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EFFECT OF HIGH ACCELERATION EXPOSURE ON VISUAL PERCEPTION IN POLISH PILOTS MEASURED WITH CRITICAL FUSION FREQUENCY TEST (CFFT)

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SUMMARY: *The relationship between flicker sensitivity and acceleration, impaired stimulation and inhibition of central and autonomic nervous system and, ophthalmologic function. It should be stressed that examination of visual perception in pilots with CFFT can be interesting.* ***Objectives:*** *The purpose of this study was to determine the effect of high positive sustained acceleration on visual perception as measured with a CFFT (Critical Fusion Frequency Test) and to determine the relationship between these changes with respect to +Gz exposure.* ***Participants and methods:*** *Thirty-one volunteers aged between 23 to 30 years participated in the study. All of them underwent training and examination in the MIAM (Military Institute of Aviation Medicine) prior to, during and after exposure to acceleration on a human centrifuge. Participants were divided into three groups, depending on their Acceleration Tolerance Level (ATL) in order to compare their +Gz tolerance with CFFT results.* ***Results:*** *No statistically significant differences were found between the changes in the CFFT control value (+1 Gz, no centrifugation) and > 1Gz exposures. Sequentially performed measurements, also resulted in no statistically significant changes.* ***Conclusions:*** *The obtained results indicate the CFFT has no value in the evaluation of a pilot's visual perception during acceleration exposure*

KEY WORDS: *acceleration, CFFT, pilots*

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Introduction

Determination of a pilot's ATL in the MIAM human centrifuge is one of a Polish pilot's routine examinations. This examination determines a pilot's tolerance to positive Gz acceleration during flight. It is known from the literature [1,4,5,6,13,] and our own studies [11,16,17,] that disorders of the body compensation mechanisms under acceleration may lead to functional disturbances of physiological systems and a decrease in the level of psychophysiological and psychomotor reactions.

One of the most important requirements of a pilot's profession is visual performance and perception. It is connected with effectiveness of pilot actions during flight in variable environmental conditions. Modern high performance aircraft fly with high velocity and routinely exceed a pilot's ability to visually identify approaching objects. Therefore, the ability for rapid sight-motor reactions plays an important role in pilot suitability for maneuvers performed during air combat.

Over the years, attempts to introduce the critical flicker fusion test (CFFT) for the evaluation of pilot visual performance have been undertaken [10,12]. Investigation of this function has had not only scientific value, but also practical character in the assessment of the occupational value [14]. Evaluation of the acceleration effect of the human cognitive behavior is a subject of continuous studies from the borderline psychology and medicine. CFFT is one of the measurements of the individual's reaction used in clinical psychology, neuropsychology and ophthalmology [7,8,17,20]. It measures the degree of central nervous system stimulation, i.e. the ability to differentiate discrete changes at the level of sensorial information.

The additional introduction of the CFFT to the examination of pilots in the centrifuge, immediately after high acceleration exposure, requires concentration and mental activity. Value of this test seems to be justified for high maneuverability aircraft pilots who fly with high velocity and high sustained Gz. Tasks performed under such conditions require perception of observed, rapidly moving objects of changeable shape parameters.

Measurements with CFFT may, therefore, enable the differentiating assessment of individual perception in pilots. Such studies were conducted in one of the first papers [10]. Therefore, new data on pilot behavior under high G may be provided.

This study aimed at obtaining an answer to the following questions:

- what effect does high sustained acceleration have on the visual perception of pilots measured with CFFT?
- to what degree is the CFFT useful in the evaluation of pilots' visual effectiveness during simulated combat flight maneuvers?

Participants and method

Thirty-one volunteers aged between 23 and 30 years were examined. Earlier, all participants were medically examined by the Main Aviation Medical Commission and considered fit for tolerating accelerations. All participants were trained and examined in the MIAM centrifuge. Measurements were made in control conditions, before, during and after acceleration. Prior to the study, each participant was acquainted with study methods, safety conditions, and type of visual test exposure. After obtaining the participants' informed consent and approval of the Ethical Commission of the

MIAM, the study program commenced.

Participants were divided into three groups according to their ATL value obtained during acceleration. ATL values in the groups were: the low group with ATL up to 5,7 Gz; the group of medium ATL between +5,8 and 6,4 Gz; and the group of high ATL; over 6,5 Gz.

