The term working memory was first introduced in the 1960s. Before that the term short-term memory that was used instead, which is our capacity to keep information in memory over a short period of time. With the term working memory the description of this memory system changed from being only a passive maintenance of information to also include active processing and manipulation of information. Working memory concerns our ability to hold, process and use information in real time.

This capacity is extremely limited, which, among others, the American researcher George Miller noticed. In his experiments in the 1950s he saw that there was a clear limit to the number of objects that test persons generally managed to repeat when he presented word sequences to them. More recent research has also shown that there is a large variation in working memory capacity between individuals, and that this variation often is an important factor for understanding the differences in intelligence, problem solving ability and reading comprehension between individuals.

We use our working memory on a daily basis in a variety of situations. Even before you leave home to go to work in the morning, you use your working memory. An example is when you pack your bag for a holiday. This involves working memory to a high degree because you need to keep in mind what you will be doing during the holiday and what you need for the different activities. To what extent you bring with you the right things for your holiday therefore depends largely on your working memory capacity. If your working memory is overloaded there is a great risk that you might forget important things. To reduce the load on working memory you can use strategies such as the one described below.

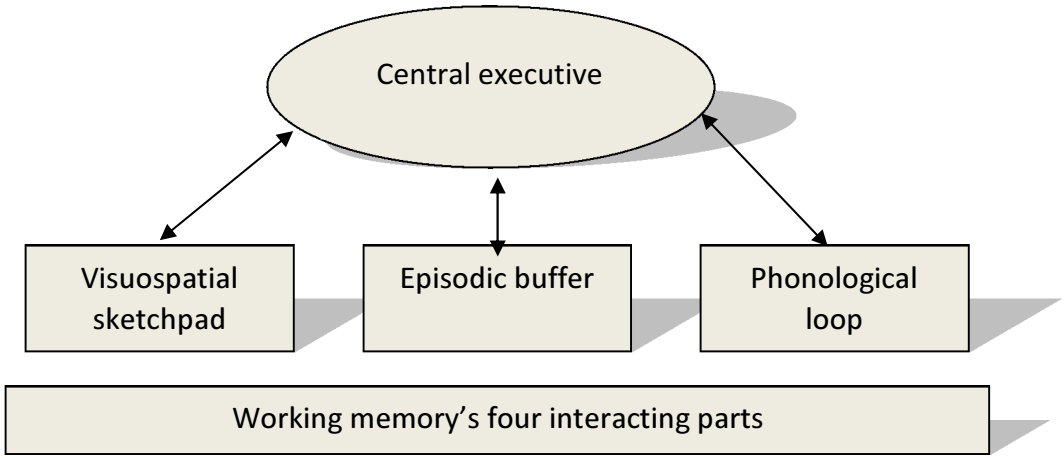
Suggestion!

An example of how you, in such situations, can help your working memory is to use a paper and pen. This way you can hold a part of the information outside yourself so that you do not need to have everything in your head. This is particularly appropriate for days when you are stressed or have slept too little, because these are factors that we know affect our working memory ability negatively.

Working memory has been studied from a variety of perspectives such as biological (cells, genes), psychological (cognitive development) and pedagogical (behaviour in the classroom). As a result there are definitions of what working memory is, and the focus and content of these descriptions often reflect the specific fields from which they have evolved. However, a common denominator for most definitions of working memory is that it is viewed as a temporary system to maintain and manipulate information and that it has a limited capacity.

The researchers Alan Baddeley and Graham Hitch presented a model for working memory that is still the most commonly used. In this book, we will use Baddeley's model to describe working memory in more detail. Baddeley's model of working memory is called the multi component model because it is composed of multiple processes (components) that interact with each other. The current model consists of four parts: the phonological loop, the visuospatial sketchpad, the episodic buffer and the central executive (see Figure 3). Studies over the past three decades have provided empirical support for the components of working memory in Baddeley's model.

FIGURE 3: BADDELEY'S MODEL OF WORKING MEMORY



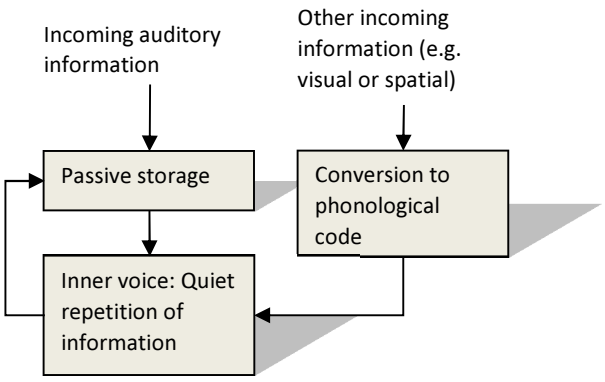
THE PHONOLOGICAL LOOP

The phonological loop manages auditory information. Here we handle not just information that we collect with hearing, but also impressions that we take in via other senses and convert to phonological code. The phonological loop consists of two parts. Firstly, a passive storage where the information will be held only a few seconds and then disappear. Information that has been lost from the passive storage, or the inner ear that it is also sometimes called, cannot be retrieved. In order to retain information submitted to the inner ear over a longer period of time, it is necessary that the phonological loop's second part, the articulatory system, is activated.

