Vestibular Activity – The Agony and the Ecstasy

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The vestibular system of humans contributes to balance, spatial orientation, and movement. The brain uses information from the vestibular system and from proprioception throughout the body to understand the body's dynamics and kinematics (including its position and acceleration) from moment to moment. Signals from the vestibular system also project to the cerebellum and to different areas in the cerebral cortex. Non-disease disturbances of the vestibular system can take different forms, but usually induce vertigo and instability or loss of balance, often accompanied by nausea. This post presents two non-disease situations related to vestibular system function – one where the result can be disastrous (***the agony***), and the other where normal vestibular activity is modified to reduce the effect of a normally functioning vestibular system (***the ecstasy***).

The Agony: Spatial D and the Leans

Aviators have to learn to second-guess their senses in order to keep from crashing their plane, especially under adverse conditions. Two contributing factors to this are Spatial D, and the Leans.

Spatial D

Spatial disorientation, or SD, is a catchall term that describes the summed result of various perceptual illusions and degraded sensory perceptions that may occur during a flight. It is a pilot's total failure of situational awareness and is considered the primary reason for aircraft crashes, and not aircraft maintenance, as is often assumed. SD is more prominent in high-speed military aircraft, but can be a problem for any aviator, regardless of the aircraft flown.

The problem is that when SD occurs, the pilot can no longer count on the normal expectation to what is happening – everything is off-kilter.[1] When this happens, a pilot's choice is to scan the instrument panel to gather as much factual information about the aircraft as possible. This is necessary to counteract the false information from deceitful bodily senses.

Figure 1. Aviators, especially those who fly high-speed planes performing aerobatic feats, can experience spatial disorientation, where they can lose situational awareness.

Leans

The ***leans*** is a type of somatogyral illusion felt in flight when the body's vestibular system and somatosensory system together fail to provide an accurate description of where gravity suggests "down" is. This can be related as to what occurs when a pilot exits a tight acrobatic turn. The fluid in the vestibular semicircular canals continues to flow even though the turn has been completed. The result is that the pilot has the feeling of now flying in a straight line, when in fact he/she is actually in a turn. The term "leans" is routinely used to describe this experience, when in fact, "leans" is the name of the solution. The pilot "leans" his/her head until the plane's instruments match the pilot's perception.

A United States Air Force spatial disorientation survey[2] showed that pilots identified the following problems at a rate of 58.2% in the previous six months: the leans, atmospheric blending of earth and sky, misjudged position in night formation trail, sloping horizon, undetected drift, misleading altitude cues, brownout/whiteout, and Coriolis illusion. While most of the problems are self explanatory, Coriolis illusion requires a definition.

Coriolis illusion involves the simultaneous stimulation of two semicircular canals and is associated with a sudden tilting (forward or backwards) of the pilot's head while the aircraft is turning. This can occur when tilting the head down (to look at an approach chart or to write on the knee pad), or up (to look at an overhead instrument or switch), or sideways. This can produce an overpowering sensation that the aircraft is rolling, pitching, and yawing all at the same time, which can be compared with the sensation of rolling down a hillside. This illusion can make the pilot quickly become disoriented and lose control of the aircraft (Wikipedia, 2014).[3]

A side effect of SD is motion sickness. This arises from a mismatch between vision and vestibular perception. There are no absolute remedies to SD. The main defense that pilots have against these dangerous misperceptions and illusions is simply the awareness that they can happen.

Chalk one up for a disadvantage arising from the activities of the vestibular system – the Agony. It could lead to death.

Ballet Dancers

Interestingly, ballet dancers can perform multiple pirouettes with little or no feeling of dizziness. This author gets dizzy riding a merry-to-round, but scientists have discovered differences in the brain structure of ballet dancers that may help them avoid feeling dizzy when they perform pirouettes.[4]

Research shows that this feat is not related just to "spotting," a technique that dancers and others who spin use that involves rapidly moving the head to fix their gaze on the same spot as much as possible. Findings of research published in the journal *Cerebral Cortex*[5] suggests that years of training can enable dancers to suppress signals from the balance organs in the inner ear.

Around one in four people experience dizziness under rotating conditions at some time during their lives. The sensation of dizziness stems from the vestibular organs in the inner ear. These fluid-filled chambers sense rotation of the head through tiny hairs that respond to the fluid moving. And, like the aviator problem listed previously in this article, after turning in circles rapidly, the fluid continues to move. This fluid movement can make one feel as if they are continuing to spin.

So, how are ballet dancers able to perform multiple pirouettes with little or no feeling of dizziness? To help answer this question, Researchers at the Imperial College of London recruited 29 female ballet dancers, and 20 female rowers as a comparison group.[5] Ages and fitness levels were matched between the two groups. Subjects were spun around in a chair in a dark room, turning a handle in time with how quickly they felt they were spinning, after the spinning chair stopped (Figure 2). Subjects were also measured relative to eye reflexes (ocular motor) triggered by input from the vestibular organs, and later, had their brain structure examined with MRI scans. The MRI scans were gray matter (GM) and white matter (WM) analyzed with group and brain size as covariates.

Figure 2. Experimental apparatus for

In dancers, both the eye reflexes and the perception of spinning lasted a shorter time than for rowers.

measuring perceptual response. Subjects sat on a motorized rotating chair in the dark. The subject's task was to rotate the tachometer wheel to match their sensation of rotation.[5]

The brain scans revealed differences between the groups in two parts of the brain. In an area of the cerebellum, where sensory input from the vestibular organs is processed, the grey matter density was reduced in dancers.

In the cerebral cortex, which is responsible for the perception of dizziness, the frontal cortical region showed a different relationship between white matter and perceptual responses between the groups. Rowers showed an extensive cortical white matter microstructure network. Dancers did not.

The authors surmise that it is not useful for a ballet dancer to feel dizzy or off balance. Therefore, their brains adapt over years of training to suppress that input. Consequently, the signal going to the brain areas responsible for perception of dizziness in the cerebral cortex is reduced, making dancers resistant to feeling dizzy. Dancing that includes repeated whole-body rotation is enhanced when parts of the vestibular system are not used, but instead rely on highly coordinated pre-programmed movements. The authors speculate that a cerebellar gating of perceptual signals to cortical regions mediates the training-related attenuation of vestibular perception and perceptuo-reflex uncoupling – in other words, less susceptibility to dizziness.

Could the experience of ballet dancers be used in the clinical management of dizziness? There appears to be two take-aways from this study. (1) If we could target that same brain area or monitor it in patients with chronic dizziness, we could begin to understand how to treat them better, and (2) another finding of the study might be important for how chronic dizzy patients are tested in the clinic. In the control group, the perception of spinning closely matched the eye reflexes triggered by the vestibular signals, but in dancers, the two were uncoupled. This shows that the sensation of spinning is separate from the reflexes that make the eyes move back and forth. As a result, it is important to look at tests that assess both reflex and sensation.

The result? Chalk up an ecstasy for dancers (at least ballet dancers) having an advantage in overcoming a vestibular system activity.

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