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Stereo vision in air force pilots in human centrifuge during +Gz acceleration

Stereo vid kod pilota ratnog vazduhoplovstva na humanoj centrifugi u toku +Gz ubrzanja

Danijela Randjelović*, Tatjana Šarenac Vulović†‡, Nenad Petrović†‡, Sunčica Srećković†‡

***Aero Medical Institute in Zemun, Department of Ophthalmology, Belgrade, Serbia; †Clinical Center of Kragujevac, Clinic for Ophthalmology, Kragujevac, Serbia; ‡University of Kragujevac, Faculty of Medical Sciences, Department of Ophthalmology, Kragujevac, Serbia**

Abstract

Background/Aim. Stereo vision guarantees good vision and is one of the three main elements of binocular vision, besides simultaneous perception and fusion. It represents the third degree of binocular vision and enables estimation of distance, depth, and space between objects, i.e., allows perception of a three-dimensional image, which is crucial for a pilot. The aim of this study was to investigate the effect of +Gz acceleration on stereo vision in pilots in the air force and student pilots. **Methods.** Two groups of respondents were tested (30 student pilots and 65 air force pilots – a total of 95 respondents). We considered the differences between these two groups as they provide important information about the condition of stereo vision at the beginning of the professional career and after a large number of flight hours over years of flying. We tested variations in stereoscopic vision based on the degree of acceleration of +5Gz by using the Randot Test, which enabled us to determine the degree of three-dimensional vision. **Results.** Temporary changes in stereo vision in student pilots were greater when compared to these changes in air force pilots when exposed to the same acceleration (+5Gz acceleration). The detailed analysis showed that the most sensitive physiological indicators were changes in stereo vision. **Conclusion.** We confirmed that individual physiological pilot training in a human centrifuge, where they are exposed to real G acceleration, improves tolerance to accelerations.

Key words:
aerospace medicine; pilots; acceleration; vision tests; space perception; centrifugation.

Apstrakt

Uvod/Cilj. Stereo vid je garant dobrog vida i jedan je od tri osnovna elementa binokularnog vida pored simultane percepcije i fuzije. Predstavlja treći stepen binokularnog vida i omogućava procenu rastojanja, dubine i razmaka između pojedinih predmeta, tj. omogućava viđenje slike sa tri dimenzije što je od izuzetnog značaja za profesiju pilota. Cilj ove studije bio je da se ispita uticaj +Gz ubrzanja na stereo vid kod pilota borbene avijacije i studenata pilota. **Metode.** Testirane su dve grupe ispitanika (30 studenata pilota i 65 pilota borbene avijacije – ukupno 95 ispitanika). Ispitivali smo razlike između ove dve grupe ispitanika, zbog važnosti informacija o stanju stereo vida na početku profesionalne karijere i nakon višegodišnjih sati letenja. Posmatrali smo dobijene razlike u stereoskopskom vidu na osnovu stepena ubrzanja od +5Gz. U toku našeg istraživanja koristili smo Randot test pomoću koga smo mogli da stepenujemo trodimenzionalnost vida. **Rezultati.** Naši rezultati su pokazali da su prolazne promene stereo vida kod studenata pilota bile veće u odnosu na promene stereo vida kod pilota borbene avijacije, kada su oni bili izloženi ubrzanju istih vrednosti (+5Gz ubrzanju). Na osnovu detaljne analize ustanovljeno je da su najosetljiviji fiziološki pokazatelji bile promene u stereo vidu. **Zaključak.** Potvrdili smo da individualna fiziološka trenaža pilota u humanoj centrifuge, gde su oni izloženi uslovima realnog Gz ubrzanja, poboljšava toleranciju na ubrzanja.

Ključne reči:
medicina, vazduhoplovna; piloti; ubrzanje; vid, ispitivanje; prostor, orijentacija; centrifugovanje.

