The Aging Human Brain

By Stephen F. Barnes, Ph.D.

The brain is the most sophisticated organ in the human body and the most complex structure known in the universe. Like the rest of our body parts and nine biological systems, it ages but on its own schedule and in its own unique fashion.

The human brain weighs on average about three pounds, consists of 200 billion cells. Surprisingly, there are only two categories of brain cells, neurons and glia, but more than 50 different cellular subtypes. Nerve cells or neurons are specialized cells that are electrically excitable, and processes and transmit information to other neurons and cells through electrochemical signaling via membrane-to-membrane junctions. Neurons are the basic structural and functional units of the human nervous system. There are about 100 billion neurons, and these make an additional 100 trillion connections to other cells at a velocity up to 250 miles per hour.

Glia cells provide a wide range of support functions to nerve cells, including surrounding the neurons and holding them in place, supplying nutrients and oxygen, forming a protective myelin sheath around neurons, destroying pathogens, removing dead nerve cells, and aiding in electrochemical signaling.

The brain operates on a "self-organizing principle" (aka, synaptic plasticity), arranging and re-arranging neurons to complete specific tasks, and changing patterns of neural connections in response to the learning and experience of each individual (Whalley, 2001).

Associated with healthy aging is the loss of brain density and weight specifically in the frontal and temporal lobe volumes (including the hippocampus located in the medial temporal lobe region), about a 5-10 percent reduction, mostly due to water loss, between the ages of 50 and 90. Additionally, the aging brain also experiences select neuron death in the frontal lobes (the most recently evolved areas of the brain that is crucial for many intellectual functions) and parts of the brain related to movement (cerebellum and basal ganglia), widening of brain surface grooves (sulci) and shrinkage of the convolutions (gyri), 25 percent reduction in overall brain electrical activity, probably related to decreased blood flow as we age, increase in neurofibriallary tangles (i.e., abnormally hard clusters of damaged or dying neurons), formation of senile plaques (starch-like deposits of amyloid protein), reduction in the amount of specific neurotransmitters (i.e., acetycholine in the hippocampus, and other specific transmitter systems), and degradation of the mylean sheath (i.e., white matter) around neurons (Glisky, 2007; Whalley, 2001; Guttman, 2001). A recent study found some but not significant neuron death as a result of aging in healthy adults, contrary to a long-held view on the subject, suggesting the likelihood of more subtle structural and molecular changes in the frontal lobes and hippocampal circuitry, the latter perhaps accounting for mild memory degradation that often appears late in life (Morrison and Hof, 1997). It is not yet known how or whether any of these observed physical changes listed above specifically affect cognition (Gazzalley, 2009), but it is clear that age-related structural brain alterations and declines in cognition are not uniform across the whole brain (known as selective abiotrophy) or across all mature adults (Glisky, 2007). These variations and exceptions signal that we still have much to learn about both healthy brain aging and brain pathology.

Of major interest here are age-related changes in the ability to think and process information, recall our memories, and solve problems. As Glisky (2007) notes in the introduction to her research review, the complexity of both the neural and cognitive functions makes exact mapping between brain and behavior extraordinarily difficult at this time, although this is the goal of cognitive neuroscience. Clearly, there is significant variability across older adults in terms of cognitive performance, with many older adults out-performing younger ones on specific cognitive tasks, particularly with coaching. However, the basic cognitive functions most affected by age are in the areas of attention and memory. Perception also shows significant age-related declines, most likely in response to waning visual and hearing capacities. Some recent research also suggests that higher-level cognitive functions, specifically language processing and decision-making, may also be age-dependent. Significant, accumulating evidence also points to impairment of executive function as a key contributor to age-related declines on a number of cognitive tasks. In the summary presented below (Glisky, 2007), it should be noted that cognitive functions are not isolated capacities but actually overlap, combine, and interact in complex ways.

Summary Effects of Aging on Basic Adult Cognitive Functions

Attention – Some form of attention is involved in nearly all cognitive domains, and attentional declines have far-reaching impacts on functional human capacity. The attention categories listed here are constructs that correlate with active research streams on normal aging.

Selective Attention: refers to the ability to attend to specific stimuli while disregarding others that are task irrelevant. Older adults tend to be slower than younger ones on such exercises reflecting, most likely, a general slowing of information processing ability.

Divided Attention/Attention Switching: refers to the ability to process simultaneously two or more informational sources or tasks (e.g., driving a car). There are significant age-related declines in this capacity, particularly when information/task is complex. There is some evidence that age differences in attention switching can be reduced through practice, extended training, and aerobic exercise.

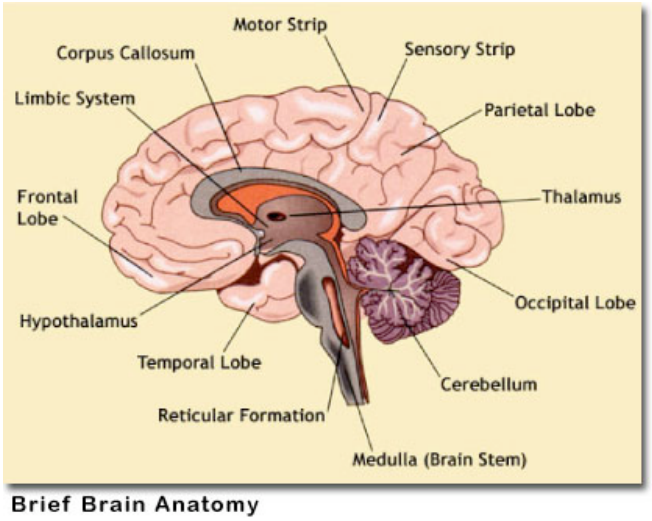
Sustained Attention: refers to the ability to maintain task attention for an extended period of time. There appears to be no age-related decline in this domain.

