TITLE: Spatial Disorientation Experiments and Training in Polish Air Force Institute of Aviation Medicine

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SUMMARY

Spatial disorientation (SD) is a long recognised problem in aviation environment. During flight the spatial disorientation may appear as a result of inadequate perception of the position or attitude of an aircraft in comparison of the co-ordinate system constituted by the Earth surface. It is extremely difficult to say how often spatial disorientation became the reason of military aircraft accidents [6] but in Poland it is calculated at around 8%. There is no ultimate cure for spatial disorientation; the two ways considered most important are pilot training and extensive research leading to better understanding of nature of SD which is little known despite of about forty years of worldwide awareness about this problem. Probably every air force in the world has its own methods for SD prevention and training programme. We think that most comprehensive approach to this question is introduction of wide training program using all available equipment and conducting of further experiments increasing our knowledge about this very complex problem.

In 1998 PAFIAM went out with initiative of conducting the initial course and training counteracting spatial disorientation with polish military pilots using three simulators.

The full – mission flight simulator "Japetus" is the first element of this system of devices to work on spatial disorientation prevention.

Another device is lately obtained Gyro – IPT spatial disorientation simulator, which's main purpose in contrary to "Japetus" is use in spatial orientation demonstration and training. Both previously mentioned devices are lacking of important possibility in terms of presentation of influence of linear acceleration on pilot's vestibular system. To make possibilities of presentation and training more comprehensive we decided to include human carrying centrifuge into spatial disorientation programme.

SD EXPERIMENTS ON "JAPETUS" FLIGHT SIMULATOR

Problem of spatial disorientation is widely recognized as one of the most serious reasons of flight accidents. In this part we would like to describe some procedures developed at the Polish Air Force Institute of Aviation Medicine with use of flight simulator "Japetus" to counteract the phenomenon of spatial disorientation including situational awareness and visual illusions. We refer to the possibility of standard flight simulator use for investigation the spatial disorientation and training embracing that phenomenon.

Disorientation can be understood as a pilot reaction during the flight when he is forced to focus his attention on difficult meteorological conditions or the other part of the task, which don't allow him to control the whole flight situation. Pilots have to concentrate on different aspect of flight situation, i.e. speed, altitude, performed mission that make them more susceptible to spatial disorientation especially in terms of conscious processing. It may be the background of unaware disorientation (disorientation of type I). The pilot's flight performance in such a case is compromised because of perceptual misinformation. What is important pilot may fly unaware of his disorientation until it is too late for corrective action.

Two kinds of experimental flights on the flight simulator were performed: flights in IFR and in VFR conditions. The flight profiles have included: take off, some navigational tasks, approach, final approach and landing. Evaluation of flight performance was done on basis of manoeuvres precision, registration of eye movements and progress in following attempts of flights.

Paper presented at the RTO HFM Symposium on "Spatial Disorientation in Military Vehicles: Causes, Consequences and Cures", held in La Coruña, Spain, 15-17 April 2002, and published in RTO-MP-086.

The obtained results indicated that in IFR conditions the symptoms of loss of spatial orientation were observed. In those cases the two types of reaction took place:
- type I of disorientation – no counteraction,
- type II of disorientation – counteraction.

Within the second type cases the oculographic registration indicated increasing intensity of eye saccadic movements and longer time of fixation.

In good meteorological flight conditions eye saccadic movements and significant changes of fixation time were not observed. It leads to the conclusion that no spatial disorientation was encountered.
Additional conclusion of this part of research was, that method of eye saccadic movements measurements could be used for detecting the loosing of spatial orientation during both simulated and real flights.

Certain flight manoeuvres provoke spatial disorientation more frequently than others [8]. When pilot is aware of such phenomenon then is possible his earlier reaction and correction. In such a case pilot performs the manoeuvre knowing possible perceptual and vestibular misinformation, which can be intellectually controlled through corrective information coming from the flight instruments and indicators. It was mentioned that spatial disorientation might occur in different phase of flight. Can special training counteract it? How does deal with it? The pilots usually ask these kinds of questions.

