What is working memory?

Think about a time when you’ve had to remember someone’s phone number and had no access to a pen and paper. Chances are you had a lot of trouble trying to recall it, or maybe you told someone else to remember the first 4 digits, so that you could just remember the last 4. As another example, try multiplying 12 by 16 in your head. Again, without a pen and paper, this is a fairly tricky exercise for most people.

In each of the above scenarios you would have been using what’s called “working memory” to solve the problems. Working memory is defined as a system for temporarily storing and manipulating information, in order to carry out complex tasks such as comprehension, learning and reasoning (Baddeley & Hitch, 1974).

So in the case of remembering a phone number, we’re not simply remembering a bunch of random numbers we just heard. We also have to organise them in the sequence in which we heard them. In the case of multiplying two large numbers together, you have to be able to perform more than one calculation, whilst simultaneously remembering what the answer to each calculation was. In fact, IQ tests often examine working memory through tests of “digit span”, which refers to the number of letters or digits a person can immediately recall.

The term “working memory” is often used interchangeably with the term “short-term memory”. However, the differences are important: working memory is not a single component, rather, it consists of a number of different parts; these parts seem to be able to function separately from one another.

Baddeley’s model of working memory

The most influential theory of working memory—Baddeley’s working memory model (1996)—divides it into 3 separate systems, which work together to help you carry out a variety of tasks. The first system, called the “phonological loop”, is involved in storing verbal and auditory information, like when you’re trying to remember a phone number or a person’s name. When one attempts to remember a phone number, they often find it easier to remember it if they continue to verbally rehearse—either in their head or out loud—the string of numbers. This indicates that these details are stored as auditory information.

The second system (called the visuospatial sketchpad) stores visual and spatial information. So as you try to find your way around a new city, this “sketchpad” is busy creating a map of your surroundings.
The final and most important aspect of working memory is your “central executive”, given its name because it acts like the boss at a company, trying to coordinate its two assistants, the phonological loop and the visuospatial sketchpad (Baddeley, 1996).

So, imagine that while you’re driving around a new, unfamiliar city, one of your friends is giving you directions, while another is telling you which streets and street numbers to look out for. The phonological loop is recording the verbal information about streets and street names, while your sketchpad is trying to visualise the city and how the streets link up with one another. The job of the central executive is to decide what you need to be paying attention to and how to coordinate the two kinds of information, visual and verbal.

**Issues associated with poor working memory**

**ADHD:** It appears working memory problems play a big role in many of the symptoms of ADHD, including problems with task planning, behaviour regulation and selective attention. In terms of the different working memory systems mentioned previously, people with ADHD often have difficulty storing and using both verbal and visual information. However, they appear to have greater weaknesses with visual information (Mezacappa & Buckner, 2010).

**Mathematical weaknesses:** Weaker working memory is related to difficulties performing mathematical calculations, as well as solving mathematical equations and word problems. It also appears to play an important role in the development of early mathematical learning (Passolunghi, Vercelloni & Schadee, 2007).

**Autism spectrum disorders:** Poor working memory has been shown to be an important source of the intellectual difficulties in children with autism spectrum disorder (Russell, Jarrold & Henry, 1996).

**Interventions and training**

In light of this information, it appears critical that teachers consider whether their practices are adequate for people with working memory problems. For instance, it may be useful to teach in small steps, using cue cards and guided practice to ensure the person’s working memory is not overloaded with new information.
**Chunking:** Often we’re forced to remember long lists of things like phone numbers or names, which can be particularly difficult for someone with ADHD or working memory problems. Techniques such as “chunking” may be highly effective as they allow people to organise information into smaller, more manageable “chunks” which will put less strain on their working memory.

So for example, the number 5681 - 2431 is easier to remember than if we thought of it as a long sequence, i.e., 56812431. Here, we’ve ‘chunked’ the longer list into two smaller lists. To make chunking more effective, one can give the chunks meaning or logic. So rather than remembering a long shopping list (cheese, apples, oranges, toothpaste, butter, milk, shampoo), one can break them into meaningful groups,

i.e.: apples and oranges
    butter, milk and cheese
    toothpaste and shampoo.

Thus, in the second, we’re really only memorising a few broad groups as opposed to a long list. And by giving meaning to each group, it allows our brain to quickly recall the items within each group.

**Training programs:** Working memory is thought to underlie general intelligence, as it appears to be a critical factor in most intellectual activities. If this is true, then improving working memory should also improve performance on many other tasks such as comprehension, reasoning and so on. Commercially available working memory training programs like *CogMed* and *Jungle Memory* promise to increase one’s working memory and even promote gains in other areas too. Though, how effective these programs are remains uncertain. Melby Lervag and Hulme (2013) found little evidence that improvements from working memory training could transfer to other tasks such as reading comprehension and arithmetic. However, this training did lead to reliable, short-term improvements in people’s working memory, which included both verbal and visual memory. An important finding was that children below the age of 10 showed much larger benefits from training than children between 11 and 18 and adults.

