Spatial Disorientation – A System Anomaly

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Consider the phrase "graveyard spiral." It's a concept so scary that your mind wants you to look elsewhere, maybe the ads on the next page. We will see how it starts but let's first see how it will terminate. Given the right circumstances (discussed below) the g-forces gather in a fury and exceed the structural integrity of the airframe causing disintegration or, as NASA would call it, a "system anomaly." A 1954 study by the Air Safety Foundation revealed 19 of the 20 pilots who inadvertently entered a graveyard spiral in IMC lost control of their aircraft and died. The average time between encountering IMC and entering into a spiral was 178 seconds. Chilling! And to boot 5- to 10-percent of GA accidents are attributed to the loss of control due to spatial disorientation and 90 percent result in the loss of life.

Space is certainly a frontier that has all to do with visual control. As long as the VFR mind can see the blue above and the green/brown below it is happy. Void the visual cues, and the mind's reliance falls on unreliable senses. So the eyes have it and they control 90 percent or greater sensitivity for orienting in space. This is by virtue of visual cues. Consider flying VFR on top of a sloping cloud deck and before you know it you will have banked the aircraft to align with the slope.

The mind isn't capable of distinguishing a gentle turn at the rate of 0.2 to 0.3 degrees per second. As the turn progresses, the pilot continues to think he/she is flying straight and level all the time never once considering the instruments crying for his/her attention. By that time the ears and the seat of your sweat-drenched trousers are crying foul, there is utter confusion and chaos because you have never felt this way before. You tug, pull and push and complicate a situation, already maximally torqued out of form, and there you have a full-blown spiral looking at a graveyard.

Let's look at the psychophysics of this event. The pilot is stationary and restrained in his seat with seat belts. The space around him is spinning and out of control. The inputs by the pilot are dictated by his/her experience and the expected performance. The susceptibility to spatial disorientation is human. It is the belief placed on the virtual environment enclosed in a grayed space of clouds where the instruments represent and depict the space around us. We have to learn to believe and then react to what the instruments are telling us and not to what out sensations would have us believe. That's what keep us from experiencing a system anomaly.

Driving a car in a two-dimensional space requires "Wayfinding" and motion to achieve the desired result of arriving at a destination. Driving a car on a banked highway prevents the centrifugal force from lifting the tires off the road. Trying to straighten the car on that banked road will lead to unpleasant results. Flying a plane is similar only in three dimensions. The banked highway in the sky is an interpolation of aeronautical facts, spatial orientation and a balance of the four forces of flight. Nowadays the mental maps of airspace are virtually depicted on the computer screens in the cockpit, hence the positional loss is a remote error at best, unless the computer gives up the ghost and we have a spine chilling lack of situational awareness euphemistically called RAIM loss.

That RAIM loss is nothing but satellite chatter providing pseudo-vectors due to downtime as there are not enough of them to provide guidance. With the GPS functional, and as long as we know where we are, the next step is to make sure we keep right side up. To keep the airplane right side up in IMC we depend on the attitude indicator along with a democratic concert with the other five standard equipments. Most of the depiction of the attitude indicator now is represented on the glass screen, but the information is the same.

Assume you have lost it in the maze of clouds. It is getting dark and a tingle down your spine tells you something is wrong but you can't figure it out. Look at the primary instrument cluster. Is the attitude indicator showing that you're straight and level? Is the Turn coordinator showing straight and level flight? Is the DG/HSI not spinning? Is the airspeed indicator constant? And is the altimeter rooted to the altitude of your designated choice? If so, then the democracy has it--you are straight and level and eventually, if you hold your brain cells together, you will fly out of the clouds – either by descending, climbing, or flying straight through. It is not a good idea, if you are a VFR pilot in the throes of a cottony smooth cloud, to attempt a turn unless ATC tells you that there is an endless sea of clouds in front of you. But then why on earth were you venturing there in the first place? No preflight weather? Uh-oh! Keep it straight and level and ask the ATC if there's VFR ahead of you. If there is a discrepancy in, say, the attitude indicator, which is banked, and the turn-coordinator is straight and level, look at the DG/HSI. If it is not spinning then the turn-coordinator is correct and the attitude indicator has lost the vacuum. Democracy amongst instruments determines the right course to follow. Navigation through the clouds is an aggregate of "Way-finding" , motoric (motion) and a relational event that requires a democracy from the instrument cluster. The discomfort of disorientation is a unsettling feeling in an unfamiliar surrounding. Ground yourself in the basics of flight.

