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Effects of interior aircraft noise on pilot performance

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ABSTRACT

How well the pilot performs tasks significantly affects flight efficiency and safety, and pilot performance is affected by factors in the cockpit environment. For example, studies have shown that interior aircraft noise affects pilot performance, but the potential cumulative effects of such noise have yet to be examined. The present study examined the cumulative influence of the interior noise of a light, propeller-driven, single-piston engine aircraft on operation-related performance of 14 civil pilots aged 22–26 years with 165–350 flight hours of experience. Pilots filled out a questionnaire asking about the perceived influence of noise on their performance. Then they were exposed to recorded cockpit noise, after which they were asked to execute a variety of standard flight simulation tasks on a flight simulator. Their performance was assessed based on objective measures. Analysis using descriptive methods, paired *t*-test and mixed linear regression showed no significant average and maximum deviations from predefined default parameters of standard flight elements in the presence of cumulative noise exposure up to 20% or 40% of permitted daily noise dose. The results of the self-report questionnaire and objective performance in flight simulations suggest that cumulative noise exposure may not significantly affect pilot aviating and navigating tasks. Further studies are eventually needed to verify and extend these results with higher cumulative noise exposure, more noise dose sequences and greater number of more experienced pilots.

1. Introduction

Pilot error during flying (aviating), navigating or communicating has important implications for flight efficiency and safety [1–3]. Environmental factors in the aircraft cockpit can influence the risk of pilot error, such as air humidity, temperature, pressure, vibration and noise; however, such factors have been neglected in reviews covering factors affecting pilot performance [4]. The large European pilot survey on Health Effects in Aircraft Cabin Environment (HEACE) [5] and an assessment of 12 interior noise patterns [2] indicate a significant impact of noise on pilot performance. A survey of pilots at the Croatian national airline concluded that pilot exposure to aircraft noise had compromised flight safety at least once among 27.8% of turbofan aircraft pilots and 38.5% of turboprop aircraft pilots [6].

Several studies have shown that noise negatively affects human performance on tasks of varying complexity [7–9], while other studies have described situations in which noise did not strongly compromise performance [10] or in which it enhanced performance [11]. These complex effects may reflect, in part, the Yerkes-Dodson law, which suggests that arousal due to noise may positively affect performance up to a certain point, beyond which it harms performance. Another complicating factor in understanding effects of noise on pilot performance is the *duration* of exposure, yet few studies have measured effects of *cumulative* noise exposure. Acute noise exposure can cause auditory physiological effects such as temporary threshold shift (TTS), as well as non-auditory physiological effects, which include various subjective disorders (intolerance, fear, headache, nausea, tiredness, irritability). The increased effort and energy consumption of pilots in the presence of noise can lead to decreases in concentration, perception and judgment sharpness; shorter working memory; increase in reaction time; and disturbance in gesture coordination. All these effects can significantly deteriorate pilot performance. Noise exposure can also cause psychological effects such as speech masking: speech becomes less intelligible, making cockpit communication unreliable and compromising flight safety [12]. Chronic noise exposure can lead to permanent threshold shift (PTS), corresponding to irreversible auditory impairment. Continuous exposure to high-intensity noise impairs pilot performance in tasks that require concentration, learning, analytical judgement, precise movements, continuous performance and long-term attention [13]. Noise also adversely affects the performance of simultaneous tasks [13].

Previous studies of the effect of cumulative noise exposure on pilots have given conflicting results. One longitudinal study of helicopter pilot performance failed to find an overall strong correlation between noise exposure and performance on a few relatively simple procedures in a

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simulator [14], yet a similar study of helicopter crews found a significant correlation [15]. This discrepancy highlights the need to clarify the potential effects of cumulative noise exposure on pilot performance.

The aim of the present research was to quantify the impact of the interior noise of a small, piston propeller-driven aircraft on civil pilot performance related to aircraft management (piloting). Pilots pre-exposed to a fixed dose of recorded cockpit noise participated immediately thereafter in flight simulations while being exposed again to cockpit noise, and their performance, when carrying out an extensive array of operations, was analyzed [16]. Pilots were pre-exposed to noise due to its cumulative character that causes non-auditory physiological effects (various subjective disorders) which can significantly deteriorate pilot performance. In our research, we suggest the parameter that simply combines noise level and exposure time, i.e. "% dose", previously developed for noise exposure measuring expressed as a percentage of an 8-h working day [17], as a useful measure of cumulative noise exposure.

2. Methods

2.1. Participants and initial assessment

Fourteen of the 60 civil pilots who had completed flight training at the European Aviation Safety Agency-accredited Croatian Aviation Training Centre (CATC) by November 2014 were enrolled in the study. This was considered an adequate sample since in any given year, approximately 15 civil pilots complete flight training. The study protocol was approved by the CATC Ethics Committee, and participants provided written informed consent.

