## **Spatial Disorientation**

## Prof. dr. Floris Wuyts Head of AUREA University of Antwerp, University of Ghent, University College London



Antwerp University Research center for Equilibrium and Aerospace (AUREA) Dept ENT, University Hospital Antwerp Belgium

Floris.Wuyts@ua.ac.be mob: 0486/637550



# **Spatial Disorientation**

- A pilot experiences SD when he or she fails to sense correctly the position, motion or attitude of the aircraft or of himself within the fixed coordinate system provided by the surface of the Earth and the gravitational vertical." Benson, 1988
- Discrepancy between what the pilot 'feels' and the real flight path



# Types of SD

- SD type I: the pilot does not realize the discrepancy between his/her internal model of the plane and what the plane really does. The pilot does not recognize he or she is disoriented.
- SD type II: the pilot recognizes the SD often referred to as 'vertigo'.
- SD type III: the pilot realizes SD and becomes incapacitated by it – can't make rational decisions, freezes.



# SD

- A misleading interplay between visual, vestibular and proprioception inputs may lead to SD
- At least 33% (military) of mishaps are caused by SD!!!
- No changes in past decades regarding mishaps caused by SD
- No pilot will ever be immune to SD.



## SD Events – Commercial Transports



A New Tool for Analyzing The Potential Influence of Vestibular Illusions. Randall J. Mumaw, Eric Groen, Richard Anderson, Jelte Bos, Mark Houben. January-March 2016 ISASI Forum





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### "Seat of the pants"



Fundamentals of Aerospace Medicine: Eds. DeHart & Davis, 2002 Universiteit Antwerpen

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Response characteristics of the canals





- The driving stimulus for the semicircular canal sensory cells is angular acceleration.
- The canal dynamics however have an integrating function and convert acceleration into angular rate.
- Under conditions of sustained rotation, the elastic properties of the cupula (the membrane with the detectors) drive it back to its zero position after ± 7 seconds.
- Despite the existence of a velocity storage mechanism (in the brain), after 20 to 30 seconds there is no accurate detection of movement.



## Transient rotations, typically for head movements, are perfectly detected





# Sustained rotations are not appropriately detected









# Example: Somatogyral illusion

- A somatogyral illusion is
  - A false sensation of rotation or absence of rotation
  - Any discrepancy between actual and perceived rate of self-rotation
- It originates in the inability of the semicircular canals to register accurately prolonged rotation (> 30 s), as well as sub threshold rotations (approx <5 deg/s)</li>





# Somatogyral illusion example: the graveyard spin

- Suppose the aircraft makes a sustained turn.
- After ± 30s, the canals stop responding and the brain has no sense of turning any more.
- If the trajectory of the aircraft is now straightened, the brain senses a turn in the opposite direction due to the angular deceleration.
- The pilot perceives a turn in the opposite direction
- He may erroneously correct for this illusory spin, and reenter the original turn to compensate, so that he perceives stable flight.
- Additionally, his gaze may be disturbed by the nystagmus of his eyes, what disables clear reading of the solely reliable instruments.



## Solution to somatogyral illusions

- Rely on the flight instruments never on your perception (or your internal instruments)
- Make the instruments read right !
- When nystagmus disturbs your vision fixate on a nearby fixed point on the instrument panel.
  - visual information is of a higher order than vestibular information
  - Converging the eyes also diminishes nystagmus
- Realize continuously that sustained rotations are per definition misperceived by the equilibrium system.



# Graveyard spin





## Is this right?







# Acceleration detectors











## **Otoconia from utricle and saccule**









# Orientation of the multi-dimensional otoliths





# Ambiguity of the otolithic membrane action

**Backward Tilt** 

Forward acceleration







## Ambiguity of the otolithic membrane action Deceleration

**Forward Tilt** 







## Gravito-inertial acceleration

• The gravito-inertial acceleration (GIA) is the vector sum of the vector of gravitational acceleration (upward) and all other linear accelerations acting on the head.



