SOARING Rx

BY DR. DANIEL L. JOHNSON

Ten-HUT!

Cockpit Attention Disorder

Attention is a complex neurobehavioral capacity without which the expression of all other higher functions of the human brain is impossible.

– *Chris Filley, MD*

Disclaimer: This monthly essay is written by an ever-older country internist. Each month, I pick something I want to learn more about, and share this learning with you. This month I bit off more than I could chew, for the neuroanatomy and neurophysiology of memory and attention is complex.

In particular, I cannot expect you to know the brain's anatomy, and SSA's budget does not call for extensive 3-color illustrations, especially those stolen from copyrighted sources. So I will suggest useful search strings for illustrative material (e.g., images.google.com) rather than adding illustrations.

So you may wish to read this piece while sitting at your computer.

Attention is a process.

The brain manages memory separately from attention. Large, widely separate areas of the brain are devoted to attention. Memory is located somewhat more centrally.

Memory and attention are thus governed by two different brain systems. Each system is altered by training. Each is susceptible to malfunction.

Both networks evolve as children mature, and may deteriorate in old age.

Both networks are susceptible to training (including the "training" that experience brings). The brain remodels itself to improve its function (called "plasticity.")

Studies have estimated that at least a third of aviation accidents, and 25-75% of motor vehicle accidents, involve attention. So it seems important.

It turns out that the historically best training practices reflect the actual neurophysiology of the brain's attention networks. For example, the scan, the sterile cockpit, recurrent emergency training all are reflected in the actual function of the brain.

Background

Part of my job is to usher people into and through old age. Senescence, if we stay healthy long enough, affects us all, usually in the last three years of life. Senescence is not uniform: one part of the body or another may fail faster than another. The tragedy we most fear is the brain failing first: dementia.

Even brain failure is never uniform. Just as our skin thins and dries, joint cartilage loses resilience and turns brittle, ligaments stiffen; so also every brain loses "plasticity" (learning capacity, essentially), connections degrade, and all aspects of cognitive performance decline measurably.

I use the MicroCog test to measure brain function. To oversimplify, on this test we expect only about 10% of 80 year olds perform as well as 50% of 25 year olds.

This does not measure wisdom, but speed, flexibility, and handling complexity. It means that my 85-year-old retired plasma physicist does not converse at the highly complex level he did when he wrote his doctoral dissertation.

And fortunately, living a normal adult life does not require much cognitive ability. However, flying safely, in a complex aircraft or environment, does.

When, long ago, I first reviewed studies of aging pilots, nearly all the work had been done by military researchers, comparing men in their 20s with codgers in their 40s. (Well, when you're 30, 45 seems pretty senescent.) At these ages, differences in ability are real, but small, and well compensated by experience.

The story is different for those in their 70s or 80s. Researchers seem uninterested in testing pilot proficiency at those ages, perhaps because the loss is obvious, perhaps because there is no "normal" at this point – we're like old rakes standing in the garage with bent and missing tines, damaged paint, and cracked and soiled handles. It is possible, of course to form a "rake" gestalt from them, but one has to view many more to be sure that one has generalized properly than when examining the newborns at the hardware store. As I watch aging pilots come through my office for flight physicals, the intellectual simplification even the academicians and professionals are experiencing is obvious.

However, I do not defer issuance, unless there's a problem with function, because they've not become incompetent, they've deteriorated from high-normal to normal. Besides, when they talk about flying activity, they reveal that they are compensating appropriately. It does not take a high degree of skill to function in a low-stress situation.

As, through the years, I've watched highly intelligent people develop dementia, the variety of ways to lose function is very interesting. Nearly everyone who ages complains of memory loss. Ironically, the most worrisome people are those who lose judgment, as they also lose insight for this and become socially unmanageable. This is a loss of "executive function" and may not be accompanied, at first, by other loss.

One of the things I've observed is that "bad memory" is really a collection of different changes, primarily two: pure memory loss, and *attention deficit*. Loss of attention capacity causes "memory" problems because we can't hold something in "working memory" (an attention feature) or store it in long term memory if we aren't able to focus on it in the first place.

For example, we hold in working memory that thing we want from the basement. With age, we are more susceptible to distraction, which bumps the thing out of working memory. We then worry about memory loss, but physiologically the defect is of attention.

This distinction does make a difference, because the adjustment is to maintain an undistracting environment – a "sterile cockpit" – not to work harder on memorization.

Attention: structure

My point in bringing this up is not to teach you the anatomy of the brain. It's to point out that attention is not just a concept: it's embedded in the brain, it is structured, and what we pay attention to and how well we pay attention is not merely a matter of will power, but of biochemistry and physics.

First, memory: The key brain structures involved in long-term memory are centrally located in the brain, especially in the limbic system (search for images of "basal ganglia"), though it also involves regions in the cortex.

