SOARING Rx

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Hand *Follows* Gaze

"...perception, especially vision, requires intelligent problem-solving based on knowledge."
***Richard L Gregory**, 1997*

This monthly essay is dedicated to the principle that the "operating characteristics" of the normal human body guarantee that even the best of us may do unintentionally awkward things. Awkwardness at just the wrong moment can break our aircraft and ourselves.

Several of these columns have noted various ways to misperceive the world, especially the effect of standard illusions. We don't see these illusions while flying – the reason to teach them is that the world is full of nonstandard forms and patterns, and that variations on standard illusions cause unrecognized misperception. We are safer if we realize that our world is rife with illusions, these are strongly persuasive, and we can recognize them if we understand the conditions under which they occur.

Today's essay brings to us the idea that we make *programmatic unconscious movements* that sometimes feel like *"illusory"* because we did not plan for them to happen. Our brain is wired in such a way that it predetermines hand motion; it makes an executive plan without us ever becoming aware of it. Some movements are so automatic that their execution completely bypasses our consciousness, and we become aware of them only after it is all over.

Frequently, such unconscious movements can land us in trouble – e.g. pulling back on the control stick when looking up in the cockpit, or steering the car in the wrong direction just because we looked to the side. For better or worse, we are prone to look – and move – in the direction we expect to need to. The only way to override these automatic covert plans of our brain is persistent training at tasks that require us to suppress the "brain-bot" in us.

The research for this column, and guidance, were provided by Maja Djurisic, a WSPA (Women Soaring Pilots of America) member and a neuroscientist. She was a happy accident; I had given an SSA convention talk on attention (see April's Cockpit Attention Disorder http://tinyurl.com/mk7s3jv), and afterwards wandered by the WSPA booth, where one can talk with interesting, intelligent women soaring pilots. Maja was there, confessed to having heard my talk ("it was OK"), and suggested this topic. Returning serve deftly, I suggested we both play in this sandbox – so this column is a collaboration.

. . . we are trying not to hit anyone who shares the same part of the sky.

The quotation at the article's head points up an important irony: "perception" is the result of "figuring things out," that is, analyzing what's around us and solving the problem of how to assemble the data streaming through our senses, and how to generate the only real reaction our bodies are capable of – movement. This is based on what we've learned (knowledge).

At the same time, this knowledge creates a model of the world around us, giving rise to unconscious (and conscious) *expectations*. This is efficient, as normally we need to simplify the world around us to its important essentials, such as threats and opportunities. But this also means that we often miss corrective subtleties.

Our perception of the world around us is a cobbled-together contraption made of sensations, facts, presumptions, expectations, and trends. We feel that we've got a firm view of reality – it's pretty close, but there are a lot of dots being connected by our brain, of which we're blissfully unaware.

This is all made more complicated by the fact that we do not live in a static world – everything moves, especially ourselves. The movements our hands make are themselves initiated and guided by expectation and our connect-the-dots perception.

However, we move and point even before we plan, because there is a more basic and powerful influence exerted on our body movements: a master template, developed in the "incognito brain" that never reaches the light of our consciousness, which dictates that the limbs will move with the eyes. This master template can be finessed with experience and training, and the expectations that arise from knowledge and learning.

But if our eyes move our limbs, what makes our eyes move in the first place?

Attention causes our eyes to move and gaze to shift

You've probably already noticed that we don't lie back and let the world flow through senses, especially in the cockpit. We are going somewhere, and we are trying not to hit anyone who shares the same part of the sky.

Standard flight training teaches us how to see and avoid in order to stay a safe distance from other gliders in the sky. "See and avoid" is a very basic tool for collision avoidance, and it is basic because it taps into the built-in neural mechanism of willful attention deployment (see top-down attention; Soaring Rx, April 2014 – http://tinyurl.com/mk7s3jv) which makes the eyes move and gaze shift to the next section of the sky we want to scan. Our attention starts a neural program that causes all this movement.

To understand why there is a need at all for the gaze to shift, we need to remind you about the characteristics of the fovea, the special part of the retina which gathers light information with high resolution (high visual acuity). We covered the optics and geometry of this challenge in June, 2011 (see http://tinyurl.com/ny2wdys).

Fine visual acuity occurs in only 1% of space, observed by the fovea, where the density of photon-collecting cells (mostly cones) is the highest (it is useful to think of cells as pixels); the 10% of space that falls outside the fovea is seen with degraded resolution because the density of rods and cones is lower. The density of cells falls off toward the periphery of the retina, and so does visual acuity.

During daylight, in order to sample and process the space surrounding us with high resolution, we must foveate continually, that is; shift our gaze from one spot to another, adding detail to our mental cartoon as we do so. To do this, our eyes must constantly jerk around – these jerky movements are called saccades (French saccade = jerk). Saccadic movement is necessary to expand our high acuity vision to the entire space within our field of view, and eventually to guide motion.

If our eyes remain still for a few seconds, the pigments in the rods and cones quickly "bleach out," and the world loses all its texture. Saccadic movement is necessary to refresh these cells in order to see edges and texture – and is also necessary to expand our perceived acute vision beyond the tiny area of the fovea, and to guide motion.

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During any visual exploration of our surroundings such as the see-and-avoid task, these saccades are *guided* by a neural program in the brain that prepares both of our eyes to shift accurately to a new area of interest. Something happens in the brain – in the region called Frontal Eye Field – before our eyes shift.