For the CFFT examination a FLIM Flicker/Fusion Frequency device was used [19]. Frequency of the light stimuli fusion ranged from 25 Hz to 60 Hz. The red light stimulus had the following physical properties: diameter; 1,2", lamination = 270 cd/m2, wavelength; 665 nm. The examined volunteer had to evaluate the moment in which the flickering light was seen as constant. Five measurements were made in each cycle and the mean value was calculated.

The program included the following stages of investigation presented in fig. 1.

- Control examination - CFF measurements in the human centrifuge cabin with no acceleration, Gz=1; this included acquaintance with the CFF device and proper reactions to the light stimulus.
- Pre-start measurements – Measurements were made 10 minutes after the control examination and immediately before the training centrifuge start up to +3Gz.
- Measurements after +3Gz training.
- Measurements after GOR (Gradual Onset Rate).
- Measurements after stopping the centrifuge every 2 minutes up to 12 minutes.

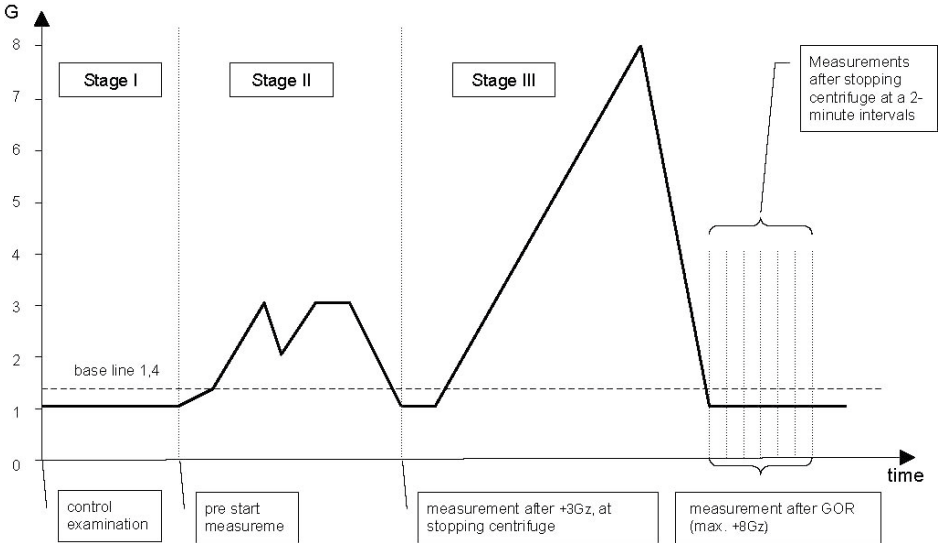

Fig. 1. Sequence of CFF measurements.

The introduction of +Gz acceleration was the following:

- In the second stage, introductory, acquaintance centrifugation from the base line start point up to maximum +3Gz was performed. During this stage, volunteers underwent the action of variable velocity of increasing acceleration in the range from 0,1 G/s to 1,0G/s.
- In the third stage acceleration was increased linearly at 0,1 G/s until subjects reported 50° PLL (Peripheral Light Loss). It was the recorded ATL. Maximum sustained acceleration was limited to +8.0 Gz.

All parameters registered by the computer determined the basic index ATL. Therefore this index was used in the statistical comparative analysis of CFFT. Results of this analysis are expressed in absolute values in both graphic and tabular forms.

Standard physiological parameters were recorded throughout the experiment. These parameters included: ECG, HR, amplitude of ear lobe vessels pulsation, reaction time to stochastically presented visual stimuli, respiratory rate, and acceleration value.

Registration of the CFFT after the GOR program in the centrifuge resulted in 29 volunteers. Two volunteers were excluded from the study because of their lowered ATL value and were not included into the results.

In order to eliminate the influence of emotional stress we used pre-start results as a baseline.

Results

Results of the statistical analysis are shown in table 1.

Tab. 1. Descriptive statistics for CFFT in various stages of exposure

Type of measurement		**Mean**	**Minimum**	**Maximum**	**Standard deviation**
Control		388,76	334	459	32,14
Pre start		391,07	341	479	34,38
Acquaintance 3.0 +Gz		382,90	335	443	33,30
After GOR, max. to 8.0 +Gz		382,07	305	468	39,09
Resting after 2 min	1	387,28	328	457	36,20
	2	384,55	326	457	36,52
	3	386,72	319	460	34,93
	4	387,28	317	459	36,08
	5	387,93	324	457	36,12
	6	387,10	322	468	36,38

Presented results include the total analysis of all volunteers who participated in this study. Analyzing this table, one may see a negligible increase in the CFFT mean value in the centrifuge pre-start stage, which slightly decreased in consecutive measurements. These differences were not statistically significant in comparison to control values. Consecutive measurements were also not statistically significant. Undoubtedly, high standard deviations had an effect on the mean CFFT values. Individual CFFT reactions also had a marked effect on the obtained results, being individually variable.