"Working memory" is located in the frontal lobes (search for images of "prefrontal cortex), and is related to the "top-down" attention system.

Second, attention: Attention is managed mainly in the cerebral cortex, particularly on the right side of the brain, though central areas are important in attention, risk assessment, and reward. (Damage to the right side of the brain, especially the parietal lobe, often causes incapacitating spatial attention defects, such as unawareness that the left side of the body exists.)

There are two attention networks: The *ventral*, or bottom-up network acts to acquire attention to new events. It acts to interrupt top-down attention and reorient attention to a new stimulus (search for images of "ventral attention network").

The *dorsal*, or top-down attention network involves connections that most importantly include the parietal lobes and frontal cortex. It seems to be important in orienting attention and maintaining focus (an "executive function"). Search for images of "dorsal attention network."

The posterior or parietal-lobe part of this does sensory surveillance and selects which stimuli to attend to. The anterior or frontal-lobe part takes care of "executive functions:" control and action. That is, it directs perceptions toward a response. Connections to the cingulate gyrus, in the brain's center adjacent to emotional centers, maintain motivation and effort during the ensuing task.

Attention: development

The brain forms and develops gradually for about 25 years. The two attention systems steadily mature during this time, so that the structure of the adult and the childhood brain attention systems are somewhat different. During formative years, the prefrontal cortex, a key element in "executive control" is the last part of the brain to mature, a reason that adolescents control impulsivity incompletely and engage in risk-seeking behaviors.

During these years, disorders of attention are common. Sadly, like so many other conditions in this culture, they are typically treated with drugs rather than remedial training (to leverage the developing brain's plasticity) and management of circumstances (to limit distraction).

The evolution of brain attention systems continues into old age, where attention-gathering connectivity decreases and attention-supervisory connections increase.

It's interesting that when attention is abruptly made non-functional through illness or injury, a person seems *confused*. The fact that the underlying cause is non-function of attention-networks is not at all obvious.

Inattention creates awkwardness

A 2013 AAA study (reference at foot) on driving points out that "inattention" is a vague term that includes fatigue, sideward glances, necessary distractions, and inessential distractions.

It notes that distractions are of three types:

- competition for visual attention,
- "manual interference" (taking one's hands off the controls), and
- cognitive distraction, in which hands are at home, eyes on target, but the mind off on other business.

They observed that such distractions increased reaction time, caused fixation (failure to scan), and failures to notice incidents and to observe rules.

It's interesting that visual distraction causes directional *instability*, but cognitive distraction causes directional *fixation* and tunnel vision.

Cell phone conversations cause *inattention blindness*, in which the driver cannot recall objects that were being looked at during the conversation. Yes, you're not talking on your cell phone in the glider, but there are similarly engrossing tasks, especially with the flight director.

The authors' task from hell involved, while driving, being given a series of words to remember alternating with a series of true-false arithmetic questions. (Perhaps comparable to charting a course change while listening to important radio transmissions.)

Since you want to know, having the radio on impairs attention mildly. Listening to a book on tape, talking to a passenger or talking on a mobile (with or without hands-free) are comparably impairing, in about that order. Interestingly, converting speech to text is clearly more distracting than these, and the memory/arithmetic challenge was clearly worst.

This nicely done study helps us understand more precisely that when aviating, both navigating and communicating are distracting *and impair pilot performance*. Plus, having to perform any complex intellectual task will cause us to tend to ritualize and oversimplify piloting tasks and will blind us to the things we are looking at, whether inside or outside the cockpit.

This is sound justification for the concept of the sterile cockpit – and this includes prioritizing off our table inessential, cognitively challenging tasks in the one-chair cockpit.

Experience and Attention

Studies of pilot distraction and decision-making show how experienced and inexperienced pilots with the same level of knowledge function differently. Inexperienced pilots perform slightly better only when a single fault emerges in simulated flight.

In all other circumstances, experienced pilots respond more quickly, alter their scan more appropriately, and afterward are able to describe or analyze the abnormality more accurately.

Their behavior shows that, beyond the knowledge required, they have built perceptual and cognitive models that permit disparate faults to be related quickly, that guide appropriate alterations in scanning pattern, and that permit the pilot to more cogently summarize the situation.

(Technically, this model of expected patterns is called "structured domain knowledge", and reflects the brain's character as a pattern-recognition engine.)

Experts have learned to allocate their attention more effectively. They understand patterns better. Experience results in better performance on more difficult tasks. They tend to focus on the most important cues in a developing situation.

It's also been demonstrated that fast and accurate response to a fault is *not* related to flight hours, but to the extent of prior experience with that fault or circumstance. Doing 1000 hours of cross-country supervising a glass cockpit is very much less valuable than 1000 hours of active piloting, manipulating stick and rudder in any dynamic flight situation.

