenance activities. Studies in this area have been evaluated in general and it is aimed to shed light on researchers for future studies. The results indicate very limited studies on the use of eye-tracking technology for better understanding the learners behaviors and cognitive processes during aircraft maintenance training programs. However, eye-tracking technology potentially can provide several insights to better development of computer-based simulation systems by providing appropriate feedback for the learners and the educators. Additionally, such information may guide the instructional system developers for developing more intelligent systems which can enhance training programs by providing anytime and anywhere type of learning options with try-and error type of learning alternatives.

Keywords: Eye tracking, human computer interaction, virtual reality, aircraft maintenance.
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Received: 21 September 2022; Revised: 23 November 2022; Accepted: 7 December 2022; Published: 13 January 2023.

1 Introduction

Aircraft maintenance is an essential part of a safe and efficient air transport system. In particular, studies investigating aircraft maintenance procedures are of great importance, as approximately 18 percent of all major aircraft accidents are due to maintenance, repair and control errors (Mehta et al., 2005). Aircraft maintenance activities are a process performed by aircraft maintenance personnel to ensure that technical failures and aircraft performance continue in a sustainable manner. Current training programs for gaining necessary skills on aircraft maintenance process is expensive as it requires long term practice on the aircraft. Additionally, it is not possible to provide anytime and anywhere type of practice options for these learners. Especially situations like Covid-19 pandemic, these training programs faced with additional challenges. These trainees are not always having chance of learning by doing or try-and-error type of learning opportunities. These barriers even make the training programs very challenging. Hence, innovative technologies and methods should be developed and used to reduce human error and sustain acceptable human performance (Gramopadhye et al., 1997; Sadasivan & Gramopadhye, 2009) and to enhance current education programs. One of these technologies is the computer based simulation environments. Because of its importance and serious requirements, first computer-

based simulators have been developed for the airplanes (Yoshino, 1979). However, in order to create successful education programs through such simulation environments, understanding the learners cognitive processes and their behaviors during the learning process is very critical. Such an information may be used to develop intelligent training programs through computer-based simulators and provide appropriate feedback for the learners and educators to improve the performance of the training programs. The feedback given may be infrequent, method less and/or delayed, or there may be problems in creating and maintaining the necessary conditions. Moreover, in certain situations, feedback is economically prohibitive or impossible due to the nature of the task (Vora et al., 2001). Human-Computer Interaction (HCI) is a term used to express the understanding and design of the different relationships between humans and computers (Harper et al., 2008). In this context, developments in computer technology can provide solutions in aircraft maintenance technician training. Recent advances in technology have made it possible to analyze visual searches using metrics other than performance metrics (such as search times and stop times). Previous attempts using these criteria tried to model that the subject did by trying to extract information from these criteria (Bowling, 2003). Recent research has focused on the use of Eye Tracking Technology to gain insight into how subjects move their eyes and what exactly the subject is looking at (Bowling, 2003). Eye tracking technology has been shown to provide objective measurements of human behavior (Bröhl et al., 2017; Yarbus, 1967). Eye tracking basically aims to detect exactly where people look at certain time periods (Cagiltay, 2021). It is possible to use different eye tracking devices for different purposes (Figure 1). These devices can continuously record the size of the pupil and the coordinates that the eye is looking at on the screen at certain time intervals by means of an infrared light reflected to the human eye (Cagiltay, 2021). Therefore, in this study a literature review is provided for better understanding the current research trends of eye tracking technology usage in aircraft maintenance field. The rest of the paper is organized as follows; section two provides a background of a study, section three presents the literature review, in section four discussion is provided and in section five the conclusion is given.

