Pilot Disorientation, Sensorial Response Measured by Dynamic Posturography in SPAF Pilots

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INTRODUTION

Spatial disorientation (SD) is a real risk and one of the main causes of aircraft mishaps. Recent studies about accidents in military aviation (1,2,3,4,5) have calculated that approximately in 32% of the most serious accidents, SD is involved. Not in vain, practically the entirety of the pilots have experienced phenomenons of this type at during their flying career (6).

SD is a term used in aerospace medicine to describe a variety of circunstances occurring in flight in which the pilot fails to sense correctly the position, motion or attitude of the aircraft or of him/herself within the fixed coordinate system provided by the surface of the earth and the vertical gravitational (7).

The first person that demonstrated the existence of SD was the Major William Ocker in 1926, but in the last decades, the concept of SD has changed. SD should not be synonymous with vestibular or visual illusions alone, it also involves the behavioral responses and the cognitive integration of all sensory inputs (1).

To be able to guide ourselves in space, to maintain the posture and to make movements in a coordinated way, is a complex function that is organized starting from the information received by three sensorial systems, which are related to one another. The somatosensorial, visual and vestibular system (7).

During the flight the visual system provides the dominant information and it is the most important sense for the maintenance of the orientation and balance (8).

The vestibular system is an accelerometer capable of detecting movements of traslation, rotation and accelerations. It is related with the visual and somatosensorial systems by means of the vestibulo-ocular reflex (VOR) which stabilizes the eyes during the movement, the vestibulcollic reflex (VCR) which stabilizes the head and the vestibulospinal reflex (VSR) wich stabilizes the body (9).

Lastly, the somatosensorial system is formed by a group of muscles, tendons, articulations and nervous terminations of the skin. During the flight, the seated aviator perceives the forces that are exercised on him and he can describe many of the movements of the airplane for the pressure that the seat exercises on his body (10).

The SD takes place as consequence of a conflict among the received sensorial inputs (1,11,12,13).

A manifestation of SD is the motion sickness. Motion sickness is considered to be a normal physiological response to real or apparent motion to which an individual is not adapted (13). Its main symptoms and signs are pallor, cold sweating, nausea, which progress in severe cases to recurrent vomiting, and in less occasions, it is accompanied by headache, apathy and drowsiness (11).

This does not only happen in real flight, but it has been demonstrated that more than 29% of the subjects experience motion sickness after flights in spatial orientation / disorientation trainers (14), which, in order to provide more realism, have been developed vastly in therecent years (15).

The training in these trainers is gaining bigger relevance day after day, because they make the pilot experiences phenomenons of SD, teaching him to recognize them and to avoid them, to correct them or to counteract them later in real flights.

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It is interesting, therefore, the evaluation of the effects caused by this type of training on the equilibrium and coordination of the pilot and the influencerepercussion that it would have on his flight activity and on flight safety.

The clinical evaluation of balance is multiple, because it supposes the study of the somatosensorial, visual and vestibular systems. They are many exploratory techniques developed up to now, for the study of these systems, but only the Computerized Dynamic Posturography (CDP), marketed as Equitest by the signature Neurocom, it allows the integrated study of balance, differentiating the contribution of each one of the three previous systems in the maintenance of equilibrium.

Nashner began to develop it with funding by NASA, in 1970, to carry out his thesis, that was based on studying, with this new technique, the postural control of the students of the University of Massachusetts (16).

Later on, this method evolved and it was used to evaluate the postural control in astronauts returning from space (17) and for the clinical study of the alterations of balance (18) and it has even been proposed intended as an useful technique to predict the future susceptibility to the motion sickness (11).

The advantage of the CDP, regarding other tests, resides in that it can evaluate the interaction of the vestibular, visual and somatosensorial inputs of the subject on a independent way to determine the individual contribution of each one of the three sensorial informations, for the maintenance of balance (18,19).

