

### Introduction

"Neuroplasticity" refers to the physical changes that are continually taking place in your brain as you experience and adapt to the world around you. During every day of your life, neurons (see picture, right, of 3D rendering of a neuron) and the connections between them change to encode information. By influencing this plasticity with the right activities, it is possible to train your brain to function better.



Learning new things and challenging yourself frequently may promote more constructive neuroplasticity and interestingly, may also help prevent or off-set the negative effects of things like brain injury or aging.

Brain training exercises are designed to stimulate the neuroplasticity that leads to improved cognitive ability and a healthier brain. Fundamental cognitive abilities – such as memory, attention and processing speed – can be improved with appropriate training.

### Working Memory: What it is and how it works

Elizabeth Buchen, neuroscientist and science writer explains why working memory is such a critical cognitive process and how it works, as follows.

The cognitive process of “attention,” allows the brain to manage the excessive amount of information we are exposed to by selecting only the most relevant information at any one time. The question then is: what happens to this information once it successfully passes through the funnel of attention?

If cognitive processing ended at attention, you would conduct your life strictly from information received at the present instant, without any internal state of the mind or abstract thought. The words of this sentence would dart, short-lived, in and out of your brain, becoming wholly devoid of perceptible meaning.

Instead of this unlikely scenario, however, your attention grants the words access to your brain's **working memory**, which briefly holds and evaluates them for the duration of their relevance (i.e. until you have finished the sentence or idea).

Working memory, though operating over a timescale of mere seconds, is central to human thought processes. It allows you to temporarily hold and evaluate information in your mind, whether from the environment, stored memories, or internal state, thus allowing you to process the world within your personal context. Thus, working memory not only allows you to remember a phone number and find your way home, but is also central to language, reasoning, and most of the mental functions associated with human intelligence.

So what is the neural manifestation of this extraordinary ability? Working memory requires cooperation between multiple brain areas (depending on whether the information comprises locations, objects, or words), but the critical orchestrating structure is the prefrontal cortex (PFC). Lying directly behind the forehead at the front of the brain, the PFC contains neurons that exhibit the special properties of working memory; that is, they are activated by a specific stimulus, and remain activated for the duration of the stimulus's relevance.

Consider, for example, when you view an image, a certain population of neurons in your PFC will experience a surge in electrical activity. Importantly, these neurons will continue to fire at this elevated rate even after the image disappears, allowing you to maintain a memory of it.

The activity of these neurons allows you to maintain the image in your mind even when the visual stimulus is gone, exploiting the basic, fundamental mechanisms of your working memory. In your daily life, these mechanisms allow you to evaluate and manipulate select information from the world in the framework of your internal state and stored memories. Accordingly, working memory is crucial for effective decision-making and for the elaboration of goals and intentions; it enables you to manipulate abstract ideas, form coherent lines of reasoning, and overall act like the intelligent being you are.

### Brain Processing Speed

Why is processing speed important?

- The speed of performing basic cognitive operations (**processing speed**) is highly correlated with measures of intelligence.
- Processing speed may affect performance on all higher cognitive tasks processing speed

The **speed** and **efficiency** of information processing may be fundamental components of intelligence. A number of researchers have demonstrated that performance on various tests of intelligence (e.g. IQ, vocabulary, reasoning ability, and other abstract tests) is correlated with reaction time - even a task as simple as hitting a button when it lights up. This relationship becomes even stronger when the task is slightly more complex, and incorporates elementary cognitive operations such as replacing numbers with letters<sup>1</sup>.

In such a task, you may be given the following key:

1= Y  
2= I  
3= K  
4= C  
5 = R

You must then replace a string of numbers (e.g. 5 2 4 3 1) with the corresponding letters as quickly as you can; your performance is a measure of your processing speed. So, what do these simple, seemingly trivial measures have to do with an entity as broad and complex as intelligence?

Regardless of how you define intelligence, all intelligent thoughts - from analysing literature to catching a ball - arise from information processing in the brain, which is mediated by electrical signals travelling through networks of neurons. If these signals travel faster, the brain can process more information in a given amount of time, permitting access to more information when formulating thoughts.

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<sup>1</sup> Vernon PA, 1983. Speed of information processing and general intelligence. *Intelligence* 7, 53 - 70.

The influence of processing speed on intelligence is particularly pervasive because intellectual activity is hierarchical - higher cognitive activities arise from the coordinated activities of more basic cognitive operations. Reasoning ability, for example, is dependent on the simultaneous availability and manipulation of several sources of information (knowledge, emotions, goals, problem-solving strategies, etc.) The speed of processing this assortment of information may have a potent impact on the eventual intellectual outcome.

Processing speed is crucial even for tasks with a substantial knowledge component. Your processing speed underlies not only the speed with which you scan your vocabulary for the appropriate words, but may also influence the size of that knowledge base in the first place.

### **Processing Efficiency**

A complementary concept to processing speed is **processing efficiency** - the efficiency with which we perform basic cognitive operations. By minimising the brain resources required to conduct a certain cognitive process, you not only expedite that process, but may also allow more information to be processed at one time. Thus by maximising efficiency, we maximise speed; by maximising speed, we maximise performance.

In fact, brain imaging studies have shown that people who perform well in complex spatial and memory tasks have lower levels of brain activity in the prefrontal cortex than those who perform more poorly<sup>2</sup>. Further, prefrontal cortex activity decreases with practice and performance improvement. Thus, **when you practice and improve at a specific task, from mastering a musical piece to exercising your working memory with a memory test, your brain becomes faster and more efficient at that task.**

Although there may not be one single factor underlying "intelligence," processing speed and efficiency are among the most basic and pervasive components.

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<sup>2</sup> Rypma B, 2006. Neural correlates of cognitive efficiency. *NeuroImage* 33, 969 - 979.