Studies show clearly that recurrent training with problem scenarios creates a brain that is ready for the unplanned. It's been shown repeatedly through the years that when a pilot has not been trained for an emergency, responsive behavior is pretty random. Rational analysis takes time, which is available to NTSB investigators and attorneys, but not in the cockpit. In emergencies, pilots do what they've trained to do.

Obviously, we need to train. It's the brain's "plasticity" which we leverage with training. Plasticity decreases with age, but does not vanish. Working to learn benefits us at every age. I think one age difference is that when young, everything is new and exciting, which enhances attention, while when old, nothing is new, half-forgotten things seem "old hat", which hinders attention. Like so many other things, learning takes more effort and discipline when we're old.

Training attention.

We can train attention management, either explicitly or as a side effect. There are two sides that may be usefully taught: selective attention and executive function. What you and your spouse consider "selective attention", cognitive neuroscientists call "useful field of view." We *learn* what patterns and alerts are valuable.

The ventral attention system presents "interrupts." Knowing that this process is a key part of attention management, we could explicitly plan training tasks that teach the pilot which distractions to ignore and which to guide attention shifts, and transition to changed flight strategies or scanning modes.

The dorsal attention system orients attention and maintains focus. It is related to working memory and connects to executive functions.

Performance has long been understood to be best when training "atomizes" actions into parts that are successively built up into coordinated programs or repertoires. This is most formally done in music and dance training, and is not usually done with beginning pilot training.

Research has revealed that as task components are learned and integrated, the involved brain regions shift and evolve. Basic actions and sequences become automated, which frees our cognitive processes for analyzing the flight situation and planning contingencies.

We can, without meaning to, adversely train our attentional systems. Many people have jobs in which interruption and distraction are frequent. I and my colleagues in primary-care medicine have a life in which one important focus may be at any moment be interrupted by another important one.

For example, as I've observed my own attentional behavior through the decades, I've realized that when young, I could focus for prolonged periods on an important task by arranging a quiet environment. After decades of interruptions, this is no longer possible. My mind is continually vigilant for the next interruption, and if it's more than a few minutes without one, I begin to feel uneasy and find my attention shifts from the present task to looking for an interruption.

Only after being away from work and the Internet for a couple of days is it possible to again maintain focus for an hour or more.

This seems like an environmentally-induced attention disorder. We can create interruptive environments in our cockpits without half trying. Or, by considering the importance of managing attention, we can arrange our work patterns and cockpit systems to minimize interruptions and distractions that are not necessary to safe and skilful flight.

Separate, but relevant, is executive control. The psychology literature has a useful classification of executive functions, which we could adapt to pilot training in explicit scenarios. These are:

- Identifying short and long-term goals: purpose and end point.
- Cognitive flexibility: learning to shift procedures or patterns quickly.
- Prioritizing: learning what cues are most important in situations.
- Organization: sorting information by relevance, importance, function, etc.
- Working memory: juggling information mentally to permit mental time-sharing or multitasking.

Self-supervision: rechecking and reviewing one's own mindset, conclusions, and perceptions.

There are some formal procedures or programs for training attention processes, such as "Field of View" and "Cogmed". Their effectiveness is debated, but their design is rationally based.

References

Filley CM. The Neuroanatomy of Attention. **Seminars in Speech and Language.** V33#2, 2002, p. 89-98. Very technical, succinct, and useful.

Morrow DG, et al. Expertise and Age Differences in Pilot Decision Making. Aging, Neuropsychology, and Cognition, V16, 2009, p. 33-55. This study involves non-simulator "scenarios" and does characterize age and experience differences.

Parks EL & Madden DJ. Brain Connectivity and Attention. **Brain Connectivity**, V3#4, 2013, p. 317-338. A very nice technical summary.

Schriver AT, Morrow DG, Wickens CD, Talleur DA. Expertise Differences in Attentional Strategies Related to Pilot Decision Making. **Human Factors**, V50#60, 12/2008, p. 864-878. One of the rare studies that actually involves a simulator. Talleur is a CFI.

Strayer DL, et al. **Measuring Cognitive Distraction in the Automobile**. June, 2013, AAA Foundation for Traffic Safety. A very thorough study, involving both a driving simulator and actual driving, of the relative importance of distracting tasks.

Acknowledgments

Thanks to Dr. David Madden and Dr. Daniel Morrow, who actually answered my emails, and provided wonderful references. And thanks to Bernald Smith, whose email demanding an OSTIV speech topic within twenty-four hours, drove this topic into my dorsal attention network.

And special thanks to Dr. Sharona Atkins, who genuinely is an expert in cognitive neuropsychology, a soaring pilot, and tired mom of new twin boys – who took time to correct my worst mistakes.