In general, "The tasks on which older adults show impairments tend to be those that require flexible control of attention, a cognitive function associated with the frontal lobes. Importantly, these types of tasks appear to be amenable to training and show benefits of cardiovascular fitness" (p. 3).

Working Memory – refers to the active manipulation of a limited amount of information that is the current focus of attention. For example, in a task that involves learning a phone number and then providing the digits in reverse, which demands active reorganization of the information, adults show significant impairment with age. This deficit appears related to the divided attention deficit phenomenon, above, but there is currently little agreement among researchers on the mechanisms involved. However, Gazzaley, Clapp, Kelly and others (2008) reported that older adults demonstrate a selective

deficit in suppressing task irrelevant information when encoding which, in turn, reduces cognitive processing speed. What is clear is that active reorganization and manipulation of complex information by adults in problem solving, decision-making, and life planning is critical to the activities of daily living (ADL), underscoring the overall importance of intact working memory across the lifespan.

In contrast, short term memory involves the simple retention of information over a short period of time, like a telephone number that is rehearsed until it is used, and then forgotten. "Older adults show minimal or no deficits in short-term memory and can typically hold about 7 ± 2 digits in mind as long as the digits are being rehearsed" (p.4).



Brief Brain Anatomy

Long Term Memory – refers to the accurate retrieval of stored information that is no longer present in an active state of consciousness. Like attention, this is a multifaceted construct. Despite what many older adults may think, their remote memories of events in terms of specific detail are not as accurate as recent ones. Particularly problematic for older adults is remembering accurately the context or source of information, that is, where or when something was heard, seen, or read, or even whether something actually occurred or was just thought about, what has been termed by researchers as "reality monitoring" (p. 8).

Semantic memory: refers to the storage of general information, facts, principles. The organization of this memory system, stored in the posterior neocortex, appears unaffected by age.

Episodic memory: refers to personal experiences connected to a particular place and time. It is considered the most advanced form of memory and may be uniquely human. It is affected by age and also appears to be the most susceptible to brain damage. At the input memory stage, older adults appear to encode some information less meaningfully and with less elaboration, such as, forgetting where they placed the car keys (locus: prefrontal lobes). Older adults also experience problems with memory storage or consolidation (locus: medial temporal lobe structures, including the hippocampus). Effortful memory retrieval is likewise impaired by aging

(locus: prefrontal lobes and hippocampus).

Autobiographical memory: refers to both semantic and episodic memories of one's personal past. More recent memories are easier to retrieve, and there is a general decrease in retention from the present to the most remote past. Autobiographical memories are largely preserved across the lifespan, however.

Procedural memory: refers to remembering how to do things, like riding a bike, driving a car, or reading. Generally, older adults show retention of acquired motor and cognitive domains until end-of-life (locus: several brain regions, including the basal ganglia and the cerebellum).

Implicit memory: refers to memory recall that occurs as a result of prior experience, even if one has no explicit recollection of that prior experience. This kind of "memory priming" remains relatively intact as adults age (loci: in the visual domain, priming involves extra-striate regions of the visual cortex; in the conceptual domain priming involves the left frontal and left temporal cortical regions).

Prospective memory: refers to remembering to do things in the future, such as, keeping appointments, paying bills, etc. Using a variety of external aids (e.g., lists, calendars) older adults retain functional prospective memory (locus: prefrontal cortex, but different from episodic memory).

Perception: refers to sensory processes that occur prior to cognition. Aging significantly impairs vision and hearing in most adults, much of which can be corrected and improved with re-training and practice. But to the extent that it is not, a broad range of cognitive functioning can be negatively impacted.

Speech and Language: In normal aging, speech and language processing are largely intact in older adults, and can even improve with age, although processing time may be somewhat slower. Older adults have well structured, elaborate narratives and extensive vocabularies, and are usually judged as more interesting *per se* than younger people. But they can experience some text comprehension problems, which may be related to working memory deficits noted above.

Decision Making: Very little research has been done in this area, but there tends to be a reliance by older adults on expert opinion.

Executive Control: refers to a range of different cognitive processes that are involved in the planning, organization, coordination, implementation, and evaluation of non-routine activities. Executive control plays a pivotal role in virtually all cognition, including allocating attentional resources, inhibiting task irrelevancies, formulating strategies for encoding and retrieving memories, and directing problem-solving, decision-making, and other higher order cognitive activities. This too is a multi-faceted research construct that has received considerable research attention in recent years.

All executive control depends on the prefrontal cerebral cortex (aka, "frontal lobe hypothesis of aging"). Neuroimaging studies have revealed a preferential

decline in older adults in both the volume and function of prefrontal brain regions.

Gazzalley (2009) has identified a number of risk factors for cognitive decline. This is not a long list, suggesting how much more there is to learn about aging and cognition:

- High blood pressure, diabetes, poor nutrition, and social isolation increase the probability of developing a neurodegenerative condition
- Heart disease
- Family history of dementia
- Psychological factors, such as, stress and depression.

What we are reasonably certain about is that brain aging is not a simple process or single phenomenon but a combination of several processes that can combine, affecting different areas of the brain in different ways. Some adults are clearly more susceptible to disease and functional decline than others. But in general the brain undertakes a lifelong commitment of brain cell "good housekeeping," relying on the body's "general health and nutrition to maintain complex functions and compensate for the wear and tear of everyday life" (Whalley, 2001, p.5).

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Graphic Sources

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