Changes in the CFFT deviation values compared to control and pre-start measurement during the entire exposure period are shown in fig. 2

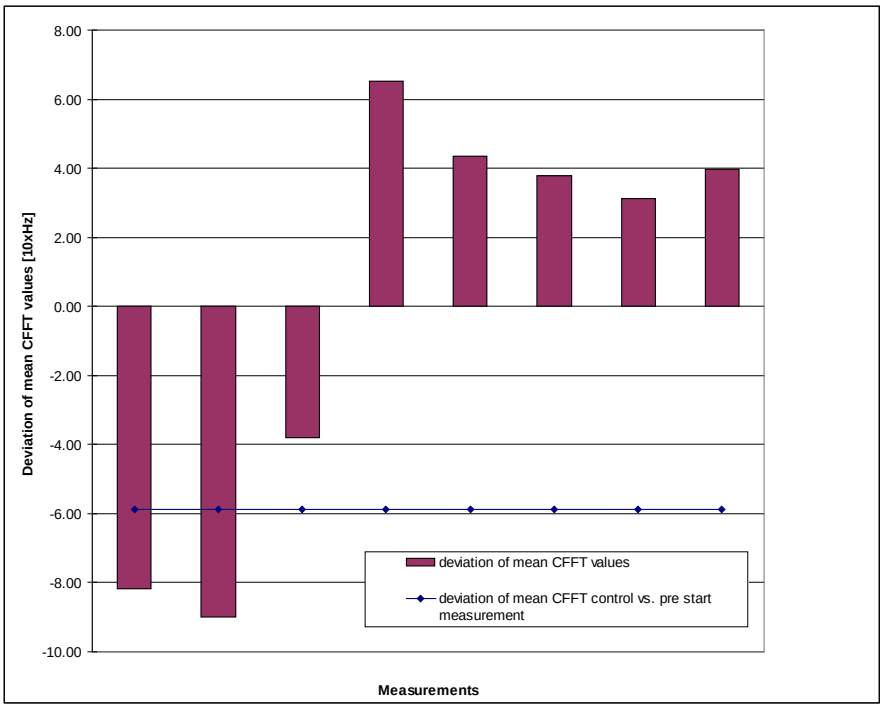

Fig. 2. Descriptive statistics of CFFT values at different moments of the measurement (mean value).

Figure 3 shows the CFFT results to the control measurement separated into the three groups: low ATL up to 5,7 Gz; medium ATL from 5,8 Gz to 6,4 Gz, and high ATL over 6,5 Gz.

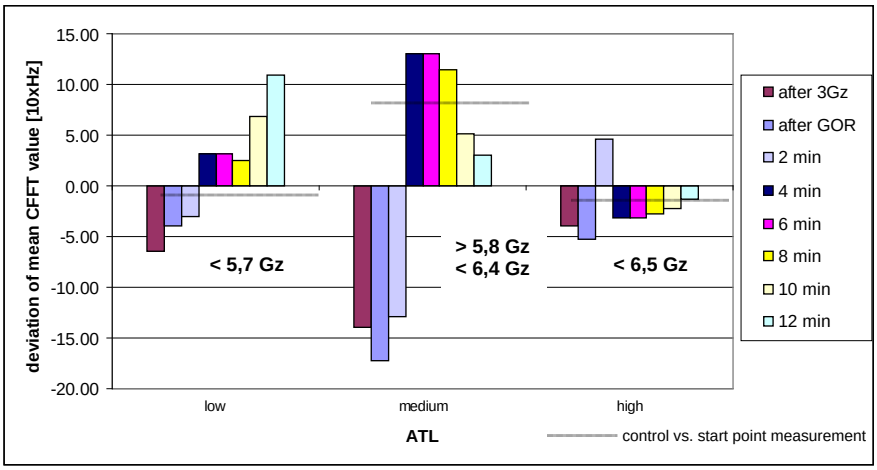

Fig. 3. CFFT value deviations in relation to the pre-start measurement value for ATL groups.

Statistical analysis

Variance analysis for repeated measurements in the scheme in which intraobject factor was the measurement moment was used.