Let's look at perception through the eyes of a pilot. The visual reference that determines our place in space is based on distance, speed and the depth of objects. The comparative size of similar objects determines distance. The change in the texture and contrast between two objects also defines distance. Relative velocity of objects at different distances determine speed. Looking through the window of a moving train, the closer trees whoosh by while the trees at a distance move slowly across the landscape. The clarity and blurriness of objects gives us the depth perception. All these perceived differences reside with the eyes and the brain interprets accordingly. Loss of the surrounding landscape can limit that focus and so trouble begins.

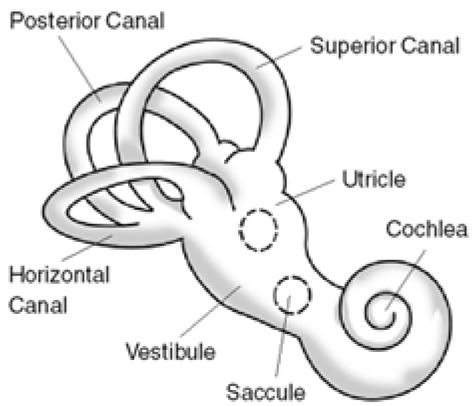
Night flights in VFR conditions can also be disconcerting to a pilot. It is important to use peripheral vision for gathering information from the landscape. Focusing on an object directly will limit information since the cones (structured for bright light and acuity) are centered and the rods (designed for lower ambient light and greater recruitment for stimulation) are aggregated around the center. The rods react to low intensity light and their function is wiped out for 30 to 40 minutes after an exposure to bright light at night, while the cones function well during the day and their recovery time is 3 to 5 minutes after exposure. So when the sun is spanning the other side of midnight, focusing on objects is not a good practice. For one, it can create a jumbled sense of understanding. It can create false movement. This is called autokinesis, an event that can occur in the dark when a lighted object is focused upon on a dark moonless night – the object appears to move on its own volition. It is therefore important to scan the environment in sectors periodically for total landscape visualization and orientation. My personal belief is to fly instruments at night all the time no matter what the meteorological condition. Oh, and by the way, if someone ahead of you on the taxiway has his/her strobes on, use your deepest airline voice and tell him, "Kill those strobes." That goes for everyone.

What, then, operates when the eyes don't have it. There are two other senses that help or hinder. The two systems that give us some back up are the vestibular system and the kinesthetic sensorium. The former is a resident in the middle ear and resides in a space a lot smaller then the ADHRS in the black boxes in the airplane. The vestibular system is comprised of a contained space with three semicircular canals mated to the cavity, the Utricle. The canals are natural gyroscopes located in three orthogonal planes depicted on (figure 1) and they alert us to pitch, yaw and roll motion. Within the Utricle and the canals is a fluid called endolymph and mixed into this fluid are little sand-like particles called otoconia. Resident in the walls of the Utricle are hair-like projections. As we move, the fluid moves within the canal and the otoconia rest on the hair cells, which bends and defines positional awareness, (Figure 2). The minimal detection rate by the vestibular system is 1.5 degrees per second. Once the movement continues in the same direction for a period of time, the fluid movement stabilizes, the hairs straighten and the sensation of movement ceases. It is the deformation of the hair cell imposed upon it by the angular force vector of movement that determines the velocity. Once the force is continuous in the same plane the hair cells relax and the perception of movement is lost. Thus the rate of change defines the position rather than the change itself. This is called the "washback motion" effect where magnitude of motion falls below the threshold of perception. That is the problem in flight. If you close your eyes and the CFI in the right seat puts the plane in a coordinated 10- to 20-degree bank turn, eventually the turning sensation will cease and you will feel that you are straight and level. Or if he or she changes the bank angle from 45 degrees to 30 degrees the student pilot will sense straight and level again. It's this very effect that causes faulty inputs in times of distress to a VFR pilot or a non-proficient IFR rated pilot.

