THE OCULOMETER TRAINING TAPE TECHNIQUE: THE REVIVAL

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The oculometer training tape technique (OT^3) aims to enhance aviation training by 1) allowing the flight instructors to provide real-time feedback, 2) improving debriefing sessions by playing back the trainee pilot's scan behavior, and 3) editing didactic videos based on the scan behavior of experienced pilots.

Despite the original positive evaluations of its usefulness, the OT^3 has failed to gain traction in aviation training programs. This is probably due to the technical difficulties as well as the intrusiveness/bulkiness of the equipment needed. Modern non-intrusive eye trackers, integrated with a forward facing scene-camera, can record pilots' eye movements and, simultaneously, capture what the pilot sees.

Here, we describe the implementation of an updated OT^3 and its potential benefits to the aviation training programs of the Spanish Armed Forces.

Since the pioneering studies of Jones and colleagues with aircraft pilots (Jones, Milton, & Fitts, 1949), eye movement recording techniques have represented one of the most reliable tools to improve aircraft instruments/panels design (e.g. Gainer & Obermayer, 1964) and to study pilots' biobehavioral states (Di Stasi, McCamy, et al., 2016). As flying is a complex perceptual task that requires, not only conceptual knowledge, but the skills to visually search for relevant information, eye tracking technology may be also used to enhance pilot training (Diaz-Piedra, Rieiro, et al., 2016). In the 70's and the 80's, NASA and US Armed Forces researchers (e.g. Barnes, 1970) already developed applications of the eye tracking technology consisting of using the pilot's scan behavior as an instructional aid (Figure 1): the oculometer training tape technique (OT^3) (Spady, Jones, Coates, & Kirby, 1982). The OT^3 objectively measures the eye positions while pilots are performing flight tasks. It provides information on the pilot's scan behavior (both direction of the gaze and fixation time). With this information, the OT^3 aims to enhance aviation training (Wetzel, Anderson, & Barelka, 1998) by 1) allowing the flight instructors to provide real-time feedback about the observed trainee pilot's scan behavior, 2) improving debriefing sessions by playing back the trainee pilot's scan behavior, and 3) editing didactic videos based on the scan behavior of experienced pilots.

Despite the original positive evaluations about its usefulness (Dennis H. Jones, Coates, & Kirby, 1982; Spady et al., 1982; Wetzel et al., 1998), the OT^3 has failed to gain traction in aviation training programs. This is probably due to the technical difficulties of recording eye movements, and the intrusiveness/bulkiness of the equipment needed (Di Stasi, McCamy, et al., 2016). In recent years, user-friendly, commercial, and portable eye trackers– e.g. located on lightweight eyeglass frames – have overcome many of these barriers. These non-intrusive devices, integrated with a forward facing scene-camera, can record pilots' eye movements and, simultaneously, capture what the pilot sees. Here, we describe the implementation of an updated OT^3 into two aviation training programs of the Spanish Armed Forces.