Contrary to the other techniques, it allows to study the VSR in an independent way, through movements of the centre of pressure and projection of the centre of gravity of the body on a platform with motion (18), it also supplements other tests that study the OVR like the caloric tests and Barany´s seat (20).

However the CDP is not valid by itself to make a differential diagnosis among different vertiginous pathologies, but it is able to differ among normal and abnormal balance and it is a very useful method to quantify the functional state of balance in patients, so much in relation to their capacity to adapt to conflicting environmental sensorial stimuli, as to reorganize the sensorial inputs in the event of pathological deficiencies (18).

The objective of the present work has been to study the relationship between subjective sensations of spatial disorientation and modifications in the response of the visual, somatosensorial and vestibular patterns, by CDP, after exposing pilots, with flight experience, to diverse profiles of SD in the Gyro GPT II trainer.

The study hypothesis was that because of in the maneuvers of SD carried out with trainers, it produces movements that stimulate the visual, somatosensorial and vestibular systems, causing disorientation and motion sickness, it is possible to expect that these stimuli generate momentary changes in the organization and maintenance of balance and that those changes can be registered immediately by CDP after this stimulation.

MATERIAL AND METHODS

80 pilots of the Spanish Air Force participated in the study. It was carried out in the of Flight Physiology Unit and in the Otorhinolaryngology (ORL) department of the SPAF Aeromedical Center (CIMA) during the months from June to December of 2001.

The sample was selected at random among pilots that came to this Center to participated in the of physiological training programme. The inclusion criteria were to belong to the Spanish Air Force, to be in active and to develop flight duties as fighter or transport pilot.

In the first phase the pilots were subjected to diverse types of somatogyral illusions (coriolis, leans, spin) in the Gyro GPT II trainer. After that they answered a questionnaire including the following data: age, weight, height, habits (consumption of alcohol, tobacco), exercise, flight hours, type of aircraft flown, previous episodes of SD and motion sickness. Personal observations about the profiles trained and presence or not of symptoms of SD or motion sickness (nausea, vomiting, sickness, pallor) during the training were also collected in the questionnaire.

In the second phase the control of balance of these subjects was evaluated by dynamic posturografy in the ORL department.

The time between the first and the second phase should not excede more than seven minutes.

In order to avoid reducing the effectiveness of the test derived from learning effects, suggested by some authors (14), and because of theses subjects, for their professional activities, have been previously selected without any balance disorders or pathologies, we did´nt carry out a previous PDC in these pilots.

The CPD (Neurocom Equitest) is a computerized method developed for the study of the posture and balance whose system is formed by a mobile platform, a visual environment and a computer system. With the CPD, the sensory organization test of balance (SOT) and the motor control test (MTC) the responses of stretching and displacement and oscilllation of feet before small stimuli can be studied. We only carried out the SOT, beacause we consider that the MTC will not provide significant data in this study since motor responses are not affected in this type of simulators. These tests consist on valuing the subject's balance measuring his oscillation postural in anteroposterior position in six different sensorial conditions. In each one a different stimuli are applied annulling the visual and/or somatosensorial inputs to study the individual values of balance:

Condition 1: open eyes, fixed visual environment and fixed support platform.
Condition 2: closed eyes and fixed support platform.
Condition 3: open eyes, mobile visual environment and fixed support platform.
Condition 4: open eyes, fixed visual environment and mobile support platform.
Condition 5: closed eyes and mobile support platform.
Condition 6: open eyes, mobile visual environment and mobile support platform.

This method allows examine the ability of each person to use the somatosensorial visual or vestibular systems in the control of balance.

The results of these tests are evaluated automatically comparing them with the normal results and they are registered in a diagram of bars scoring the results from 1 to 100%.

For each one of the six conditions we consider as normal (control group) the mean values obtained in a study carried out in the ORL department in a population of 250 soldiers with ages between 20 and 45 without signs or symptoms of previous pathology of equilibrium (Table 1).