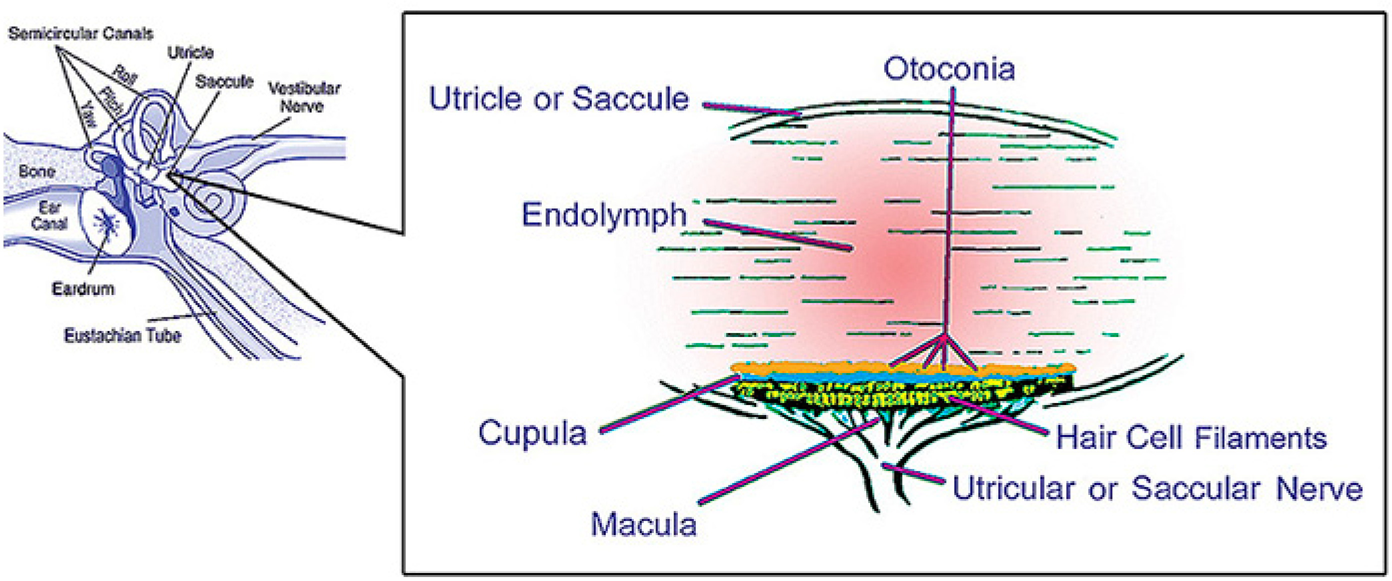
The Kinesthetic sensorium is located in the skin and the joints. The baro-receptors in the joints give us the tale related to g-forces, hence the "flying by the seat of the pants." A CFI does not have to see the attitude indicator, nor the VSI, to see the student is doing poorly on 45 degrees banked 360 degrees turn. He "feels" it!

Conclusions drawn from above lead anyone, including pilots, with one and only one determination:

1. If you are a VFR only pilot, get an IFR rating and fly in actual conditions with an instructor to get comfortable.
2. If you are IFR rated, then fly in actual instrument conditions with an instructor till you have achieved a level of comfort.
3. Flight at night should be considered an instrument flight. Reliance on the eyes in the cockpit on reliable instruments is a gateway to safe flight.



The Human ADHRS **Figure 1**



The Human ADHRS and its micro-components **Figure 2**

Let me change hats and discuss the rationale for cerebral (brain) safety. By that I mean the cognitive efforts of understanding the information gathered and interpreted by the brain. If the brain is under duress from any sets of circumstances, then the interpretive imaging by the brain will falter and alter the perceived data. Studies done by using the

BOLD method (Blood oxygen level dependent) fMRI (functional Magnetic Resonance Imaging) revealed that there is a definite reduction in the functional cortical mass given a depressive influence. These influences include: Fatigue or Lack of Rest, Alcohol, Sedatives, and Tranquilizers, Some Over The Counter medications and Emotions. It is therefore imperative to have a fully functional vault of tricks up your cortex prior to a flight. There are many things that will make you go bump in the night. Limit them to zero and live to fly another day.

Here are a few rules to help you have a long life:

1. Don't drink and fly.
2. Don't take medications and fly – unless you are past three times the dosing time of the medication. If the medication is to be given every six hours then delay flight 18 hours after the last dose.
3. Get plenty of rest.
4. Get plenty of daily exercise and don't smoke--nicotine is a drug!
5. Drink fluids – dehydration makes for sluggish blood flow and contraction of the blood supply.
6. Check you emotions at the cockpit door – if you can't, wait till the cause of that emotion is past.
7. Don't fly with a cold – congestion blocks the Eustachian tubes to the middle ear and makes one susceptible to false sensory input and ear aches – as babies on commercial flight will attest.
8. Always have a plan A and a plan B – and execute them in sequence as needed.
9. Get an IFR rating if you don't have one, even if you don't intend to fly IFR.
10. Verify and trust your instruments.

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