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RECOMMENDATION TO IMPLEMENT GYRO-IPT FOR DISORIENTATION TRAINING AT CFSAT

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Executive Summary

With the acquisition of the GYRO IPT (ETC) at the Canadian Forces School of Aeromedical Training (CFSAT), an evaluation was completed to determine the usefulness of this device and how it might be implemented into existing undergraduate pilot training syllabus.

The GYRO IPT is the most recent version of the GYRO-1 series of flight simulators. It features upgrades on the pitch and roll motion capability and options for data acquisition and medical monitoring. The major advantage of the device is its interactive closed-loop (pilot-in-the-loop) feature that forces the trainee to relate any demonstration to actual flight situations. In summary, the motion capability of the GYRO-IPT is able to elicit the type of vestibular illusions that are related to the inadequacy of the semicircular canals system (incapable of detecting constant velocity motion).

However, due to the limited pitch (+/- 15 degrees) and roll (+/- 30 degrees) capability and the lack of planetary rotation, disorientation illusions that can be demonstrated by the GYRO IPT are limited to the type of vestibular illusions that are related to the inadequacy of the semicircular canals system. For example, Coriolis cross-coupling and somatogyral illusions are very convincing. The device also reasonably demonstrates most of the visual illusion profiles such as autokinesis, black hole approach, false horizon, runway width and up-sloped runway. We find that the listing of nystagmus as an illusion is erroneous. Nystagmus is not an illusion but a physiological response to the sustained angular acceleration and deceleration acting on the semicircular canals. Due to the lack of positive G forces greater than one (which normally accompany the graveyard spin and graveyard spiral illusions in an aircraft) it is recommended that graveyard spin/spiral be replaced by a spin demonstration only. The timely implementation of the GYRO-IPT into current spatial disorientation lectures will be crucial to effective flight training.

Introduction

The GYRO-IPT (Integrated Physiological Trainer) manufactured by ETC of Southhampton, N.J. is a flight simulator designed to demonstrate selected spatial disorientation (SD) illusions. With the recent acquisition of the device at CFSAT (Canadian Forces School of Aeromedical Training), the appropriate and timely implementation of this device is highly desirable in order to realize its potential. The objectives of this DCIEM technical memorandum are: (A) evaluation of the capability of the GYRO-IPT and (B) recommendation for implementation of GYRO-IPT to SD training at CFSAT.

A. Evaluation of GYRO-IPT

The GYRO-IPT is the latest version GYRO-1 series of flight simulators with upgrades on the pitch and roll motion capability. The major advantage is purported to be its closed-loop feature that forces the trainee to relate any demonstration to actual flight situations. According to the manufacturer, this device can simulate the following illusions for fixed and rotary wing aircraft:

Fixed Wing	Rotary Wing
1f. Coriolis	1r. Coriolis
2f. Somatogyral Illusion	2r. Leans
3f. Graveyard Spin/Spiral	3r. Nystagmus
4f. Oculogyral Illusion	4r. Autokinesis
5f. Leans	5r. Black Hole
6f. Nystagmus	6r. Distance Depth Perception
7f. Autokinesis	7r. Flicker Vertigo
8f. Black Hole	8r. False Horizon-Night
9f. Dark Takeoff	
10f. False Horizon	
11f. Runway Width	
12f. Up-slope Runway	

The authors visited CFSAT in July 1998. During our visit we were able to experience most of the disorientation illusions as listed except the ones that were specifically designed for the helicopter. Our main objective was to integrate the GYRO-IPT into current undergraduate pilot training. The implementation of the GYRO-IPT into SD training for rotary wings will be dealt with at a later date.

The manufacturer has given Dr. Cheung numerous demonstrations on the device in the past years. Capt. Wong, a former Tutor Instructor from Moose Jaw, was given the opportunity to experience the disorientation profiles designed by ETC on July 22-23. Our observations and comments are reported as follows and are intended as positive

feedback to facilitate the implementation of this device into the Canadian Forces flight training program.