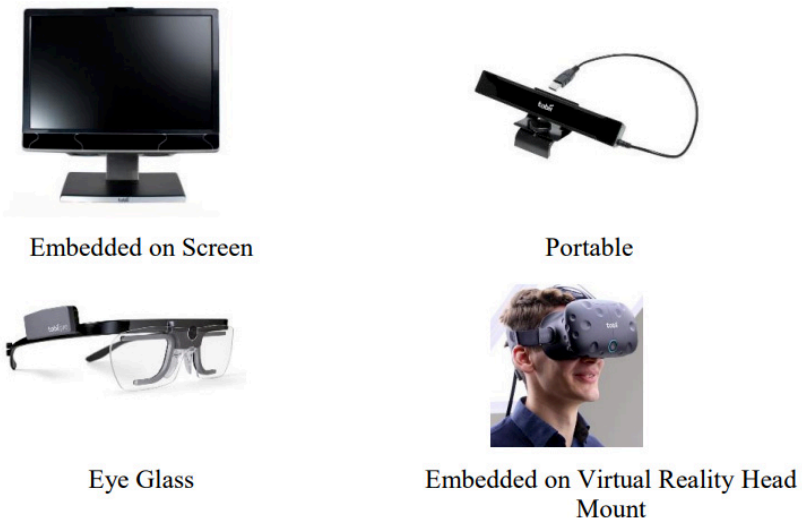

Figure 1: Eye Tracking Devices (Tobii Pro, 2015)

2 Background of the Study

Eye tracking systems have many useful features and it is possible to collect and analyze eye movement data with these systems (Tien et al., 2015). From the data obtained by recording eye movements, it is possible to reach information such as the regions where people first focus on the image, which areas attract their attention most, through visuals such as gaze order (Figure 2.a) and heat map (Figure 2.b). It is seen that eye tracking technology is used in many areas. Pilots' training (Schriver et al., 2008), arts (Vogt & Magnussen, 2007), sports (North et al., 2009) and vehicle driving training (Crundall et al., 1999) can be given as examples. Vickers reported eye movement variations between expert and novice basketball players in foul shots (Vickers, 1995). According to the results obtained from this study, it was reported that expert basketball players program the visual system motor controls, that is, they do not have to follow the whole shooting process with their eyes. However, novice basketball players watch the ball throughout the process to adjust their shots (Vickers, 1995). The author reported in his study (Kasarskis et al., 2001) the differences between the eye movement behaviors of expert and novice pilots while simulating the landing operation, and showed that the expert pilots took less time to fixate on a point with their eyes because they were able to obtain information faster. Various researches related to eye tracking technology are also carried out in the field of medicine. For example, they argue that expert radiologists generally do not scan the edges of the lungs and prefer to look at other areas because there are fewer lesions at the corners, while novice radiologists also examine the corners of the lungs (Nodine & Mello-Thoms, 2000). Significant differences in gaze patterns were also reported when eye movements of surgeons of different skill levels were examined while watching surgical videos (Khan et al., 2012). As a result of an analysis, it was found that the time of fixation on an area with the eyes of experts was shorter than that of non-experts (Gegenfurtner et al., 2011). Studies have suggested that recording eye movements can be useful for both skill assessment and training (Hermens et al., 2013).

It is known that there is a need for better assessment methodologies for skill-based education programs (Cagiltay et al., 2017). Eye tracking metrics through virtual simulated environments are recommended as objective measures for assessing skill levels (Richstone et al., 2010). It has also been reported that the vast majority of virtual reality tasks related to psychomotor skills are valid for one or more measures (Sinitsky et al., 2012). Similarly, based on the results of a systematic review, it was concluded that eye tracking provides reliable quantitative data as an objective assessment tool with potential applications to improve performance. Therefore, this field remains a promising area of research with the possibility of future applications in skills assessment (Tien et al., 2014). Although there is research on eye movements, there are very limited studies in the field of aircraft maintenance that analyze the cognitive workload of technicians when performing different tasks.

3 Literature Review

To find out the existing studies in this field SCOPUS database was searched with the keyword "aircraft maintenance" AND ("eye tracking" OR "eye-tracking") as a result 5 publications returned. As one of them was a theses study and the other one was produced from the results of this theses study 4 publications were evaluated in this study. A study is conducted by Duchowski et al. (2000) and simulated a cargo bay environment of the airplane and describes the development of a binocular eye tracking Virtual Reality system for aircraft inspection training (Duchowski et al., 2000). ISCAN eye tracker was used within a Virtual Research V8 (high resolution) Head Mounted Display (HMD). They dedicated PC calculates the point of regard in real-time (60Hz) from left and right video images of the user's pupils and infra-red corneal reflections to analyzing recorded gaze intersection points for comparison with stored locations of artificially generated defects in the inspection environment (Duchowski et al., 2000). Bowling (2003) stated the ef-