As first, the authors decided to analyze qualitatively descriptive statistics for each moment of measurement, depending on the time of exposure to acceleration in +Gz axis. Similarity of mean values, range of the registered values and SDs enabled to assume that +Gz stimulus had no significant value for CFFT after the first stage of qualitative analysis.

Results of the statistical analysis confirm a assumption indicating the lack of statistically significant effects on changes in the critical light stimulus fusion frequency resulting from the exposure to acceleration in +Gz axis.

Analysis of the obtained results for CFFT value deviations according to control and pre-start measurements are shown on the figure 2 have $F(8,208)=1,253$; $p=0,269$ values, and the results presented on the figure 3 in relation to ATL also did not show statistically significant differences between the groups $F(8,208)=1,217$; $p=0,29$.

Discussion

In our investigation of CFFT in pilots we assumed that the method of +Gz examination would have a significant effect on pilot cognitive function and visual perception during acceleration exposures. Therefore, the use of the flicker test in pilots of high performance aircraft has been justified, in spite of results from some other authors, who did not reach significant results with the CFFT. Keighley et al. [10] measured the CFFT of subjects exposed to +Gz levels from +2,5 Gz to +3,2 Gz for 45 sec. The mean CFFT value, at peak G, was only 0,18 Hz lower than the control value. Their results showed no change in CFFT threshold. It should be pointed out that our results were similar. Cavaglia F. [2] has used CFFT as a cognitive function measure. The examination performed CFFT in eight F-16 jet pilots. Their cognitive function was thoroughly evaluated before and after a cognitive activation task. The task comprised a 90 minute sequence of emergencies in a 1 Gz flight simulator. The authors confirmed, that the CFFT differences were not significant (CFF before: mean: 28,07±2,90; CFF after: mean: 28,07±2,74). The correlation obtained was $r=0,953$ which implies a shared variance of 90,8%. This result indicates that each pilot provided a very similar result in both evaluations. Their study could reflect a possible trait marker property for CFFT, although after their opinion, new studies are needed to better clarify these findings.

It is well known, that the visual disturbances manifested by PLL in the critical phase of acceleration result from after-effects of disturbances in the cardiovascular system. In the phase, cardiovascular system and CNS (Central Nervous System) functions are disturbed as well as sensory receptor functions [16,17]. Moreover, within several functioning disorders, one should also mention physical and psychological overload resulting from high G [1]. These abnormalities increase proportionally with the increase in G and affect precision of the visual evaluation of the observed objects and spatial orientation. CNS ischemia under such conditions undoubtedly affects visual perception. Therefore, psychological workload requires high concentration by the subjects on tests displayed on the monitor during acceleration and should

have an effect on stimuli visual perception.

In our study, we used linearly and GOR acceleration enabling compensation mechanisms to react. Use of this program for GTP determination helped us to answer the following question: "What level of sustained acceleration leads to hemodynamic disturbances, resulting in reduced blood flow to the head vascular area and consequently visual ischemia and peripheral visual field loss?". During the investigations of this type of G exposure, variable tone of the autonomic nervous system develops. This phenomenon is also confirmed by the results of registered physiological indices reported by other authors and seen in our own studies.

Sympathetic nervous system stimulation occurs before the start and during initial acceleration exposure while after acceleration cessation, this role is taken over by the parasympathetic nervous system leading to the observed delay in reaction time [11,18]. Reports of other authors confirmed this fact [5,8]. It should be stressed that the process of parasympathetic system stimulation may develop at various times after the cessation of acceleration. In this study, by using a prolonged time of measurements after stopping the centrifuge, we could observe this phenomenon.

Results of our study did not show statistically significant changes in CFFT, depending on autonomic nervous system changes. However, slight differences in CFFT mean values may suggest it. The small increases in the index values immediately before the start may, therefore, result from emotional tension of different intensity [7,9]. This was the basis for acceptance of the subsequent results. Predomination of this sympathetic system stimulation is present during the entire acceleration exposure. Results of our physiological indices, registered during ATL determination, suggested so. The observed slight decrease in two consecutive CFF measurements could indicate a delayed reaction in visual perception testing. However, differences were not statistically significant. Therefore, we cannot answer the question posed as an objective of this study: "To what degree is the CFFT useful in the evaluation of pilots' visual effectiveness under sustained acceleration?" It should be concluded that the flicker test proved to be inadequate [2].