Table 1: Results of the equitest in a population of 250 soldiers (control group)

Condition	Means values N=250 Age = 20-45
1	94
2	92
3	91
4	82
5	69
6	67

For the sensorial analysis we consider as normal the mean values obtained in the same population for each one of the different patterns (somatosensorial, visual, vestibular and preferential) as it is showed in table 2.

Table 2; mean values obteined in the population taken as reference (control group) for each one sensorial pattern (somatosensorial, visual, vestibular and preferential)

SENSORIAL ANALYSIS	Means values N=250 Age = 20-45
Somatosensorial pattern Condition 2/ Condition 1	0.97
Visual pattern Condition 4/ Condition 1	0.87
Vestibular pattern Condition 5/ Condition 1	0.73
Preferencial pattern Condition 3 + 6 / Condition 2 + 5	0.98

The results of the equitest and the data obtained in the questionnaire were incorporated into a database using the Statistical Package for the Social Sciences (SPSS) 9.0 statistical computer program for Windows Release 6.0. We carry out a descriptive study of the variables using the Kolmogorov-Smirnov test to determine the adjustment to the normal of the quantitative variables. We calculate mean and standard deviation by the quantitative variables and proportions for the qualitative ones. For the comparison of means the Student´s t-test or ANOVA have been used according to the characteristics of the variables and the Chi2 test for the comparison of proportions. Chance probability of $p \leq 0.05$ was accepted as critical for statistical significance.

RESULTS

All subjets studied were male with ages ranging from 20 to 39. The mean age was 27.29 ± 4.74. The average height was 177.71 ± 7.52 cm (range from 154 to 195 cm) and the mean weight was 76.71 ± 9.58. 44.8% of the subjects were fighter pilots and 55.2% transport pilots. The mean flight hours was 1309.84 h.

The data collected in the questionnaire showed that 40% of pilots suffered from motion sickness, mostly during the instruction period and later starting again flight duties after a resting period.

According to the type of aircraft flown, we found that 43.3 % of fighter pilots and 33.3% of transport pilots described motion sickness symptoms but this difference not was statistically significant.

On the other hand, 50% of the pilots reported spatial disorientation episodes mostly flying under conditions of limited visibility and changing from visual to instrumental flight.

Relating to type of aircraft flown and presence of spatial disorientation episodes, were the fighter pilots who suffered these episodes with greater frecuency (73.3%), comparing them with transport pilots (25.9%), having besides this relation statistical significance ($p = 0.000 < 0.05$).

61.5% of pilots said to be experimenting light sensations with regards to the stimuli provoked during the training in the Gyro. These sensations were moderates in 34.6% of pilots, however in no case, major symptoms of motions sickness, like pallor, nausea or vomiting, appeared.

Table 3 shows the results obtained in each one of the six conditions of balance after subjected the pilots to trainning in the Gyro.

Table 3: Results of the equitest for each one of the 6 conditions of balance.

	N	Minimun	Maximun	Mean	Desv. típ.
CONDITION 1	80	86.00	98.00	94.78	2.25
CONDITION 2	80	80.33	97.00	93.12	2.55
CONDITION 3	80	87.00	97.66	93.10	2.52
CONDITION 4	80	74.33	96.33	88.55	3.94
CONDITION 5	80	5.00	94.33	68.65	11.70
CONDITION 6	80	.00	88.66	68.38	14.82