For the purpose of that paper we have defined spatial disorientation as a state characterised by the false perception of one's position in relation to the Earth surface, which is caused by the senses misinterpreting the pilot's position in space. We have limited this part of experiments to the spatial disorientation caused by the visual factors.
The reason of such decision was, that during our research and analysis we found that classic hexapod (Stewart type) motion system of our flight simulator is practically unusable for spatial disorientation research and training in terms of producing illusions caused by angular or linear accelerations.
For our practical purposes we will discuss only vision as the most important source of information, which provide orientation to pilots. In that manner vision can also be thought of as being the most important sense controlling flight situation. That visual dominance is a potential cause of illusions and disorientation during flight. Aircraft accidents have occurred because of illusions caused by limitations of our sense of vision. Pilot's awareness of these illusions is important step in the prevention of possible incidents and accidents. The reduction of aviation mishaps can be achieved through improvement of spatial disorientation understanding and development of pilot training programs.

In these works we considered hardware improvements and practical possibilities of simulator adaptation and construction of methodical foundations counteracting to occurrences of spatial disorientation. Flight simulator "Japetus" serves as a one element of the complex system used to demonstrate and estimate the spatial disorientation.
Realisation of this assignments demanded many changes in the simulator software. These changes refer to:

- introduction additional element of visualisation. Those elements are mainly connected with meteorological conditions,
- textures Of Baltic Sea with the coast line,
- lights of cities with respect of their localisation. They are situated in vicinity of airfields with regard their geographical co-ordinates and have to be taken into account accidental configurations of street lights lying in straight lines,
- textures of skies including lights of stars. Points of light are motionless,
  using accidental arrangement and diverse intensity of shining,
- upper limit of clouds (with angle in range 1-5^{o}) which is diagonal to natural horizon,
- using the special plane-target, which serves as a tracking point for training pilots to shift their attention. The control of plane-target should take place from positions of instructor,
  -profile of plane appearing in central section of visualisation of simulator, having possibility of moving oneself in range of height 50-3000 metres. and dynamics of plane TS-11.
- "freezing" of flight instrument position with possibility of return to normal indications after time defined by instructor,

EXPERIMENTAL METHODOLOGY OF SPATIAL ORIENTATION TRAINING.

The initial course was projected for military pilots and included both theoretical background of spatial disorientation and experimental flights . In the first phase of the course pilots were prepared through series of lectures concerning the occurrences of spatial disorientation and its consequences. The main goal of this preparation was to increase their knowledge about the phenomenon and achieve better understanding of SD problems.

There were two kinds of experimental flights. The first one consists of start, approach, final approach and landing according of NDB's (non direction beacons) system and runs in instrumental meteorological flying conditions (IFR) with strong turbulence. The second one consisted of repetition above-mentioned flight pattern without turbulence in visual flight conditions. The valuation of flying performances was achieved thanks registration of eye movement and progresses in following attempts of flights.

RESULTS AND CONCLUSION

Results indicated that in IFR conditions with strong turbulence symptoms of loss of spatial orientation were observed which in consequence led to worse performance of executed flights. In cases of loss of spatial orientation (almost 60% of all flights performed) two typical reactions were observed:
type I of disorientation - no counteraction – (20%) and type II of disorientation- counteraction reaction – (40%). The oculographic registration in first group indicated increasing intensity of eye saccadic and fixation probably caused by necessity of verification of flight parameters.

In second group there weren't significant changes in intensity of eye saccadic and fixation. This fact can be confirmation of type II spatial disorientation.

SD TRAINING POSSIBILITIES ON "GYRO- IPT" SIMULATOR

Polish Air Force Institute of Aviation Medicine has acquired "Gyro – IPT" training device which is designed mainly to conduct spatial disorientation training for pilots. Gyro – IPT has a wide possibilities of presentation of visually evoked illusions and illusions based on angular accelerations in three axes. Significant advantages of this device are extended editing options. They cover possibility of changing aerodynamic aircraft model, mission parameters, navigation aids etc. It allows development of country - specified training program in terms of used aircrafts, procedures and terrain. Apart from software options provided by the manufacturer we have developed some our own training procedures. Proposed training syllabus consists of three steps.

First part of training is prepared for cadets of last year of Polish Air Force Academy and pilots with low experience in flying in IFR conditions (III class military pilot).

Second part is designed for pilots with medium experience (II class military pilot).and those returning to flying duties after long absence (more than 6 months).

Third part covers most advanced aspects of spatial disorientation and is suitable for experienced pilots (I and master class military pilot).

Every part of syllabus is in some matters repetitive because is designed partially as a "refresher" for previous parts.

Total training time is 2 hours of practical exercises on simulator per step predecessed by 3 hours of lecture and presentation.