This FEF is tied to top-down attention (goal-driven, willful). There is a division of labor among the neurons in this FEF area – some are busy making us attend to a problem at hand, and some are doing the work of translating that attention into an oculomotor 'program' that will eventually result in contraction of muscles around the eyeball, cause the saccadic movement and the gaze shift.

As an aside, it's fascinating that physiologic changes occur in the visual-perception brain cortex, in the area represented by the object needing attention, even before saccadic eye movements occur. At this time, the FEF is preparing muscles of the eyes to contract via an oculomotor plan, and it synchronously sends information to other visual areas of the brain and "primes" them for new visual stimulus even before the eyes shift, effectively increasing the acuity of the scene that is still imaged with the more peripheral retina.

For example, our brain becomes more sensitive to brightness changes at the spot that *will be getting attention* before our eyes are directed to focus on it. Thus, in addition to programming the eyes to move, our brain prepares ahead of time to process and capture the sensory data that is to become relevant next.

On the other hand, when we are distracted by something unexpected – the bright flash of a nearby wing, for example – there's no prior attention and no oculo-motor programming in FEF. This sudden diversion of our attention to a new "interest" is really just the deployment of another attentional mechanism

– "bottom-up" attention, in which case saccadic movements are triggered in different brain areas.

Our eyes and hands move in coordination.

My mother, when I started to drive, warned me not to let a side-gaze linger, "because then you'll steer where you're looking." This was annoying only because I'd already figured this out riding bicycles and had disciplined myself to suppress this.

This is actually pre-conscious. When we are about to shift our gaze to an object, the muscles that might grasp it are simultaneously primed to grasp it; muscles needed for pointing, are also getting into the ready-set-go state if we decide to point when our eyes focus on an object.

Now, in flying an aircraft, nearly everything we need to shift our gaze to is beyond our grasp, but we do use the control stick to point. We point the nose of the glider to a desired heading – probably a landmark, or we point the glider towards the desired touchdown spot on the runway. We always need visual input, with our target focused in the fovea, in order to point correctly.

There is a network of areas in the brain's cortex between the frontal and parietal lobes that builds a reference frame for reaching. The reference frame is what our brain uses to translate the representation of the spatial coordinates built by our vision into the corresponding "coordinate system" that the muscles of the body can use.

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The parietal cortex builds reach goals using eye coordinates, but then it has to send the code, for how to reach, further into the area called the pre-motor cortex, from there into the motor cortex, which finally projects to the spinal cord, priming muscles for appropriate contractions.

The term, "eye coordinates" reflects the fact that visual perception is geometrically arranged all the way from the retina into the brain; the geometrical representation becomes more complex at higher levels, and this mapping is forwarded to non-visual centers.

A reference frame for eye to hand coordination built in the pre-motor cortex has to be informed also of the anatomical status like joint position, muscle and ligament tension, and both angular and linear motion vectors. Coordination requires a sophisticated dynamic mapping of visual geometry and anatomy.

Eye movements affect muscle tone.

Even when we do not move our hands, shifts of gaze change the excitability of neurons governing muscles in the spinal cord in less than 0.2 second. This biases muscle tone – and the point we are getting to is that, when you are near stall speed, preparing to land, this can undermine your intentions. For example, this may change finger pressure on the control stick unconsciously, which, if not caught, could bring you into an unexpected stall.

The lesson for us in this is not just that my mother was right. Our purpose is to help you understand *how* this works, and that it's fast and subconscious, so that you can be prepared for it, can recognize it, and compensate for it.

It's not possible to know what accidents might have resulted from this built-in mechanism – as with the standard illusions, we can say that our "operating characteristics" may pull us in the wrong direction at a crucial time. For sure, nobody plans their accidents, so every accident must comprise a collection of perceptual-motor inaccuracies.

Mike felt a little nervous flying base, as he always had, even before he passed his checkride last month. He heard Tom call short final, and looked down and to the left to find him, to figure out whether to adjust his own altitude, speed, or direction. He imagined Tom landing slightly short and himself too low to land over him and too fast to stop before colliding. A trickle of humidity wandered down from his left armpit, tickling annoyingly.

Mike looked forward at his aim point. Oops, cutting inside a little. He pressed the right rudder to move the nose. Then he glanced back at his panel. Jeez! What happened to the airspeed? He'd lost 5 knots! He lowered the nose, then looked back to see where Tom was headed. Should he turn final early, and land to his left? Or later, and land to his right on the wide grass strip?

It took a few seconds of watching Tom to figure out his trajectory. Then Mike looked back, and again had to correct his own direction and airspeed. Jeez, he felt awkward. He was glad there wasn't an instructor yelling at him from the rear seat, but he heard a snide voice anyway. "Watch your airspeed! Keep the attitude constant! Don't rudder the nose around like that! The glider wants to fly straight, please let it!" The voice in his head was less polite than his instructor.

Mike turned final, carefully keeping the yaw string away from his left shoulder, and was relieved to see Tom staying to the right on the runway. There was plenty of room. He relaxed, and the glider suddenly was easier to control precisely.

Mike didn't know why his flying was so awkward on that base leg. He felt incompetent. He decided maybe he should talk to Dr. Djurisic when the day was over; maybe she could explain the clumsiness; maybe it wasn't sheer incompetence.

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