SPATIAL DISORIENTATION DEMONSTRATIONS IN A DYNAMIC FLIGHT SIMULATOR

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Disclosure Information
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I have the following financial relationships to disclose:
• Consultant for: Qinetiq Sweden AB

I will not discuss off-label use and/or investigational use in my presentation
Background

Loss of spatial orientation remains a cause for accidents in military flight

Countermeasures used are:
- Technical solutions, such as terrain avoidance systems
- Preparation and planning, avoid potential disorienting situations
- Education for spatial orientation

Source: Finnish Air Force image gallery
Typical approach

Make the pilot familiar with disorienting situations

Education includes combinations of:

• Academic lessons
• Basic aviation physiology
• Review of SD accident reports
• Practical demonstrations of sensory illusions in some kind of ground-based training device
• In-flight demonstrations
Ground-based training devices

- Capability to generate visual illusions
- Scenarios and environmental control
- Pedagogical instructor functions
- Time efficiency, repeatability and safety
- Limitations in generation of vestibular stimuli (illusions)
- Limitations in generation of G-forces
DFS Simulation capabilities

- JAS 39 Gripen cockpit mock-up
- Real aircraft hardware: MB-seat, HOTAS and G-valve / breathing regulator
- Delta wing flight model
- Head-up and head-down display instrumentation
- Visual out-the-window displays, 100 degrees FOV
DFS concept

- Take advantage of the existing capabilities: the G-forces, the flight simulation and the scenario
- Make the pilot familiar with disorienting situations in a flight-like manner while exposed to realistic G-forces
- Flight instructor guided demonstrations
- Complimentary to G-training
Questions to address

There is a debate about transfer of training from ground based simulators

• Are there potential side effects of ground based training?

A 6-DOF trainer provides moderate cueing

• With the angular rotational events in the DFS, will there simply be too much going on?
Specific controls

Additional flight instructor controls for SD purpose:

- Remove HUD or selected parts of HUD
- Create IMC
- Pilot can be instructed to close eyes in order to create SD
Somatogravic pitch-up/down illusion

Stimulated in the DFS by pushing the throttle forward to max afterburner and back to idle

Initial condition: Speed < 400 km/h, < 400 m altitude, AB accelerate to Mach 0.85 -> Gx of +0.5

Simulated in other devices by pitching the subject backwards

Linear acceleration affects the otoliths

Forward acceleration

Perceived situation

Tangential acceleration

+ Gx
(chest-to-back direction)
Somatogyral coriolis cross-coupling

Stimulated in the DFS by instructing the subject to turn/tilt the head in yaw, pitch and roll plane -> strong sensation of rotation in other direction

For example: Instructor
-What’s at 9 o’clock?

Angular rotation affects the semi-circular canals

In flight: May occur in case of sudden tilt of the pilot's head, to look at side panels, knee pad etc., while the aircraft is turning.

Compare angular velocity:
2 Gz turn in fast jet = 4 °/s
2 Gz in DFS = 78 °/s
Recovery from unusual attitude

Objectives: to demonstrate first big SD in safe environment and execute recovery from unusual attitude as in flight training during Phase 2

Student pilot climbs to 4000 m, Mach 0.85, 3 Gz descent turn with bank 65 °, pitch -25 ° for 20 sec

Setup 1: Keep turning 6 seconds with eyes closed, try to level eyes closed and recover from unusual attitude

Setup 2: Remove HUD and create IMC, keep turning 6 seconds, restore HUD, and recover from unusual attitude

Perform procedure with left or right turn
Training concept in progress

• Examine concept together with Finnish Air Force and gain experience
• Two groups of student pilots (Phase 3) from the Finnish Air Force during 2012
  • 16 with 100 flight hours experience, group 1
  • 16 with 150 flight hours experience, group 2
• Demonstrations of vestibular illusions in addition to high G centrifuge training
Method

• 1. Preparatory academics lesson and flight briefing

• 2. Approximately 9 min GOR and free-flight session (part of G-training), served as warm up and familiarization with DFS motion characteristics

• 3. SD demonstration run based on pre-defined initial conditions, and verbal instructions to pilot, lasted 8 to 10 min:
  • Fly to a certain altitude, speed, G-value, and/or roll/pitch angle
  • Perform a certain action, task or maneuver
  • Notice A/C and own body responses
  • Pilot - Physician (T.L.) asked about perceived sensations and discussed the implication to real flight
Results, pitch-up/down illusion

- Push throttle forward, eyes closed, try to keep level flight, open eyes when instructed,
  - ended up as far as -30° nose down and felt a pitch-up of 10-15°
  - others felt a pitch back of 30° while A/C was -15° nose down
- Pulled back throttle, same procedure
  - Similar response, individual differences
- Less response with eyes open
Results, unusual attitudes

- Group 1 performed two maneuvers, setup 1
- Group 1 experienced SD and some lost control before recovery from unusual attitude
- This exercise was an eye-opener for young student pilots
- Group 1 was not familiar with HUD (no Hawk flight hours)
- Group 2 performed one maneuver, setup 2
- More accurate recoveries
Results, coriolis illusion

- Left level turn (up to 4 Gz), when instructed:
  - Turn head left and right (what’s at 9 and 3 o’clock respectively)
  - Turn head up and down

- Individual differences in reaction and interpretation of instruction

- Sensations were described as mild to strong

- Improvement: Explain intended head motion prior to DFS run
Discussion

• Time constraints
  • Often limited time available in simulator
  • Scheduling issues, large group creates idle time
  • Practical considerations, such as motion sickness

• SD demonstration additional part of regular centrifuge training

• No cases of motion sickness, however some students reported arm and leg pain
How can we convey the message?

- Instructions and feedback during run
  - The exchange of information between pilot-physician and student is critical (own language used)
- Precise guiding to the setup condition
- Discuss student perceptions
- Carefully explain how the illusions occur in flight
- After runs
  - Debriefing and group discussion
How can we convey the message?

• Transfer to real flight
  • Make setup A/C-like, use tricks and secondary tasks to distract student
  • Adapt approach to appropriate student level, timing
  • Repeat regularly, include new illusions
  • Encourage student interaction, student tasks
Further research/development

- Investigate differences between DFS and real flight
- Include automatic objective and subjective measures
Lessons learned

• Student pilots with no jet trainer flight hours are optimal group for SD demonstrations in DFS
• Combine recovery from unusual attitude (Phase 2 flight training) to SD makes training more realistic
• Flight safety: to experience first big SD in the simulator environment
  • Future flight planning and potential SD conditions
  • Positive experience: with flight training SD can be controlled
Thanks for your attention!

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