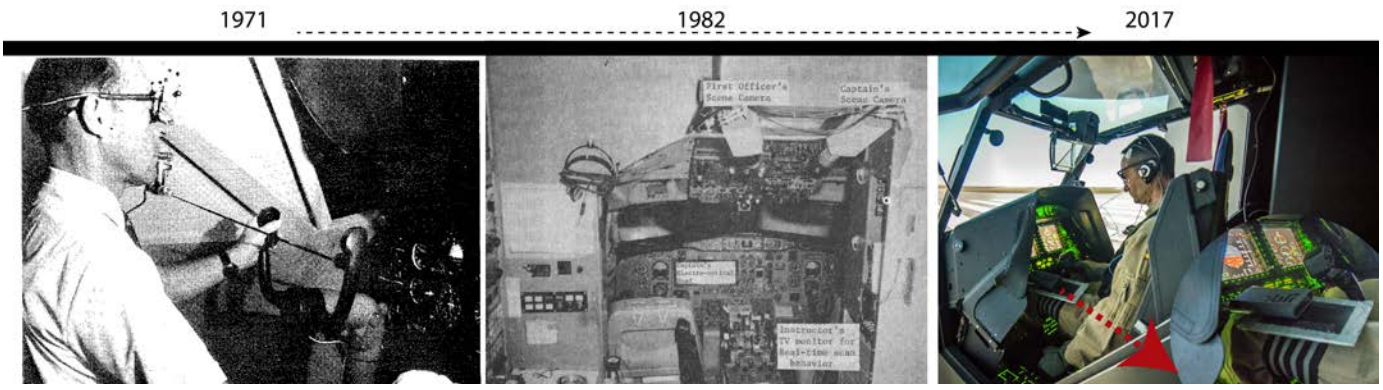

Figure 1. Advances in eye tracking technology in aviation settings. From left to right: **1971)** Eye Point-of-Regard System mounted in an eyeglass frame (Source: Weir & Klein, 1971). **1982)** Honeywell electro-optic head (Source: Harris, Glover, & Spady, 1986). **2017)** Tobii Pro Glasses 2.0 and its recorder unit (attached to the pilot's kneeboard) (Source: Diaz-Piedra, Catena, et al., 2016).

Our Experience

We recorded flight sessions of flight instructors and trainee pilots from the Spanish Army Airmobile Force (First Attack Helicopter Battalion I – BHELA I, Almagro, Ciudad Real) and the Spanish Air Force (78th Wing, Helicopter School, Armilla, Spain), while they performed simulated flight tasks. To record eye movements, we used the Tobii Pro Glasses 2.0 (Tobii AB, Sweden), a portable eye tracker, worn as normal glasses (in this case, comfortably under the helmet, see Figure 2). We performed the calibration procedure inside the aircraft/simulators (Airbus Helicopter Tiger and Sikorsky S-76). Gaze data and the first-person perspective video could be viewed in real time on a tablet computer. All data and videos were stored on a SD card for later replay (see below).

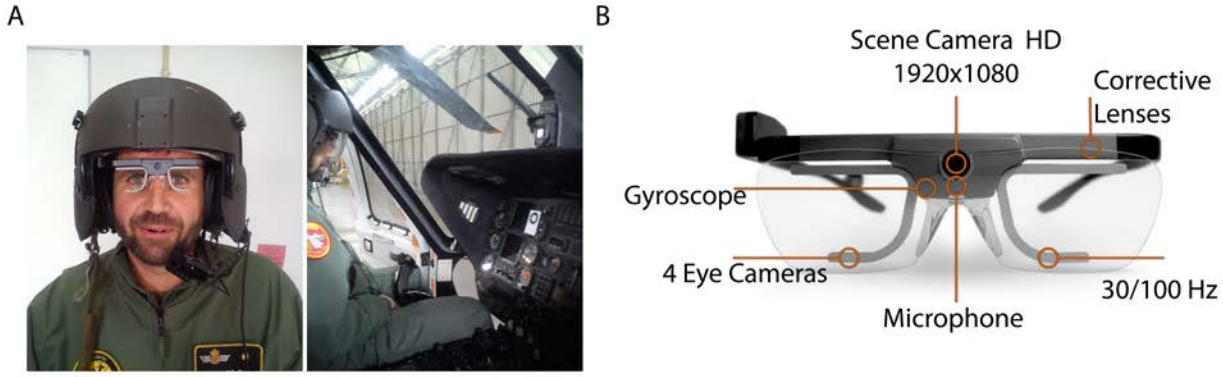

Figure 2. A) Left. A flight instructor from the Spanish Air Force Helicopter School (78th Air Base Wing) (Armilla, Spain), wearing his helicopter flight helmet and the eye tracker. Right. Calibration procedure inside a Sikorsky S-76 helicopter using a single point calibration. B) Tobii Pro Glasses 2.0 and its technical details.

Real-time Feedback

Visual scan patterns might be guided to improve the performance of flight tasks (Wetzel et al., 1998). However, in order to provide the best feedback to the trainee pilot (in the right form and at the right time), the flight instructor needs to know how the trainee pilot allocates his/her (visual) attention.

Eye tracking technology provides an objective measure of where the pilot is looking at. Furthermore, a wireless live view function allows the flight instructor to monitor the trainee's eye movement behavior online and to provide real-time feedback (Figure 3).