Currently available SD training sorties are:

1. Coriolis illusion emerging as a result of cross – stimulation of vestibular apparatus after rapid head movements during circular motion.
2. Somatogyral illusions – result of false perception of rotation through semicircular canals
3. Oculogravic illusions – false perception of motion of another object as a result of nystagmoidal movement of eyeballs after stimulation of vestibular system by angular acceleration
4. Advanced oculogravic illusions – false perception of motion of another object as a result of nystagmoidal movement of eyeballs after stimulation of vestibular system by angular and linear acceleration
5. Graveyard spiral – ceasing of perception of prolonged circular motion (despite its continuation)
6. Nystagmus – cyclic, involuntary eyeballs movements after stimulation of vestibular system with variable angular accelerations.

7. Leans illusion – false perception of wings not being level after subtreshold roll movement with supratreshold recovery from previous attitude.
8. Advanced version of the leans illusion – during complex roll and yaw subtreshold movements with supratreshold recovery from previous attitude.
9. Autokinesis illusion – false perception of movement of stationary light in darkness.
10. Illusions connected with wrong perception of attitude and distance caused by atypical dimensions of runway .
11. Dark hole illusions – caused by lack of auxiliary fixing light points in pilot's field of view.
12. False horizon illusions – false interpretation of visible horizon e.g. clouds lines.
13. Dark takeoff illusions – uncertainity in assessment of attitude without visual reference.
14. Sloped runway illusions – false perception of attitude in distance in mountain terrain.

GYRO – IPT is also equipped with "helicopter option" which means possibility of simulation one engine rotary wing aircrafts. Program for presentation and training SD for helicopter pilots is currently under development.

SD EXPERIMENTS ON HUMAN CARRYING CENTRIFUGE

Previously mentioned training devices have disadvantage of lacking possibility of simulation of gravitational environment similar to real flight conditions. "Japetus" flight simulator has no such possibility at all, "Gyro – IPT" capabilities are limited to angular accelerations of limited magnitude. Because of importance of acceleration induced illusions we decided to use human carrying centrifuge to set – up somatogyral and somatogravic illusions.

Main goal of this task was to project and verify acceleration profile, which should generate illusions in trained pilots. In our preliminary test the subjects were 6 pilot candidates with small or no previous flight experience. For this research we used Polish Air Force Institute of Aviation Medicine centrifuge. It is centrifuge with 9-meter rotating arm, which we think, has a better possibility to add linear acceleration to angular in order to set – up somatogravic illusions than short arm devices (Gyro – Lab). Our centrifuge has a free moving gondola, which's angle with arm is dependent on current acceleration in range from 24° for 1,1G to 15,5° for 4G. We didn't use acceleration greater than 4G because change of angle with greater acceleration is very small and we were mainly concerned about Gx not Gz acceleration.

During our experiments we measure an angle between real horizon and the line representing horizon in centrifuge cockpit. Test task for subject was maintaining with flight controls level of artificial horizon in accordance to perceived real horizon level. Value of the test was assessed on the base of conformance of phase of registered stick movement with gondola movement phase. We discovered high variability of results between subjects with maximal difference between best and worse result being 22°. Greatest disturbances of perception of gondola roll we discovered during centrifuge "creeping" with acceleration in order 1,4 – 1,5G. It is also moment of greater change in angle of bank from 0° for full stop to 48° for 1,5G. The results obtained revealed two important factors: firstly in one subject we observed high repeatability of angle of bank in consequent runs and secondly persistence of bank perception during centrifuge braking. First observation is of great importance suggesting that despite individual variations, susceptibility for SD on one subject is fairly stable what after further research in extended time period can give assumption to selection of candidates in aspect of SD susceptibility .

FINAL CONCLUSIONS.

During last few years our knowledge about both theoretical and practical aspects of spatial disorientation increased as a result of conducted research works. But question of providing some precautive measures against SD is very complex and still open. Because of its nature phenomenon of false perception of spatial attitude and motion is difficult to quantify and matter of development selection test is remote in time, but current works show some promising results especially in area of oculographic measurements. Further directions of research should be improvement of current training protocols and extension of training possibilities in terms of available simulators. But development of method estimating spatial disorientation if of great importance because apart from selection will allow us to validate current methods of training as a method of SD prevention and probably develop new ones with greater efficiency in preventing aircraft mishaps caused by this phenomenon.

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