The motion capability of the GYRO-IPT is able to elicit the type of vestibular illusions that are related to the inadequacy of the semicircular canals system (incapable of detecting constant velocity motion). Therefore, it effectively demonstrates most of the listed disorientation illusions with the following areas that require further attention and in some cases the explanation of the illusion should be elaborated to achieve effective training.

Stick Handling Pressure

At the time of our trials the stick-handling control of the GYRO-IPT remained too sensitive. Pilots that were exposed to the device have also noted this problem. Twelve out of twenty-six pilots reported that: "it is difficult to fly" or "the simulator is not working properly" (from CFSAT questionnaires). CFSAT was alerted to the problem of unrealistic feel. Attempts to correct the problem have been made. However, in our opinion, further adjustments are required. If the problem persists, it will interfere with the intended training. One pilot from the survey commented that he had to concentrate on the stick control so much that he was not aware of the illusion that was being demonstrated to him. Another direct quote from the same survey: *"the Gyro is very touchy, very difficult to fly, it's difficult to tell whether one's inability to fly is based on SD or the touchy control"*. We would suggest that (i) ETC should be contacted again to rectify the problem, (ii) if time permits, trainees should be given ample amount of time to become familiar with the control characteristics of the device before being exposed to the various types of disorientation illusions.

1f. Coriolis Illusion

The Coriolis illusion or Coriolis cross-coupling is demonstrated effectively. Even if it is not directly responsible for spatial disorientation in flight, it is an important exercise to demonstrate the fallibility of the vestibular system as orientation cues. This illusion can also be demonstrated using any rotating chair if the GYRO-IPT is not readily available.

Coriolis illusion or Coriolis cross-coupling effect is a common perceptual illusion that causes almost as much confusion in its discussion as in its experience. It is compounded by the results of frequent unpleasant motion sickness symptoms. Therefore the demonstration should be accompanied by careful explanation as to the imperfect integration of the semicircular canals and conflicts with the otolith systems during such movements. At the very least the correct consequences of the demonstration should be given during debriefing. For example, if the trainee is given a constant velocity yaw rotation to the right for 30 seconds or more (until the sensation of yaw rotation dies off) and is instructed to execute a pitch forward movement, the resulting Coriolis illusion experienced by the trainee is that of a sudden rolling and yawing to the right. The

sensation of discomfort and development of motion sickness symptoms resulting from these cross-coupled angular accelerations are most likely attributable to the conflict between the semicircular canals and the non-confirming otolith cues rather than to the unexpected cross-coupled angular acceleration signal acting on the canals themselves.

Minor Coriolis sensation could be induced when pilots in high performance aircraft undergo prolonged constant angular velocity and instrument flying. The Coriolis cross-coupling effect should not be confused with the G-excess illusion. The G-excess illusion also involves head movements in flight. However it occurs when a large radius coordinated turn is flown with a resultant acceleration of 2-3G but with very low angular velocity.

The Coriolis illusion should be demonstrated again prior to instrument flight, the idea to impart on pilots is that the vestibular sense cannot be trusted, the most important lesson of all for instrument flying.

2f. Somatogyral Illusion

The somatogyral illusion is a false sensation of rotation or the absence of rotation that results from the inability of the semicircular canals (acting as angular accelerometers) to detect a prolonged constant speed rotation. Therefore, during a prolonged turning maneuver at constant angular speed, either in a coordinated turn, a sustained roll, or a spin, receptors in semicircular canal report only correct information during the first few seconds of the maneuver. The graveyard spin and the graveyard spiral (common in modern aviation) are two classic examples of how the false sensation of rotation (and the lack of it) can disorient pilots. The graveyard spin and graveyard spiral should be introduced as examples of the somatogyral illusions but not as separate categories.

In general, we feel that the demonstrated somatogyral illusion was valuable. However, the bank angle should be reduced to avoid the possibility that the pilot may acquire the desired heading too soon, thus rolling out prior to the sensation of spinning in the opposite direction is perceived.