fects of feedforward information on process measures in a simulated 3-dimensional environment (aircraft cargo bay) by the use of virtual reality (Bowling, 2003). The study was conducted using six subjects performing inspection in a simulated aircraft cargo bay (Bowling, 2003). Results show that the use of feedforward information positively impacts inspection performance in terms of fixation points, fixation durations, and area covered measures (Bowling, 2003). Later, Bowling et al. (2008) reported results of their research where they have used a binocular ISCAN eye tracker mounted within a Virtual Reality V8 head-mounted display (HMD) with separate eye feeds, each with a resolution of 640Γ − 480. As a performance measurements percentage of defects detected, mean search time, fixation points, mean fixation duration and area covered was evaluated (Bowling et al., 2008). According to their results participants perform better on process measures, have more fixations, lower mean search times, lower mean fixation durations, and higher percentage area covered (Bowling et al., 2008). Mehta et al. (2005) performed another study in the Virtual Reality Eye Tracking Lab at Clemson University (Mehta et al., 2005). Eye movement events fixation point and fixation duration are tracked using a video base corneal reflection (Mehta et al., 2005). They used HMD and 6 DOF mouse binocular eye-tracker from ISCAN mounted in the helmet with the frame rate 30 fps (frame per minute) (Mehta et al., 2005). A total of 22 defects were used in scenarios such as crack, corrosion, hole, abrasion and broken electrical conduit and they compared two groups of participants (Mehta et al., 2005). The results showed that the gain in the average fixation duration differed significantly between the participant groups (Mehta et al., 2005). Paris et al. (2022) conducted a study for measuring the activities while performance of a maintenance tasks like removal, disassembly, inspection, reassembly and installation of a helicopter system (Paris et al., 2022). The task is arranged by a 21-pages aircraft maintenance documentation to distinguish the use of the procedural documentation during the maintenance task and the method presented in this study is based on data recorded by an eye tracker and video by the egocentric camera of the eye tracker (Paris et al., 2022). However, their experimental study is conducted with only one person which limitedly shows the possible educational benefits of the developed system and generalizable results and insights about the learners' cognition and learning behaviors.

Figure 2: (a) gaze map, (b) heat map (Tobii Pro, 2015)

4 Discussions

In this study, the literature on the use of eye tracking technology in improving performance in aircraft maintenance activities has been reviewed. The aim of the current studies is to enable students to acquire the necessary skills by analyzing their eye movements in a virtual environment. However, current studies were carried out in limited conditions with a small

number of participants using out-of-date devices. As it can be understood from the literature review, the number of studies examining eye movements in this area is very limited and the scenarios used, eye movements measured, eye tracking devices used are old and inadequate (Bowling et al., 2008; Duchowski et al., 2000; Mehta et al., 2005). The accuracy and recording speed of the devices used in these studies are low. In the current studies, the Virtual Research V8 HMD and the ISCAN eye tracking device integrated in this device were used with 30fps and 640x480 resolution (Bowling et al., 2008; Kaewkuekool, 2003; Mehta et al., 2005). The advancement of technology has also been effective in the development of eye movement tracking devices, as in every field, these levels have increased to 90fps and 1440x1600 for each eye today. It is necessary to carry out up-to-date studies in this field, which has such a critical importance. In addition, there is no study conducted in this area in our country. For this purpose, the practical trainings that students should receive can be transferred to the virtual environment with different and various scenarios. In scenarios presented with a virtual reality headset, feedback can be provided to the participants during the execution of the tasks, so that they can perform the tasks correctly and learn. This feedback can be based on gamification/scoring or by including the trainer in the virtual environment. The prototype obtained from the study can be used as a training tool, thus reducing the cost, the need for manpower and the time spent on training. In this way, time, risks will be reduced and cost savings will be achieved.

5 Conclusions

The scenario-based virtual environment for skill-based processes within the scope of Human-Computer interaction and the examination of its effects on students' competencies have the potential for widespread impact in terms of being a basis for applications in different fields. In addition, during the training of aircraft maintenance technicians, it may be possible to determine in which subjects there are differences according to skill levels and in which tasks the cognitive load increases, with eye tracking technology. In addition to these, it is predicted that giving practical application training in the virtual environment in the epidemic environments that we are fighting today will also benefit the health of students and educators. For application-based trainings, a unique approach can be presented to support both educational situations such as the epidemic period and post-epidemic face-to-face training with digitalization and virtual platforms. To conclude, in this study a literature review was conducted for the implementation of eye tracking technology in aircraft maintenance activities to better understand the current literature and find out the future directions that can help researchers for their studies.

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