AIRCRAFT CARRIER TAKE-OFF



# Somatogravic illusion

 A somatogravic illusion is a false sensation of body tilt that results from perceiving as vertical the direction of nonvertical gravitoinertial acceleration or force.



#### AIRCRAFT CARRIER TAKE-OFF



# Somatogravic illusion during take-off

- The somatogravic illusion of 'nose-up' sensation after take-off and the erroneous correction of the pilot to push the yoke forward has caused already more than a dozen air transport aircraft crashes.
- An aircraft accelerating from 170 to 200 knots over a period of 10 seconds, just after take off, generates +0.16G on the pilot.
- The GIA is only 1.01G.
- The corresponding sensation is 9 degrees 'nose up'.
- When no visual cues are present and the INSTRUMENTS are IGNORED, an unwary pilot might push the nose down, and crash. Universiteit Antwerpen

# Somatogravic illusion during final approach

- Deceleration due to lowering the flaps is by the naïve pilot perceived as a steep nose <u>down</u> sensation
- On the runway, before the nose wheel touches down, the deceleration may be perceived falsely as a too low vertical attitude.
- A possible correction to move up the nose to prevent damage, will cause damage...











## Internal model

Based on our sensory inputs, memory, expectations, etc,... we build an internal model on how we are situated in space (stationary, moving, upright,...)

Sustained conflict between sensory inputs and this internal model leads to motion sickness, disorientation, nausea,....



#### Theoretical considerations on canal-otolith interaction and an observer model

Jelte E. Bos, Willem Bles

Biol. Cybern. 86, 191-207 (2002)

TNO Human Factors, P.O. Box 23, 3769 ZG Soesterberg, The Netherlands





# Motion (Air)sickness

- Conflict between sensory inputs (vision, vestibular,...) and internal model of self motion
- 40% of aircrew trainees become airsick during training program







## Diagnostic guidelines for Mal de Debarquement Syndrome (MdDS)

(Adapted from Van Ombergen, Wuyts et al, J Neurol (2016) 263:843-854)

(a) Chronic perception of rocking dizziness (e.g., rocking, bobbing, swaying) that started after passive motion such as sea, air and land travel or exposure to virtual reality

(b) Symptoms lasting at least 1 month

(c) Normal inner ear function or non-related abnormalities as seen by ENG/VNG and audiological tests

(d) Normal structural brain imaging (simple)

(e) Symptoms not better accounted for by another diagnosis





Therapy modalities: Method by Dr Dai and prof B Cohen – New York, now adopted in University of Antwerp AUREA lab





# Conclusion

- Would the best pilot be the one who has no 'misleading' vestibular organ?
- No, since he or she would not be able to stabilize his/ her gaze to read the instruments.
- However, being conscience of the misleading information of the vestibular organ is crucial.

## - Humans are not designed to fly.

• Debrief on pilots erroneous perception and realize that it is a perfectly 'human' and 'normal' sensation (we can't help it). BUT, it is 'not suitable' for flying.



## Conclusion cont.

- Confidence, competence and currency in instrument flying reduce largely the risk to disorientation
- Prioritize the workload. First fly the aircraft. Then everything else.
- Build up experience in controlling the aircraft in an environment of conflicting orientation cues (cfr training in appropriate sims).



## Conclusion cont.

- Pilots can avoid disorientation
  - by making frequent instrument cross-checks, even when the AP is on.
  - By matching the reading of the instruments with their internal mental representation of the flight path
- Recover from disorientation by the instruction:
   *Make the instruments read right, regardless of*
  - your sensation.





## Conclusion cont.

- Pilots should not trust their own build-in equilibrium organs, particularly in low vision conditions
- In moments of stress, pilots should make decisions based on the instruments, and not fall back on 'instinct', i.e. perception.
- Garbage in  $\rightarrow$  garbage out.
- The equilibrium system is designed to function on the prairie, to chaise animals..., not to fly aircrafts
   Universiteit Antwerpen



### Those who say: The sky is the limit



## ...have no imagination