Conclusions

1. The use of measurements of visual perception in pilots during acceleration did not show statistically significant differences in comparison with control values.
2. Comparing the three groups of pilots with marked differences in their ATL limits, no statistically significant flicker test results were noted.
3. Results of the analysis indicated no statistically significant differences in the critical frequency of light stimuli fusion during acceleration exposure. Therefore, the flicker test is rather useless in the ATL determination.

References

1. Burton, R.R., Smith, A.H. (1996). Adaptation to Acceleration Envirinments. In: M.J. Fregly, C.M. Blatteis (Eds.). Handbook of Physiology: Environmental Physiology. *An American Physiological Society Book*, vol.II.

2. Cavaglia, F., Simões do Couto, A., Matos-Pires, R., Cabrita, F. (2002). Arriaga is critical flicker fusion a trait marker? *European Psychiatry*, 17, (S1), 120.

3. Collyer, S.C. (1973). Testing psychomotor performance-during sustained acceleration. Springfield, Virginia VA; US National Technical Information.

4. Comens, P., Reed, D., Mette, M. (1987). Physiologic responses of pilots flying high performance aircraft. *Aviation, Space and Environmental Medicine*, 58 (3), 205-210.

5. Convertino, V.A., Ratliff, D.A., Doer, D.F., Ludwig, D.A., Muniz, G.W., Benedetti, E., Chevaria, J., Koreen, S., Nguyen. D., Wang, J. (2003). Effects of repeated Valsalva maneuver straining and baroreflex responses. *Aviation, Space, and Environmental Medicine*, 74 (3), 212-217.

6. Eiken, O.,Kolegard, A., Lindborg, E. M., Mekjavic, J. B., Linder J.(2003). The effect of straining maneuvers on G-protection during assisted pressure breathing. *Aviation, Space, and Environmental Medicine*, 74 (8), 822-826.

7. Goldstone, S. (1953). Flicker fusion measurements and anxiety. *Journal of Experimental Psychology*, 49 (3), 200-202.

8. Howard,I., Miller, H. I.,(1969). Effect of auditory stimulation on critical flicker fusion frequency. *Journal of Experimental Psychology*, 81 (2), 365-369.

9. Jing, X., Wu, P., Liu, F., Wu, B., Miao, D. (2011).Guided imagery, anxiety, heart rate, and heart rate variability during centrifuge training. *Aviation, Space, and Environmental Medicine*, 82 (2), 92-96.

10. Keighley, G., Clark, W.G., Drury, D.R. (1951). Flicker Fusion Measurements on Man Subjected to Positive Acceleration on a Human Centrifuge. *Journal Applied Physiology,*4 (2), 57-62.

11. Kopka, L., Wojtkowiak, M. (1981). Zachowanie się układu krążenia w okresie utraty świadomości podczas badań w wirówce przeciążeniowej. *Medycyna Lotnicza*, 73, 1-8.

12. Krugman, H., E. (1947). Flicker fusion frequency as a function of anxiety reaction – an exploratory study. *Psychosomatic Medicine*, 9, 269-272.

13. Shubrooks, S.J., Leverett, S.D., (1973). Effect of the Valsalva maneuver on tolerance to +Gz acceleration. *Journal of Applied Physiology*, 34, 460.

14. Takahashi, K., Sasaki, H., Saito, T., Hosokawa, T., Kurasaki, M., Saito, K. (2001). Combined effects of working environmental conditions in VDT work. *Ergonomics*, 44 (5), 562- 570.

15. Wojtkowiak, M., Kowalski, W., Kwarecki, K., Zużewicz, K. (1983). Zachowanie się organizmu człowieka w warunkach działania przyspieszeń o zmiennych charakterystykach. *Medycyna Lotnicza*, 80, 56-70.

16. Wojtkowiak, M. (1990). Effects of +Gz acceleration on human body systems as a form of training based of physiological data. *Materia Medica Polona*, 22, 311- 316.

17. Wojtkowiak, M. ,Wołkanowski, M. (2007). New method of visual disturbances assessment in pilots during tests in the Polish human centrifuge. *International Journal Occupational Medicine and Environmental Health*. 20 (1), 44-47.

18. Wood, E.H., Lambert, B.H., Code, C.F. (1981). Involuntary and voluntary mechanisms for preventing cerebral ischemia due to +Gz acceleration. *The Physiologist*, 24, 33-36.

19. Schuhfried, G. Vienna Test System psychological assessment catalog, Austria, 2009/2010, 63.