Other studies have found more impressive results from working memory training. Westerberg and Klingberg (2007) found that training programs produced not only improvements in working memory, but also increases in general intelligence and a greater ability to focus one’s thinking on specific tasks. Furthermore, in studies on children with ADHD, those who used working memory training programs were better able to focus on tasks, showed higher scores on intelligence measures and ADHD symptoms were reduced (Klingberg et al., 2005).

**Mindfulness and meditation based techniques:** These techniques, commonly used by psychologists, help clients to focus on the “here and now”, and apply an accepting and non-judgemental attitude towards their immediate experiences. Mindfulness has been shown to increase concentration skills, as well as working memory, on a range of working memory tasks. These improvements have been shown to carry over into other areas, such as reading comprehension (Mrazek et al., 2013).
What is processing speed?

Processing speed generally refers to how quickly one can complete simple or automatic tasks with a reasonable degree of accuracy. Measures of processing speed might include: looking at a picture of various items and being asked to quickly search for specific targets within the picture; or having to rapidly name certain images on a computer screen. In the real world, someone with good processing speed would likely be a fast reader, would be able to quickly find numbers in a telephone book, and would thrive in jobs which require rapid responding (Groth-Marnat, 2009).

Processing speed is not a good predictor of how quickly someone is likely to learn a new skill. However, once a person has learnt a task, it becomes a very good predictor of how skilled they can become. This basically means that two people may be equally good at learning a new skill, but they may differ greatly in how quickly and accurately they can perform the skill (Lichtenberger & Kaufman, 2012).

Relation to psychological and neurological disorders: Processing speed is the component of IQ tests most sensitive to the types of intellectual difficulties seen in a variety of disorders, including dementia, traumatic brain injury, ADHD and so on (Strauss, Sherman & Spreen, 2006). In fact, evidence suggests that processing speed problems are a major underlying factor in both reading disability and ADHD, as the two disorders often go hand in hand (Shanahan et al., 2006). Studies also suggest the slow reading and slow motor responses often seen in those with dyslexia may be related to poorer processing speed (Stoodley & Stein, 2006). Of the various facets of IQ, processing speed appears to decrease the earliest, beginning in people’s 20’s, but experiencing a bigger drop during our 30’s.

Serious brain damage is most likely to affect a person’s processing speed. People with Alzheimer’s disease and traumatic brain injury both score lowest (regarding IQ tests) on measures of processing speed. However, low scores on processing speed can also reflect problems with physically controlling our movements. In fact, people with ADHD often have these physical problems too, so their low processing speed can be mistaken for an intellectual problem, when it may be a physical one. Also, those who have very high IQ’s often score lowest on processing speed compared to the other indexes of IQ (e.g., working memory, verbal comprehension) (Groth-Marnat, 2009; Lichtenberger & Kaufman, 2012).
Processing speed, working memory and intelligence

Processing speed is related to working memory ability, as those who can process information quickly don’t have to hold as much information in working memory. Additionally, our working memory can only store information for brief periods of time, so people who process things slowly will quickly fill up their allotted storage time.

Fry and Hale (1996) carried out a large study of children, adolescents and adults, looking at the relationship between processing speed, working memory and intelligence. They found that as people got older, the increases in intelligence were to a large extent, a product of improvements in working memory and processing speed. Furthermore, it was improvements in processing speed over time that led to improvements in people’s working memory.

So the process goes something like this: During childhood, we gradually get faster and faster at processing information. This faster processing allows us to store more information in our working memory. AND...since working memory is involved in all sorts of mental operations like reasoning and comprehension, this in turn leads to greater intelligence.

Interventions and training

Children and adolescents with poor processing speed may need more time than most to complete tasks and activities. Similar to those with working memory difficulties, they may feel easily overwhelmed when learning a variety of new things. Reducing the workload and providing instruction at their pace is crucial for adequate learning. It may also be necessary to break work requirements down into more manageable and well-organised chunks, to ensure one’s cognitive resources are not overloaded.

Training programs: Recent studies suggest that brief, processing speed training can lead to improvements in processing speed for young and older adults. These gains were long lasting and appeared to transfer to new tasks, unrelated to the ones the participants were trained in (Ball, Edwards & Ross, 2007; Edwards et al., 2005). Elderly Japanese people were trained for 4 weeks on games aimed at improving processing speed, and compared to a group who did not receive training. After the 4 weeks, the trained group showed better processing speed and scored higher on other intellectual functions like concentration and memory (Nouchi et al., 2012).

Exercise: Rikli and Edwards (1991) had women between 57 and 85 complete a 3 year exercise program which included exercises focused on flexibility, balance and grip strength. They were compared to a group of women who did not exercise for the same period of time.
The exercise group showed increased motor coordination and physical functioning. Importantly, their intellectual processing speed increased a lot too.

**Mindfulness and meditation:** Similar to the results seen for working memory, Zeidan et al. (2010) found that brief mindfulness training (4 days) led to improvements in processing speed, as well as general improvements in attention, concentration and other intellectual functions.

**Video games:** Recent research suggests that action video games can increase processing speed, even on tasks which are very different to the types of activities performed in these video games. These increases are also related to improvements in other areas, such as multitasking, tracking several objects at the same time, and processing information that’s been presented briefly (Dye, Green & Bavelier, 2009).

**References**


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