3f. Graveyard Spin/Spiral

This maneuver should be renamed simply as "Spin Demonstration and Spin Recovery" as there is no significant spiral action. The term "graveyard" is not appropriate due to the lack of G force during the pullout phase. In order to make it more convincing, we suggest that (i) before the demonstration, notify the pilot that there will be a lack of G forces during the pull-out due to the lack of planetary rotation of the device; (ii) reduce the indicated airspeed. The spin should be entered at 25,000 feet AGL with the command to recover at no lower than 13,000 feet AGL to avoid conflict with unusual attitude recovery procedures in Moose Jaw. This spin should be administered under VFR conditions of flight preferably over a combination of water and land so that the

pilot may see when he/she has stopped the autorotation during the spin recovery (i.e. provide an improved visual reference). As well, the velocity of the aircraft while in the spin should be reduced to 20-30 knots thus the lack of "G" experienced by the pilot during recovery will be more appropriate.

4f. Oculogyral Illusion

We were unable to evaluate this illusion due to the break down of the device. However, in simplified terms, oculogyral illusion is the visual correlate of the somatogyral illusion. We are confident that if the somatogyral illusion demonstration was given properly as stated above, the oculogyral illusion would not be far off. In this illusion, when the pilot falsely perceives that the aircraft is turning in a particular direction (for example to the right), he/she should also observe the instrument panel moving in the opposite direction (to the left).

5f. Leans

The GYRO–IPT introduces the leans (false sensation of bank) effectively during a simulated coordinated bank turn with a subthreshold roll motion. Trainees should be made aware that there is more than one form of this illusion, although the common cause is the result of unperceived error in roll attitude. Three other forms have been identified:

- (i) Pilots allow one wing of the aircraft to drop at a rate below threshold roll detection (0.5-5 degrees/s).
- (ii) A supra threshold change in the roll attitude (a sudden gust) followed by a sub threshold return to the wings level position.
- (iii) An innate directional asymmetry in the pilot's ability to detect changes in roll attitude has also been cited as one of the causes of leans.

6f. Nystagmus

The listing of "Nystagmus" as an illusion is erroneous. Nystagmus is an involuntary eye movement. It is a normal physiological response to sustained angular acceleration and deceleration acting on the semicircular canals. This characteristic jerky movement of the eyes is observed at the start and end of a period of rotation. It is a reflex that maintains visual fixation on stationary points while the body rotates. When rotation starts, the eyes move slowly in a direction opposite to the direction of rotation. When the limit of this movement is reached, the eyes quickly snap back to a new fixation point and then again move slowly in the other direction. The slow component is initiated by the impulse from the semicircular canals; the quick component is triggered in the brain stem. Nystagmus is frequently horizontal (i.e. the eyes move in the horizontal plane); but it can also be vertical during pitch rotation, or torsional during roll rotation. Our current research further demonstrated that nystagmus can also be induced by high

frequency linear acceleration (as one would experience during tangential accelerations in F-18s). It is demonstrated in the GYRO-IPT by performing two prolonged banking maneuvers followed by a leveling maneuver. A sub threshold spin is maintained throughout the demonstration resulting in nystagmus once the pilot levels the GYRO-IPT.

The reason that nystagmus should be discussed and demonstrated (either using the GYRO-IPT or a simple rotating chair) during SD lectures is as follows. In order for us to maintain visual acuity, the retinal image must be stabilized; that is, any eye movements should not be greater than 3 degrees/second. Therefore, if nystagmus is to occur during an inopportune time, it might interfere with object recognition (i.e. cross-checking an instrument). The etiology of SD includes inadequate or erroneous sensory input (in this case, visual input) being transmitted to the brain. One of the remedies for nystagmus is visual suppression by asking the pilot to fixate on a point source that could shorten the duration of nystagmus.

7f. Autokinesis

The amount of time required to perceive the illusion was unusually lengthy (3 min. was reported from one of the CFSAT questionnaires and our experience was 60 seconds). Typically, the autokinetic effect is apparent in 6 to 12 seconds. We suggest that reducing the size and the brightness of the light seen against a dark background would shorten the latency of autokinesis.

