

# The Aging Brain

## At the Crossroads of Attention and Memory

By Adam Gazzaley, M.D., Ph.D

**WE'RE ALL AWARE** that the population is aging. The baby boomers—a huge cohort of the population in industrialized countries—have started reaching age 60 and they will be a significant portion of the population for many years to come.

Our expectations of aging have also changed. For example, those who have reached age 60 are still demanding a lot of themselves: they don't necessarily want to retire, but would prefer to stay active and engaged at an optimal level. However, they, and others, are aware that various cognitive abilities (such as attention, memory, and multi-tasking abilities) often decline with age. This risk of, or actual decrease in, cognition is troubling to older individuals and represents a threat to their quality of life.

### What Changes with Age?

All animals experience degenerative changes over the course of their lives; irrespective of size or life expectancy, they suffer decline in their physical systems: the brain and cognition

We also used to think that the brain grew and formed only until adulthood and then stopped. More recently we have come to understand that the brain's plasticity (the ability to change and make new connections) is retained to some degree and allows structural, chemical, and functional changes throughout life.

### How Attention Influences Perception: The Simple View

How you view the world around you, or your perception, is not a passive process. It is influenced by attention. We generally think of two types of attention as influencing perception:

- External, or stimulus-driven attention
- Internal, or goal-directed attention

All interactions in the world involve the

we're studying memory for visual stimuli. Our research subjects are adults, in two age ranges: 18-30, and 60-80. We ask them to watch a series of images (a mix of faces and landscape scenes) displayed briefly and then, after a pause, we show them one more photograph (either a face or a landscape). For some trials, the instructions direct subjects to ignore the faces, just pay attention to the landscapes. For other trials, we tell them to ignore the landscapes. And for a third group of trials, there are no special instructions; we call it the *passive view* and it serves as our baseline condition.

We measure our participants' accuracy in reporting which images they've already seen and which images are new. We also measure what's happening in their brain while they're looking at the pictures they have to remember and ignore. Given that we keep the bottom-up stimuli constant for all three groups, any differences we see in their brains while they are viewing the images must be due to the influence of top-down (goal-directed) modulation.

### How We're Studying It

In our lab, we use a number of techniques to investigate what's going on in the brain.

- fMRI (functional Magnetic Resonance Imagery) helps to answer *where* in the brain changes are occurring
- EEG (Electrical Encephalography—sixty-four electrodes on a cap) answers *when* they are occurring

fMRI has been around since the early 1990s: it uses the same machinery that is used for diagnostic purposes (MRI scanner), but in this case we track blood flow as an indirect measure of activity in specific areas of the brain. Rather than lying in the MRI and doing nothing, as is the case for medical evaluations, our participants engage in visual experiments and use a button box to make selections.

The downside of fMRI is that it doesn't

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are part of that. Structurally, we know that the brain shrinks with age, and not just after age 60. Starting in our twenties, we can measure the shrinkage.

We used to think that we lost brain cells with age. More recently we've come to understand that larger cells become less, and smaller cells take their place. Even axons, a part of the neuron which are wrapped in moist tissue, shrink from the loss of moisture. The substance and structure, however, are still largely there.

interplay of both internal and external influences on our perception. We can think of these two forces as *bottom-up* processing (driven by external stimuli) with *top-down* modulation (driven by goals). The ability to *focus* or pay attention as well as *ignore* are two aspects of top-down modulation.

### What We're Studying

The experiments we're doing in our lab at University of California, San Francisco, focus on the normal aging process: specifically,

respond as quickly as the brain works. It shows activity over a span of seconds, whereas real brain activity occurs in milliseconds. EEG allows us to look at the timing more accurately, but even with sixty-four electrodes on the cap, we can't use it to determine where activity is happening. So these two methods complement each other.

### Results for Younger Subjects

The fMRI results for the twenty younger subjects show lots of activity in the visual regions of the brain when they're *paying attention*, little activity when they see the images they're supposed to ignore, and levels in between when they're passively viewing. The difference between the higher level of activity and the passive level is called *enhancement*, and the difference between passive level and the lower level of activity during ignoring is called *suppression*.