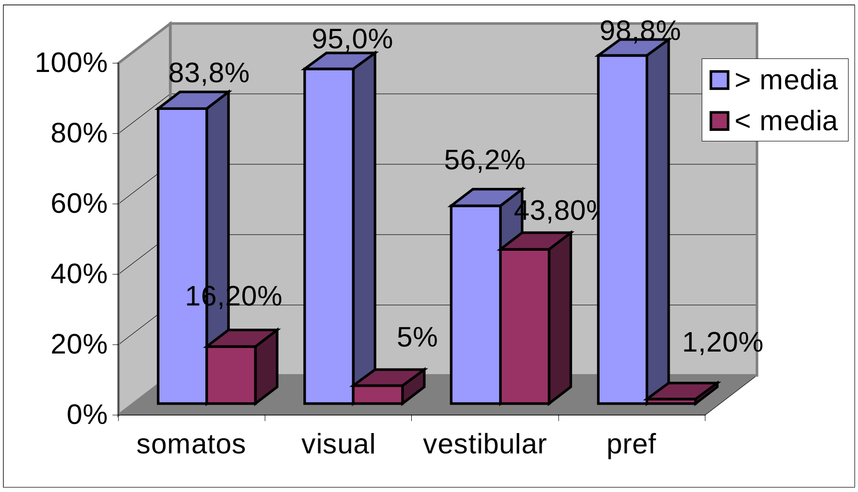
The results of sensorial analysis for visual, vestibular and somatosensorial patterns are in table 4

Table 4. Results of sensorial analysis

	N	Mean	Desv. típ.
somatosensoria	80	0.98	2.741E-02
visual	80	0.93	4.236E-02
vestibular	80	0.72	0.1240
preferential	80	162.49	12.5323
Total	80		

Comparing the results obtained after submmiting the pilots to several spatial disorientation profiles with the control group (fig. 1) we found that was the vestibular response the most affected, since the 43.8% of pilots reached values under the mean taken as reference (table 2) and even in three cases we found a disfunctional vestibular pattern. The 16.2% and the 5% of pilots presented a somatosensorial and visual pattern respectively, after stimulation, under the mean values comparing them with the control group. However the preferential pattern hardly was affected (1.2%) reaching a mean value above of control group.

Fig 1: Results obtained in pilots comparing them with control group



We did not find any relation statistically significant between the values obtained in the sensorial analysis for each one of patterns of equilibrium and age, height, weight and flight hours.

When we analysed type of aircraft flown and results of the equitest after stimulations we obtained a mean for the vestibular pattern lower in fighter pilots (0.67) comparing with vestibular values in transport pilots (0.73), being this relation statistically significant ($p = 0,01 < 0.05$).

On the other hand, there was not a statistically significance between results obtained in the equitest and sensations reported by the pilots during the training and collected in the survey.

However comparing each one of the differents patterns of balance with presence of previous symptoms of motion sickness we got a statistical significance for the vestibular pattern. That is, the majority of subjetcs with history of motion sickness showed higher values in the vestibular pattern after trainning in the Gyro, while the majority of pilots without previous symptoms of motion sickness the values reached for these pattern were much lower.

DISCUSSION

The DCP is a diagnostic technique that supplements other methods and it also provides new possibilities for the study of balance system. This method is used as much in pathological as in healthy people for the study of equilibrium, being able to determine the level of affectation of this system in those subjetcs exposed to certain movements and specific conditions, like astronauts returning from space, marines after a trip in ship and aviators after flights or simulator training (18,20,21).

All studies that have been carried out wiht this technique (11,13,14,19,20,22) have conclude that DCP is an useful test, because it offers the possibility to supress one or simultaneously two sensorial inputs, vestibular, visual or somatosensorial, that the subject receives for the organization and maintenance of balance, in order to evaluate the individual contribution of each one of these sensorial systems in the maintenance of equilibrium.

In our study, the results obtained by DCP have shown the functional state of balance in pilots after exercises of SD, in relation to their capacity to adapt to unusual or conflicting environmental sensorial stimuli, so it confirms that indeed changes in the functional organization of balance of pilots during the training have been produced, regarding the control group, and that this changes can be registered by DCP.