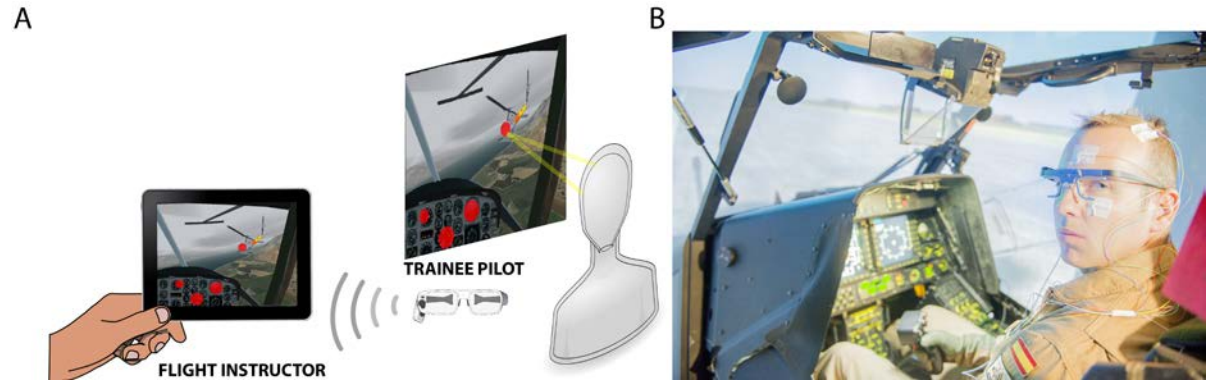

Figure 3. OT^3: *real-time feedback*. A) Sketch of our OT^3. Gaze fixations are illustrated by red circles, and circle diameter indicates fixation duration. During the flight simulation, trainee pilot's eye movements are continuously monitored by the flight instructor using a wireless system so that he/she can correct trainee pilot's scanning behavior in real time. B) A pilot member of the First Attack Helicopter Battalion I – BHELA I (Spanish Army Airmobile Force, Almagro, Ciudad Real, Spain) wearing the eye tracker inside the Airbus Helicopter Tiger simulator.

Debriefing Sessions

Another application of the OT^3 aims to improve debriefing sessions. Flight instructors might play back trainee pilots' flight videos and, consequently, show them their visual scan patterns (Harris et al., 1986), and where they focused during the flight session (pilot's eye movements are superimposed onto the recorded video). In this way, flight instructors can easily point out examples of missed cues or other events that could compromise flight safety.

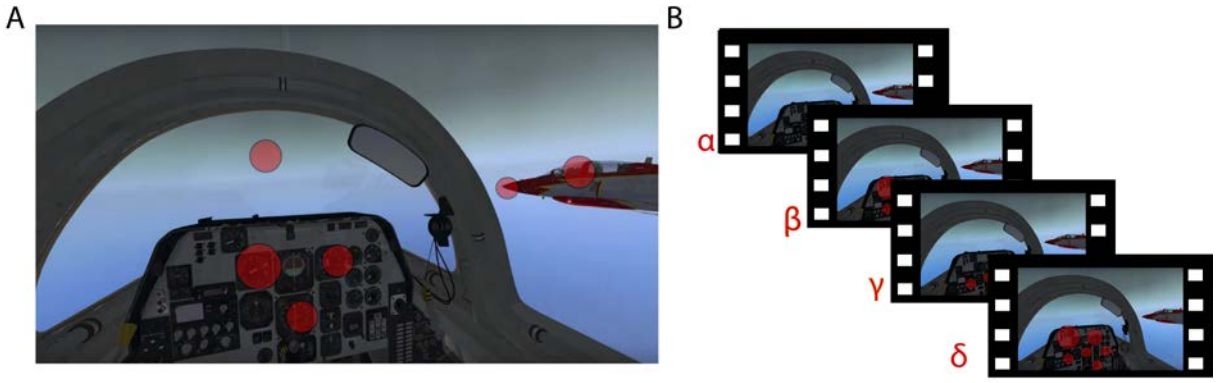

Figure 4. OT^3: *augmented videos*. A sketch of our OT^3 showing different frames of an augmented video. These videos contain the trainee pilot's eye movements superimposed onto the first-person perspective video captured by the integrated scene camera. Also, the communications between the flight instructor and the trainee pilot are recorded. Flight instructors can use these videos to point out accurate and mistaken maneuvers in debriefing sessions.