Correspondence to: Danijela Randjelović, Aero Medical Institute in Zemun, Deparment of Ophthalmology, Crnotravska 17, 11 000 Belgrade, Serbia. E-mail: danijela_randjelovic@yahoo.com

Introduction

High speeds during take-off, flight, and landing of modern aircraft place an additional strain on the human visual system. Since the very beginnings of the development of aviation, the visual function has been assigned considerable importance. Owing to its considerable practical importance in air combat, the effect of +Gz acceleration on the organ of vision has been a significant variable in research. Such strain leads to changes caused by inertia forces occurring due to changes in acceleration. In aviation, the applied acceleration is usually referred to as G forces [1].

In the course of instrument flight, the pilot almost entirely depends on his/her organ of vision that allows him/her to read the information on the instruments [2, 3]. Having a high level of visual acuity is considered a quality of utmost importance, even today when there are aircraft capable of reaching extraordinarily high speeds and flying at all altitudes [4]. The information gained through our organ of vision is most important in maintaining orientation on the ground and in the air during a flight. In conditions of limited external visibility, spatial orientation may be affected [5]. Central vision is responsible for producing precise information on distance, speed, and depth, and in the course of instrument flying, it allows the pilot to receive information from flight instruments in the cockpit [6]. Stereo vision guarantees good vision and is one of the three main elements of binocular vision, besides simultaneous perception and fusion. It represents the third degree of binocular vision and enables estimation of distance, depth, and space between objects, i.e., allows perception of a three-dimensional image, which is crucial for a pilot [7]. It occurs when objects in front of and behind the fixation point stimulate simultaneously horizontally disparate retinal points. The whole object is perceived as three-dimensional as light falls on slightly different points. In order to achieve this, images of the object being observed must fall on identical spots on the retina, primarily in the foveola. All elements of binocular vision are interdependent and cannot exist separately, except for simultaneous perception. One requirement for the existence and development of binocular vision is appropriate visual acuity. If visual acuity in one eye is the normal 1.0, and if binocular vision is to be developed, visual acuity in the other eye must be minimum of 0.3. Other requirements are that the visual centers of the brain are able to fuse two retina images and that there is precise coordination of movements of both eyes in all directions. Particularly significant is the binocular vision, which is controlled by optomotoric reflexes that are rather complex in nature and develop until the age of five and are solidified until the age of seven (fixation reflex, fusion, movements, accommodation, convergence). The third and highest degree of binocular vision is the stereo vision which represents a person’s sense of three-dimensional space. The sense of three-dimensional space is tested by quantitative and qualitative research methods. The simplest qualitative method of testing the sense of three-dimensional space is by synoptophore with pictures for this particular test. Qualitative testing of stereo vision is conducted through a variety of tests: Stereo Fly Test, Randot Stereo Test with polarized specs, Lang Stereo Test Mark 1 and Mark 2, TNO Stereo Test [8–10]. The Randot Test contains a test with polarized circles (stereo-circle test) and is the most differentiated test that enables precise determination of the degree of three-dimensional vision. Ten sections contain four circles each, out of which only one is polarized. The polarized circle is made of two superposition rings, each positioned at a different angle. The greater the angle of polarization, the more visible the third dimension. The greatest angle is the one of 400 seconds (") of arc, and the smallest is of 20" of arc. The Randot Test is in the form of a test booklet [11, 12].

The aim of this study was to investigate the effect of +Gz acceleration on stereo vision in air force pilots and student pilots.

