SOARING Rx

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Noticing **3-D** Status, *Dynamically*

Tom circled low over the mountain ridge in a thermal that swept up through a sunlit groove that ascended the mountain face, a geologic convenience that today faced sun and wind. He was delighted by the responsiveness and performance of his new long-winged, sleek white ship.

Others had gotten there before him. After establishing a steep left turn, Tom looked straight up to check the Schweizer 1-26 circling above him. "Golly, that thing can turn tight circles," he thought.

Suddenly, the ailerons went slack. The nose dropped despite back stick. Tom looked across the glare shield and saw trees. There was sudden, loud cracking and snapping, then silence. Tom's legs were caught under the panel, and hurt terribly. He dug for his cell phone, called his wife. "I'm in the trees. I broke the glider. A thermal gust caught me. I'm sorry! Call Mountain Rescue." He read the coordinates off his GPS. Thank God that still worked.

But – *was* it a rogue gust? A pilot not yet adept with a new ship? Carelessness?

Later, his GPS log showed that in the last seconds before the crash, its trace became almost straight; the glider climbed and slowed, then descended rapidly. Obviously, a stall-spin. Why? Well, he *was* flying close to stall; after all, he wanted to turn tightly in the small thermal. He was banked steeply for the same reason. This is what we do.

But, the key to understanding what happened *physiologically* is that the trace *straightened*; the glider *climbed* and of course slowed. It was, essentially, a straight-ahead stall. This is exactly what should happen, given the function and alignment of the semicircular canals.

The vestibular system always does what it's designed to do. When operated outside its design parameters, the consciousness enveloping it may receive a wrong analysis of the status of the glider in the 3-D space-time continuum, which may cause the fingers unconsciously to twiddle the stick they hold in the wrong direction or by the wrong amount. Just to be clear for the folks who took Shakespeare instead of Anatomy, the vestibular system comprises three organs: the cochlea (hearing), the otolith apparatus (acceleration) and the semicircular canals (rotation).

The semicircular canals are filled with stuff – endolymph – that flows like honey (not very fast, not very far). A *change* in rotation causes the endolymph not to flow enough at first, then to catch up. But the endolymph not-flowing while the head is turning is a *change*, and this tells consciousness and subconsciousness about the new rotation. It takes about 15 seconds for this disturbance to settle out.

This means that when we enter a stable turn, we only need to be stable for about 15 seconds in order for the endolymph to be ready to detect another change. For Tom, this means that his semicircular canal endolymph was in a steady state before he was halfway 'round the first time.

Then he caused a change: he looked straight up. To look straight up from a left bank, requires that we turn our head to the right and extend our neck. To the stable endolymph, this feels like the left bank has suddenly gotten much steeper, and the nose has dropped. In the absence of visual markers to correct this sensation (typically a cloud, for fixation, to allow us to perceive that the glider's really not changing status), the *well-trained* pilot's subconscious automagically corrects the bank that now feels too steep, and raises the nose that feels to be dropping.

As you know from spin training, the break and rotation can happen *very* quickly. The semicircular canals now correctly sense the nose to be dropping; the subconscious reflex is back-stick. If Tom was 150 feet above the ridge, and is suddenly in a 600 fpm stalled descent, he has less than 15 seconds to figure this out, make the correct control inputs, and wait-wait-wait for airflow to reattach, so he can regain control authority – hopefully, high enough above the trees to curve away from them. Might not be possible.

Now, my point is not that Tom was stupid or careless or badly trained. In fact, I think he was smart, expert and careful. And I think that his vestibular system just happened to be working correctly, and sent the messages it was designed to send, subconsciously, to his muscles.

It doesn't matter, at the heart, whether a turbulent thermal gust helped this along. Tom's normal physiology and his well-trained pilot's reflexes operated as expected, breaking his nice glider and his legs, bringing excruciating physical and financial pain, not to mention shame, embarrassment and spousal eyebrow-raising.

The point, for real life, is that we need to continually move our heads around while repeatedly fixing our vision on one outside point or another, to give our conscious and subconscious neural networks corroborative visual data with which to adjust the acceleration data from the vestibular system. (Isn't jargon fun?)

Part II: How our dynamic sense of body position ("proprioception") works.

(Those of you who snore through technical detail, go ahead and skip to the next article.)

A French study of glider accidents (Frank Caron, Technical Soaring, V13 #3 71-75, July 1999) showed that *misunderstanding the aircraft status relative to its environment* accounted for 89% of the accidents, 91% of the injuries, and *all* the fatalities.1 There are three areas of sensation that are integrated by the brain (cerebellum, mostly) in order to arrive at a psychomotor conscious and subconscious understanding of the dynamic 3-D status of the glider:

- Vision
- Vestibular sensation (rotation and acceleration)
- "Touch" (broadly speaking)

I use "touch" to summarize all the types of sensors in joints, ligaments, muscles, and skin that are integrated (chiefly in the cerebellum) to complete the picture of our body's and our airplane's speed, orientation, and rate of change during flight.