### Results for Older Subjects

We found that enhancement is preserved for a similar number of older subjects. The big difference between the age groups is that the older participants are not suppressing the irrelevant pictures relative to the passive viewing. We also see that their overall accuracy (approximately 80 percent) on the memory test is significantly lower than that of the younger subjects (approximately 90 percent) ( $P < 0.05$ ).

Interestingly, if we split the older adults based on their performance, we find that the higher performing older adults who are no different in their accuracy compared to younger subjects, also do not have a deficit in suppressing the irrelevant information. This is in contrast to the lower performing subgroup, which had both a memory deficit and impairment in suppression. Furthermore, we found there was a direct correlation between the degree of suppression and memory performance.

This is a different way of understanding the relationship of memory and attention: it's not the classic emphasis on *focus* as the key to memory or attention. Instead, this experiment shows us that how well you ignore information directly relates to how well you remember what's relevant.

### Post-Experiment Memory

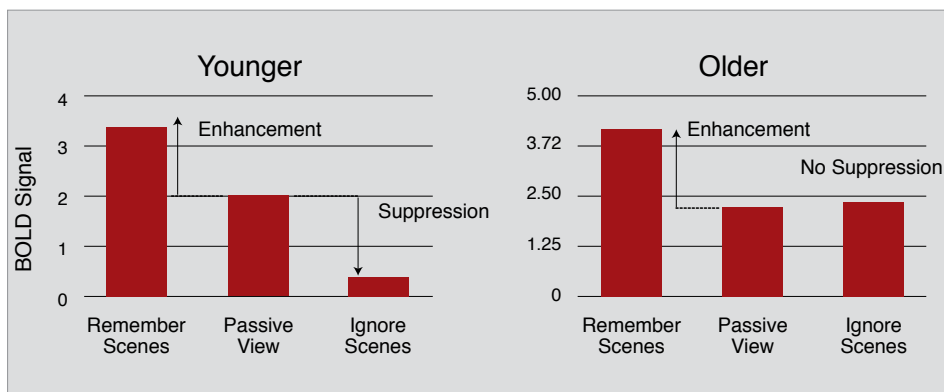
When the experiment is over and the participant leaves the fMRI scanner, we surprise them with another experiment. We now show them all the images they had previously seen during the experiment, plus an equal number of new images. They have a four-point scale to indicate how certain they are that they have or have not seen this image earlier in the day.

What we find is that the lower performing older participants on the scanner experiment remember the scenes they were told to ignore better than their higher performing peers and



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Top: Figure 1 - fMRI (functional Magnetic Resonance Imaging) scanner control.  
Above: Figure 2 - fMRI results for younger and older subjects.

better than the younger subjects. So it seems that these older adults actually have a better memory—at least for things they were not supposed to remember.

### EEG Data Shows Slow Suppression

When we looked at the EEG data for the older adults, which looks at timing of activity in more detail, we find that the suppression deficit occurred in the first two-tenths of a second after the irrelevant picture was presented; activity after that first two-tenths was similar to the young adults. This information now provides a more complete description:

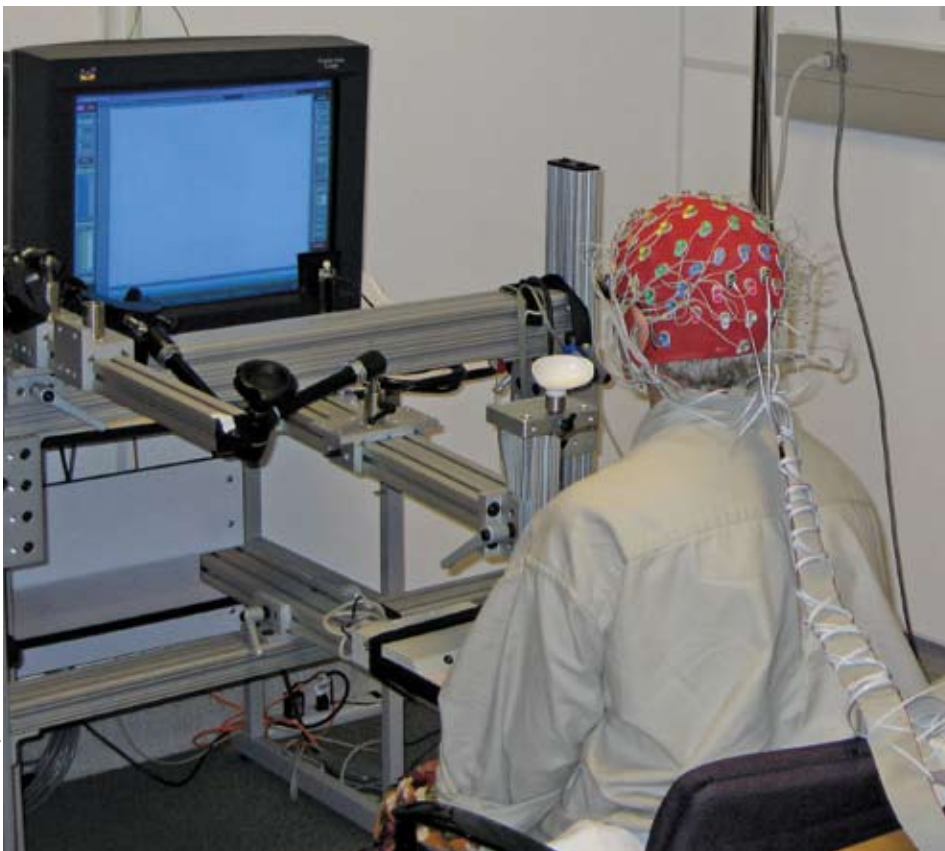


Figure 3 - EEG (Electrical Encephalography) electrodes on a subject.

the older adults were slower at suppressing the irrelevant information.

In other words, if you let things that are not relevant to your task in, it can cause interference, so even if you can suppress it later, suppressing it quickly enough is what's important. Deficits with age are associated with lack of speed in processing.

We recently performed this experiment substituting the faces and outdoor scenes with different colored dots that are static or moving. We ask the subjects to remember the color or remember the movement, which makes the task harder. Now we can see—even across trials—that this interaction between suppression and accuracy is not just an aging phenomenon, but

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### Moving Forward

Normal aging is associated with a selective deficit in the top-down suppression of irrelevant information. Suppression ability is not abolished with aging, but is slowed. These results establish a critical relationship between attention and memory impairments in aging.

is true for all age groups. Even the 20 year olds on the trials where they performed poorly had let in too much of the irrelevant information.

We are now performing this experiment on children 8-12 years old, looking into whether they show the selection suppression deficit that the older adults exhibit. We'd like to know if it's the same pattern.

## Can We Prevent or Delay Cognitive Aging?

I wish we were further along in answering this question and could give specific recommendations. We'd very much like to know where to act therapeutically. The recommendations mentioned below are largely based on epidemiological results, rather than controlled studies. Under controlled studies we might find that these are only related and not causal. Although not indisputably proven, these suggestions are likely not harmful.

- Mental exercises (for example, cross-words) are often touted as keeping the brain healthy. So far we don't have a lot of good evidence about the many brain-training games. There's nothing wrong with doing things that give you mental exercise, but hard evidence is lacking.
- We're currently working on developing a training experience, essentially a video game that trains people to ignore. The idea is that if you learn to ignore better, you will be able to remember better.
- We are investigating the utility of using brain recording intervention before and after cognitive training, with and without medications (such as those used with Alzheimer's or dementia patients). Hopefully we'll soon be able to look at brain activity before training or drug treatment, and predict the success of an intervention.
- Like a physical fitness trainer that takes you through the gym on a first visit and customizes a training program, we'd like to have a comparable brain fitness trainer whose role is to customize brain training, perhaps in a brain gym, for individuals who'd like to tune up their aging brains. **UX**

### About the Author



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