The ability to use the vestibular inputs was the more affected after trainning, showing in 43.8% of the pilots a vestibular pattern below the mean value of the control group and even in 3 cases a pattern of moderate dysfunction. On the other hand we observed in these pilots a higher dependence on the visual information for maintenance of balance and to overcome spatial disorientation phenomenons since practically the ability to use the somatosensorial and visual inputs were not affected, at the time that the preferential analysis, or dependence on the visual information for maintenance of equilibrium, was normal or lightly above the mean taken as reference.

This results indicates that the pilots, during the flight, use much more the information that they receive through the vision system than the one collected by the vestibular system and this could explain why the pilots describe more SD phenomenons in circumstances in wich the visual inputs are diminished like flying in bad conditions of visibility or changing from visual to instrumental flight. Other authors have also demonstred in their studies this increase of SD phenomenons in pilots flying under conditions of diminished visibility (23,24).

We coincide with Black et al. (17,20) who have demostred by DCP that astronauts after a space flight, presented a higher dependence on the visual and somatosensorial systems that the vestibular system for the organization and maintenance of balance, during the period of recovery after flight.

We have also found a relation statistically significant ($p < 0.05$) between previous episodes of motion sickness and values obtained in the vestibular pattern. That is, those pilots that have reported more motion sickness symptons during real flights, along their professional trajectory, presented a higher ability or dependence on the vestibular inputs for the maintenance of balance while the ones with no history of motion sickness gave a lower ability or dependence on the vestibular inputs for the manteinance of equilibrium.

These results also agree with Black (20) where astronauts with lower dependence on the vestibular inputs have manifested less symptoms of motion sickness.

On the other hand, we have not obtained a relation statistically significant between sensations manifested by the pilots during the trainnig and results obtained in the DCP.

In relation to the type of aircraft flown, the mean value for the vestibular pattern in fighter pilots (0.67) was lower that for the group of transport pilots (0.73), althought was not a correlation with motion sickness sensations described by the pilots after stimulation in the Gyro. So we think it could be the type of flight (higher accelerations and maneuverability in fighter aircraft), what determins the postural responses and the strategy of balance in the group of fighter pilots.

For this reason we think that the results obtained by DCP can be influenced by the type of individual training during long time and not for the stimuli generated during exercises of SD in the Gyro, and that they are the repeated expositions to complex movements and accelerations (higher in fighter than in transport aircrafts), the cause of changes in the strategy of balance in pilots (theory of the plasticity) (7,21), generating stimuli that alter or reduce the capacity to use the vestibular inputs for the maintenance of equilibrium, at least during a period of time and while the exposition to these stimuli is repeated in a regular way.

This indicates that the learning of pilots, to depend on the visual references above the vestibular ones, provides a higher resistance to disorientation episodes and decrease the presence of neurovegetatives symptoms associated to sickness. However, the high dependence or ability for the use of vestibular inputs, as use to happen after a resting or inactivity period, favors the appearance of sikness.

This habituation of the pilot to conditions of sensorial conflict, which occur in an adverse environmental like the air one, it has been showed in others studies (8,11,22).

However we cannot assert, as other authors (11,19) that the DCP is a valid test for the prediction to suffer motion sickness during flights, in inexperienced subjects, because our study has been carried out in personal with a great flight experience; although this technique could be useful to evaluate the level of training and adaptation of the pilot to the flight, according to its more or less dependence on the visual and vestibular inputs for the maintenance of balance.

CONCLUSIONS

We conclude saying that the results obtained by DCP have shown the functional state of balance in pilots after SD exercices, in relation to their capacity to adapt to unusual or conflicting environmental sensorial stimuli.

It was evidenced in pilots a higher dependence on the visual information for the maintenance of balance and to overcome spatial disorientation phenomenons and a lower ability or dependence on the vestibular inputs.

We think that the most dependence on the visual information above the vestibular inputs contributes to reduce the appearance of neurovegetative symptoms associated to sickness.

And lastly, the relationship between the results of the DCP and neurovegetative symptoms associated to sickness allows us to conclude that the DCP could provide information about the level of training of pilots and their sensibility to disorientation maneuvers.

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