Pol J Aviat Med Psychol 2014; 20(4): 37-39
DOI: 10.13174/pjamp.20.04.2014.5

TECHNICAL NOTE

THE IMPACT OF THE COMBINED EFFECTS OF CORIOLIS ILLUSION AND HYPOXIA ON SACCADIC EYE MOVEMENTS DURING FLIGHT SIMULATIONS

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Source of support: Polish National Science Centre (NCN): 2013/09/B/NZ7/03763 (to SPG)

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Background: The objective of this study was to verify the impact of the Coriolis effect and altitude hypoxia of intensity typical for aviation on the eye movements of pilots using state-of-the-art oculographic equipment. The activity of the eyes is one of the determinants of pilot's spatial orientation during the flight. Even a short-timed loss of vision or impairment of the vision organ may lead to irreversible, often tragic consequences. Preliminary studies available to date were performed in the 1970s with no effect of interest being observed. However, much progress has been made in oculographic methods from that time.

Keywords: Coriolis effect, eye movements, fixations, flight simulation, hypoxia, saccades

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INTRODUCTION

Altitude hypoxia is encountered in aviation in both emergency situations and regular flight conditions. The subject experiencing hypoxia is at a risk of insufficient oxygen supply-related cognitive and psychomotor deficits [10], vision disturbances [5] and loss of consciousness [9,11]. Such an impairment may lead to significant difficulties in handling the plane and, in extreme cases, complete loss of control over the craft. Spatial disturbances are estimated to account for about 20% of accidents in modern-day aviation [1]. Hypoxia is one of the factors that significantly and negatively affects pilot's orientation flight safety [2]. However, it is not obvious whether it affects the basic parameters of the autonomous eye movement processes. Studies of saccadic movements carried out in alpinists while climbing the altitude of 7500 m asl revealed no changes in oculomotor activity occurring as a function of altitude [8]; however, altitude adjustment capabilities of subjects who had been living in low-oxygen conditions for many days might have had an important impact on the results. Likewise, no effects of previous hypoxia on ocular movements were observed after termination of hypoxic conditions [4]. Nonetheless, there is a need to study the effect of acute hypoxia on the oculomotor activity in pilots with no prior acclimation as these are the conditions encountered by aviators during the flights.

The Coriolis effect is induced by stimulation of at least two semicircular channels. The effect is associated with a sudden movement of the pilot's head during the flight upon the turning maneuver. The resulting Coriolis effect leads to a sensation of "tumbling" which markedly hampers the maintenance of proper parameters of the flight. Studies revealed increased frequencies and durations of saccadic movements in pilots bowing their heads during plane rotation maneuvers [3]. Air density is another variable factor during the flights. It is unknown whether the Coriolis effect occurs in hypoxic conditions upon simulated flights at altitudes of 5000 m and 6000 m.

METHODS

Fourteen male, experienced flight instructors (aged 25 to 45 years) took part in a simulated flight using an Integrated Physiological Trainer flight simulator (Gyro-IPT, ETC, Southampton, PA, USA) capable of generating hypoxic in-flight conditions [6,7]. The testing procedure consisted of three tasks (course change and ascension for 180 s, head bow, straight and level flight) carried out while breathing with low-oxygen air mixture typical for conditions at altitudes of 5000 m and 6000 m. The mixture was delivered using the air mask. The simulator rotated around its axis with angular acceleration of 0.2 deg/s2 for the first 180 seconds to reach the speed of 36 deg/s at the moment the pilots pushed their heads forward.

Ocular activity of subjects was recorded and measured using a JAZZ G-Plus saccadometer (Ober-Consulting, Warsaw) operating at 1 kHz frequency [7]. The measured parameters included mean amplitudes and durations of saccades, saccade frequencies, mean durations of fixations, velocities and accelerations of pupils during saccadic episodes. The parameters were recorded both before and after the head movements causing the Coriolis effect.

RESULTS

No effects of low-oxygen air mixtures were observed prior to the Coriolis effect. At the altitude of 5000 m and during the Coriolis effect, the mean amplitude of and mean duration of saccades increased by ca. 30%-40% ($p<0.005$). An increasing tendency could also be observed in the frequency of saccades which reached 20% ($p=0.08$). At the altitude of 6000 m, a 14% increasing tendency in mean saccade duration and a 30% increasing tendency in saccade frequency could be observed ($p=0.08$ for both parameters). No significant differences were observed between altitudes of 5000 and 6000 m except for a 17% dropping tendency in saccade durations at a lower altitude ($p=0.06$). No effects of hypoxia could be observed on either of the analyzed parameters.

DISCUSSION

We could observe the effects of Coriolis illusion on the saccadic movements of pilot's eyes in hypoxic conditions. The lower number of statistically significant differences in parameters due to the Coriolis effect as observed at 6000 m is probably due to the wider variability of results as compared to the altitude of 5000 m. The absence of the effect of hypoxia on the intensity and duration of saccades may be explained by the involvement of compensation mechanisms. The potential effect, if subtle enough, could have been undetected by the equipment which, as any other device, is subject to its own limitations.

AUTHORS' DECLARATION:

Study Design: Krzysztof Kowalczuk, Marek Gąsik, Rafał Lewkowicz, Marcin Strojek, Mariusz Wyleżoł; **Data Collection:** Krzysztof Kowalczuk, Michał Janewicz, Stefan Gaździński, Marek Gąsik, Rafał Lewkowicz, Marcin Strojek, Mariusz Wyleżoł; **Statistical Analysis**: Krzysztof Kowalczuk, Michał Janewicz, Stefan Gaździński, Marek Gąsik, Rafał Lewkowicz, Marcin Strojek, Mariusz Wyleżoł; **Manuscript Preparation:** Krzysztof Kowalczuk, Michał Janewicz, Stefan Gaździński, Marek Gąsik, Rafał Lewkowicz, Marcin Strojek, Mariusz Wyleżoł; **Funds Collection:** Krzysztof Kowalczuk, Marek Gąsik, Rafał Lewkowicz, Marcin Strojek, Mariusz Wyleżoł. The Authors declare that there is no conflict of interest.

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Cite this article as: Kowalczuk K, Janewicz M, Gaździński S, Gąsik M, Lewkowicz R, Strojek M, Wyleżoł M. The Impact of the Combined Effects of Coriolis Illusion and Hypoxia on Saccadic Eye Movements During Flight Simulations. Pol J Aviat Med Psychol 2014; 20(4): 37-39. DOI: 10.13174/pjamp.20.04.2014.5