8f. Black Hole Approach

An analogy should also be made after this demonstration that in the Canadian climate, an atmospheric whiteout and blowing snow whiteout approach can be as difficult as a blackout approach for essentially the same reason, which is the lack of sufficient ambient visual orientation cues. During a black hole approach, pilots would continuously cross-checking his/her instruments, therefore the altimeter should not be deleted from the pilot's view.

9f. Dark Takeoff

This illusion should not be given. The misperception of pitch angle is artificially given by freezing the attitude indicator (A/I) after takeoff. Pilots in Moose Jaw are trained specifically to transition visually to the A/I after a dark takeoff in order to ensure a climbing attitude. This is a standard safety practice. By freezing the A/I to demonstrate the misperception of pitch angle from a linear acceleration this illusion casts doubt upon this safety practice. This illusion would thus be contrary to SOP (Standard Operating Procedure) in the CF.

10f. False Horizon

The false horizon indicates the condition where the horizon perceived through ambient vision is not really horizontal. For example, when a pilot misperceives a sloping cloud deck as the horizontal surface. Misperception of the horizontal could create hazards in flight. This particular demonstration is restricted due to the limited horizontal visual field afforded by the 21-inch monitor. A possible remedy for this limitation is to turn the trainee (the cockpit) 90 degrees to the right so that they may actually see the sloping cloud bank against the true horizon.

11f. Runway Width and 12f. Up-Slope Runway

Both of these mis-perceptions (of being too high or low on approach due to runway width or slope) are satisfactory as presented. After the demonstration of an up-slope runway, in which the pilot may fly too low due to the illusion of being high on the approach path, the effect of a down-slope runway (which has the opposite effect) should also be discussed.

B. Recommendation to implement GYRO-IPT to disorientation training at CFSAT

Currently, the Canadian Forces pilot training curriculum is separated into 3 distinct stages:

- Stage 1. Primary Flying Training at Portage la Prairie,
- Stage 2. Basic Jet Training at Moose Jaw, and
- Stage 3. Advanced Jet/Multi-engine/Helicopter Training at either Portage la Prairie or Moose Jaw.

After the third stage, a pilot is wings qualified and located onto an operational squadron.

Timing of SD training is one of the important factors in achieving the effectiveness of the training program and to fully utilize the potential of any training devices. This issue has been previously discussed in DCIEM report no. 98-R-32 (Cheung 1998). If SD training is too far in advance of flight training, students might forget important material concerning SD before they get the chance to experience SD in flight. It is suggested that training of any nature is more effective if distributed over several sessions. Therefore, "reviewing" SD is more effective after primary flight training ground school (before actual flight) at Portage la Prairie and after basic jet training in Moose Jaw with the implementation of the GYRO-IPT in both stages. We recommend implementing GYRO-IPT as part of SD training to be carried out as described below. We are fully aware of the possible restriction that might be imposed by fiscal restraints, but the possibility of a future SD-related accident will be more costly.

Phase 1 after completion of ground school at Portage la Prairie and prior to flight.

A basic introduction to SD illusions should be integrated with the following demonstrations.

1. Coriolis Illusion
2. Spin demonstration and spin recovery demonstration
3. False Horizon

Much of what students learned about SD is not formally tested and therefore may not receive the attention it deserves. We would recommend that formal testing should be implemented as part of the training at this stage.

After Phase 1 at Portage it is not necessary to bring the students back to CFSAT. In fact this may be detrimental to their training because all student pilots at this stage of their flying careers are VFR pilots. That is, the pilots are taught to look outside to fly. Since the simulator has only a forward-looking screen and many of the maneuvers require use of the instruments, this may cause a new pilot to "bury his/her head" in the cockpit; a definite undesirable effect before jet training in Moose Jaw. After basic jet training in Moose Jaw a pilot has had a number of instrument flying hours, has flown at night, and is better prepared to understand and appreciate the illusions.

Phase 2 after completion of basic jet training at Moose Jaw.

A comprehensive course on SD including the following demonstrations should be given.

1. Coriolis
2. Somatogyral Illusion
3. Closed Loop Spin Recovery
4. Leans
5. Autokinesis
6. Black Hole Approach
7. False Horizon
8. Runway Width
9. Up-slope Runway

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Spatial Disorientation Training