The analysis and integration of this diverse information occurs subconsciously and reflexively. The result emerges in consciousness if we pay attention. This reflex, in its most powerful and basic form, is the *righting reflex* (proprioceptive reflex). This is what lets a cat land on its feet when dropped; it's what makes a baby crane its neck to keep its head level – and it's what makes the pilot's head tilt so that the eyes are about level with the horizon. Our body parts will move swiftly, involuntarily, at maximum speed, in ways that keep our eyes level. You can probably remember your body doing some pretty amazing things, all by itself, when your feet have slipped.

The fact that this is complex does not mean it's failure-prone. The "failures" are mostly illusions of one type or another that occur due to incomplete information. Actual failure is due to disease or senescence – itself a significant topic for the aging glider pilot (we assume here that if you're reading this, you're still aging).

There are specialized nerve endings around our body to provide the data for proprioception: position sensors that detect the angle of joints; tensiometers in the ligaments and muscles; four different types of pressure sensors in our skin – information from this large variety of "touch" sensors is combined into the "where am I ('proprioception') and what's happening to my position ('kinesthesia')" gestalt, to which we respond with control movements.

Our central nervous system has to do stupendous number-crunching, of binary signals (varying in frequency) from millions of diverse nerve endings, integrated into a potentially conscious summary of position and motion whose accuracy is verified by visual reference and skin pressure.

Pressure sense involves five receptors: continuous pressure is detected by Rufini endings; the beginning and end of continuous pressure by Meissner corpuscles; light pressure by free nerve endings and heavy pressure by Pacinian corpuscles. The Merkel disk is a slow receptor that responds to maintained deformation of the skin surface (use Google if you want to see images).

The muscle monitor is the *muscle spindle*, a specialized muscle cell whose sensitivity and responsiveness is dynamically adjusted by spinal cord reflexes. Four different nerve fibers detect stretch and velocity of movement, alter spindle tone and sensitivity, and set an expected template of muscle activity, permitting deviations from the muscle's planned movement. This is probably the most important detector of joint position.

The Golgi tendon organ is the actual tensiometer, located in large numbers at the junction between muscle and tendon. Each Golgi organ monitors a small portion of the tendon and attached muscle fibers (about 10 fibers per organ). These permit fine adjustment of muscle effort.

The joints have four types of nerve receptors. One is located in the joint capsule and ligaments, is most active at the limits of joint movement, and responds to change of joint direction, to the size of movement, to pressure in the joint, and the velocity of movement. The second is active only at the limits of movement, and increase muscle contraction as movement begins. The third is in the joint ligaments, detects tension, and activates a protective reflex. The fourth is located throughout the joint and acts to initiate the reflex that stops joint movement.

Add to this basic complexity the fact that in the neck alone, there are seven vertebrae, most of which involve 4 joints, surrounded by complex musculature.

I list these things because we tend to think in terms of vision and the semicircular canals when we consider position and motion sense, and the attitude and speed of the glider we are piloting. But these are only the most important. The otolith organ, detecting accelerations in three dimensions, and the complex cutaneous, joint, muscle, and ligament sensation and the coordination of the muscle tone, movement, and position of our body, especially the joints and muscles of the neck, are very important in creating the overall impression of our present status and motion vector. Putting all this information together requires a powerful and resilient analytical engine.

This engine can be fooled: bad data (intoxication, fatigue, dehydration, nerve damage, hypoxia, hypothermia, depression, etc.) or missing data (partial vision, especially) can create a wrong analysis.

As we age, everything works a little less well, plus disease or injury may add big incremental setbacks. We need to test our abilities, note what we do well or do not, and adapt or retrain as needed. As a physician, I've noticed that my aging patients always, at some point begin to complain of subtle defects in balance and coordination that may become quite scary in those who are lucky enough to survive to physical senescence. This change must be a reason why some aging pilots quietly hang it up – without explaining, because to talk about losing the right stuff is just too humiliating.

Now, a variation on this tune: Our central nervous system, working in a healthy, highly trained individual, is processing extremely complex data at very high speed, and is capable of amazing accuracy and insight. When we allow our body to become stressed in any important way, it's not just our conscious thoughts that may become impaired – the entire subconscious brain is impaired as well. Under physiological stress, these subconscious analytical and coordination functions will be more susceptible to error or illusion – and we're unaware of the deficiency precisely because it operates in the unconscious space: we are aware of neither excellence nor impairment.

Thus, when we're *conscious* of feeling exhausted, distracted, or fuzzy; when we are aware of impairment, we have to infer that *all* the complex subconscious processes are impaired as well, and compensate appropriately by double-checking, by performing precisely as trained,

This subtle impairment is the opposite of what took down Tom: he simply realigned, abruptly, his semicircular canals, inadvertently creating a sudden, powerful sense of banking more steeply and tipping nose-down. Without clear visual fixation to correct this, he will automatically and *subconsciously* reduce bank and lift the nose – not realizing he's reacting to falsity. It got quiet, the controls got sloppy. He looked down from the Schweizer to see the trees filling the view over the glare shield. He blamed a sudden thermal gust – it was all he could think of – but the reality was that he and his glider were broken by his senses acting normally. It could happen to me; it could happen to you.