Methods

The research was carried out in the human centrifuge in the Department of Biodynamics at Aero Medical Institute. It was carried out following the instructions given for each test. We tested variations in stereoscopic vision based on the degree of acceleration of +5Gz. Two groups of male respondents were tested, air force pilots and student pilots. We considered the differences between these two groups as they provide important information on the condition of stereo vision at the beginning of the professional career and after a large number of flight hours over years of flying. This would give us more reliable indicators for a better quality selection of candidates, future pilots. In the course of our research, we performed the Randot Test, which enabled us to determine the degree of three-dimensional vision (Figure 1). The test was placed at a distance of 40 cm from the respondents and was carried out binocularly with the respondents wearing polarized viewing glasses. The respondents were asked which of the three circles in the first section seemed to be in front of the other observed circles. The result was read in the special supplement to the test. The test has ten sections, and it is more difficult to notice the difference between circles in each subsequent section, which means that it is also more difficult to notice the third dimension. Stereopsis is quantified in seconds of arc, the test being able to measure

No	SCORING KEY	Seconds of arc at 16 in.
1	L	400
2	R	200
3	L	140
4	M	100
5	R	70
6	M	50
7	L	40
8	R	30
9	M	25
10	R	20

Fig. 1 – Randot test.

stereoscopic sharpness of 20" of arc. Normal stereo sharpness is 60" of arc. If the respondents reach the tenth section without making a single mistake, they score 20", if they make one, they score 25", two 30", and three 40".

Results

Prior to testing, all respondents in both analyzed groups (student pilots and air force pilots) had a normal stereo vision of 20". Upon linear increase in acceleration, a statistically significant difference was noticed in stereo vision between the two observed groups of respondents ($p = 0.000$) (Table 1). In the student group, a statistically higher frequency of respondents with changes in stereo vision was recorded ($p = 0.000$). In the air force pilots group, 92.3% of respondents had unchanged stereo vision, while 7.7% had a stereo vision of 25°. After the test, in the student group, slightly more than half of the respondents, 53.3%, had a normal stereo vision, 23.3% had a stereo vision of 25°, 16.7% of respondents had changed stereo vision of 30°, and 6.7% of 40°. Therefore, statistically significant differences in stereo vision occurred both in the student group ($p = 0.000$), as well as in the group of air force pilots ($p = 0.025$) (Table 1).

Table 1

Stereo vision in student pilots and air force pilots before and after the test of the linear increase acceleration

Stereo vision	Student pilots (n = 30) n (%)	Air force pilots (n = 65) n (%)	Significance*
Before the test			
20''	30 (100)	65 (100)	
After the test			
20''	16 (53.3)	60 (92.3)	
25''	7 (23.3)	5 (7.6)	
30''	5(16.7)	0 (0)	$p = 0.000$
40''	2 (6.7)	0 (0)	
Significance†	$p = 0.000$	$p = 0.025$	

Statistically significant difference: *between student pilots and air force pilots; †before the test vs. after the test within the observed groups of subjects (χ2-test).

Discussion

Average values for stereoscopic vision in student pilots and air force pilots upon exposure to positive G acceleration showed that there is a statistically significant deviation in comparison to stereo vision values prior to being exposed to acceleration force. Interestingly, no changes of this kind have been recorded by other authors. Stereo vision testing has mostly been conducted on motor vehicle drivers [9, 10, 13–15]. Changes in stereo vision observed in our research may affect flight safety and good performance in combat missions.

Good stereo vision, being the highest degree of binocular vision in the pilot population, allows the pilot to see the landscape and all the perceived objects as they are (slope of the terrain, height, depth, flatness of terrain). Therefore, stereo vision is an important visual function that undergoes considerable changes when exposed to positive acceleration. In our research, stereo vision returned to its normal value 30 minutes after being exposed to acceleration.

Conclusion

The obtained results will contribute to the expansion of knowledge necessary for the quality selection of pilots, the most expensive population in any army. It is important to know the limits of tolerance to positive acceleration and find ways to tolerate such acceleration in the best possible way with minimum consequences to the pilot's visual functions while flying modern high-performance fighter aircraft. Temporary changes in stereo vision in student pilots are greater when compared to the changes in the same functions of vision in air force pilots when exposed to the same acceleration (+5Gz acceleration). The detailed analysis showed that the most sensitive physiological indicators were changes in stereo vision. We confirmed that individual physiological pilot training in a human centrifuge, where they are exposed to real G acceleration, improves tolerance to accelerations.

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