The pilots were aged 22–26 and had 165–350 flight hours of experience spanning 2.5–5 years. All participants were screened for hearing impairment by determining the average hearing threshold in each ear at typical octave frequencies (0.5, 1, 2 and 4 kHz). This audiometry was performed in a climate-controlled room at 21 °C, relative air humidity of 50–60%, air movement at head and knee level of 0.05 m/s, and average brightness at working surfaces of 450 lx. The average hearing level of all participants was between 1.25 and 18.75 dB, well below the World Health Organization threshold of 25 dB for hearing impairment.

After audiometry, participants provided background data on a survey, which asked for demographic data, total number of flight hours, years of flight duty, and self-assessment of the degree to which cockpit noise affected their mood, concentration, performance of analytical tasks, performance of simultaneous tasks, management of the airplane (piloting), i.e. aviating, communicating and navigating. Participants were also asked how many times interior noise had compromised their flight safety.

2.2. Noise recording

Interior noise was recorded in a Cessna 172 N single-piston propeller-engine aircraft, routinely used by the CATC for civil pilot training. The recording was taken during the standard domestic route from Zagreb to Varaždin (Croatia) at a flight level of 5500 feet and nominal airspeed of 90 knots. Class 1 sound analyzer and measuring microphone were positioned between the pilot's and copilot's seats at ear level, according to ISO 5129 procedures. Under these conditions, an equivalent noise level of LA_{eq} = 88.9 dBA was measured.

2.3. Flight simulations with different noise exposure

Flight simulations were performed under conditions identical to those described for the initial audiometry assessment. Participants completed simulations on a flight simulator approved by the European Aviation Safety Agency and routinely used for training at CATC. In the simulations, which took 15 min each, participants had to execute 18

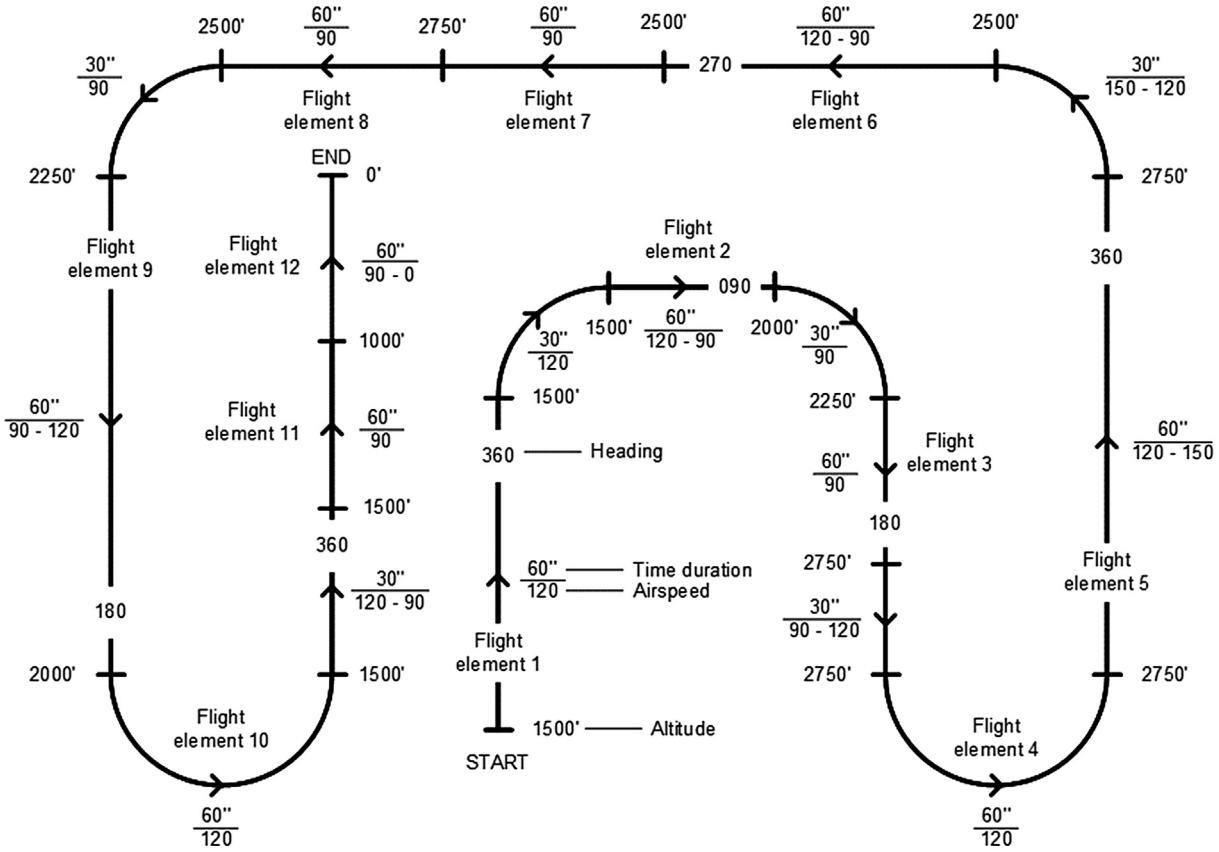

Fig. 1. Graphical outline of the flight exercise scenario with maintained flight parameters within the supervised flight elements.

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