Expert Guidance

When accomplishing complex visual tasks, experts possess sophisticated visual observation skills which enable them to find relevant features of a visual stimulus with irrelevant features and to interpret these observations (Jarodzka, Scheiter, Gerjets, & van Gog, 2010). Therefore, even though Jones and colleagues already noted that flying training based on individualized feedback would be more helpful (Jones, Coates, & Kirby, 1983), using visual observations of experienced and successful task performers (for example, standardized videos) might also improve instruction by cueing (Gog & Jarodzka, 2013).

For our OT^3, we recruited expert pilots (flight instructors) to perform, in a didactic manner (i.e. avoiding knowledge-based shortcuts), several simulated flight maneuvers (mostly abnormal/emergency flight conditions) during the flight while their eye movements were recorded. Then, we created augmented videos superimposing the pilot's eye movements onto the recorded flight video and the verbal explanation about how he/she was performing the flight tasks (Figure 5). Trainee pilots could watch these augmented videos as part of their aviation training.

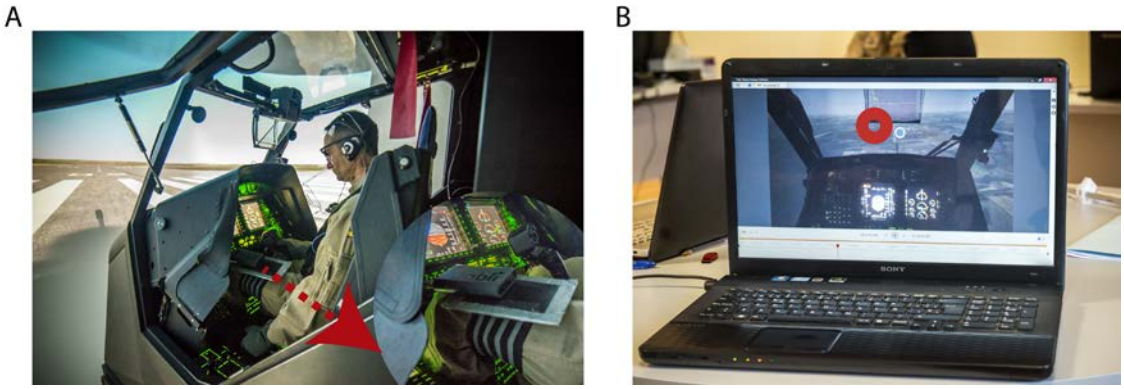

Figure 5. OT^3: *expert augmented videos*. A) A flight instructor from the First Attack Helicopter Battalion I (Spanish Army Airmobile Force, Almagro, Ciudad Real, Spain), performing a standard pre-flight checklist procedure while his eye movements are recorded. B) Example of video editing (cyclopean view [red circle] superimposed onto a frame of the scene) using the software Tobii Pro Glasses 2.0 Controller.

Final remarks

Flying an aircraft is a highly demanding cognitive task where performance heavily relies on visual search and the interpretation of visual information. Training is a key element to acquiring effective scanning patterns that allow safe interactions with the aircraft. During the training of scanning strategies, flight instructors often face the dilemma of knowing when and how to provide the best feedback to the trainee pilot (Sullivan, Yang, Day, & Kennedy, 2011). Modern eye tracking technology applied to flight training might offer a real opportunity to learn, as it provides valuable, objective, and real-time information for both the flight instructor and the trainee pilot. Furthermore, this information can be used to create augmented videos.

The expected outcome of our application will be to enhance flight safety, decrease in-flight errors, and optimize performance by developing complementary educational materials. Finally, the proposed OT^3 will also have applications across a wide range of disciplines in and outside of the aviation industry (e.g. medicine [Di Stasi, Diaz-Piedra, et al., 2016]).

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