The articulatory system serves several purposes. It uses an inner voice to retrieve information from the passive storage, repeats it quietly and then returns it to the passive storage in order to be able to retain the information over a longer period of time. This, thus, becomes a loop that retrieves the auditory information and then returns it. This function is called the articulatory loop (see Figure 4).

The articulatory system also converts visual impressions to phonological code by using the inner voice to give names to the visual impressions. An example of this is that when we are shown a digit code on a piece of paper that we must remember we often (automatically) choose to repeat the digits "quietly in our head" to remember them better.

FIGURE 4: THE ARTICULATORY SYSTEM



There is support from several studies that the phonological loop provides an accurate description of how memory actually works when we handle auditory information. It has been shown that it is easier to remember words which sound different than words that sound similar. If we try to recall a series of words that sound similar, the likelihood that we will remember wrong significantly increases, because we are more likely to mix up similar words. It is therefore more difficult to remember the series "blue, canoe, clue, shampoo, shoe" than the series "cat, yellow, kangaroo, house, soap". This is called the phonological similarity effect.

It has also been shown that it is more difficult to remember sequences of words with many syllables than series of monosyllabic words; it is therefore more difficult to remember the series “catamaran, rhinoceros, crocodile, lighthouse, telescope" than the series "dog, boat, salt, bat, screen". This is called the word-length effect. This effect is believed to be due to the fact that it takes longer for us to repeat long words and that we lose information along the way before we manage to repeat all words in a sequence of words with many syllables. This means that the number of items you can remember on verbal working memory tests is dependent of what language you speak. For example, it has been shown that Welsh children can repeat fewer digits than English-speaking children because lists of digits take longer to articulate in Welsh.

The amount of information we can keep in the phonological loop is also connected to our speech rate; that is, individuals with a strong verbal working memory often have a higher speech rate (measured in words/second) than individuals with weak verbal working memory. This depends on the fact that the speed of our spoken voice is approximately the same as for our “inner voice" (which we use to maintain information).

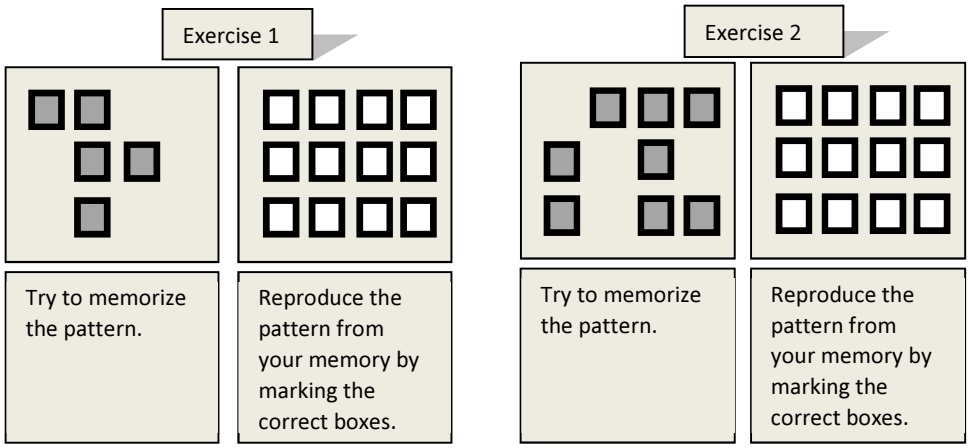
An example of when the phonological loop is used is when you are trying to remember an entry code that someone has told you. Imagine that you are in town and bump into a friend. You decide to meet at his friend’s home for a snack an hour later. You have forgotten your mobile and neither you nor your friend has pen or paper. You are on the way to work, one block away, where you have access to pen and paper. Your friend says her entry code to you: "18 24" and you part ways. To remember the entry code while you walk to work you will repeat the digits in your head with your inner voice. When you then arrive at work, you have succeeded in retaining the information in your memory and can write it down.

THE VISUOSPATIAL SKETCHPAD

The visuospatial sketchpad handles visual and spatial information. Just like in the phonological loop different types of impressions are processed in the sketchpad, but here they are transformed into visual impressions or spatial code. The visuospatial sketchpad is also necessary for our ability to create and manipulate mental images. The sketchpad can be divided into two parts: a visual part that takes care of information about objects shapes and colours and a spatial part that manages information about movement and direction.

To measure visuospatial working memory, tests in which visual sequences are to be encoded are often used. An example of this is to present block patterns that become more and more complex and within which positions for more and more blocks are to be memorized (see Figure 5).

FIGURE 5: EXAMPLE OF BLOCK PATTERN



An example of when you use the visuospatial system is when you need to remember directions of how to get somewhere. Imagine that you are out walking in town when a friend calls. She wants to meet you in the new shopping mall. You do not know where it is but she describes it for you. She knows where you are now and explains exactly which way you go in order to get to the mall.

She says – “first you go straight forward. At the convenience store turn left. Then you go past a toy shop and turn right. When you turn the corner you will see the shopping mall.” In order to remember how you will find your way you must maintain the description in your head. You must remember which places you will pass (convenience store, toy shop). Moreover, you must remember in which direction you must go at the different places (straight, left, right).

Another example of when the visuospatial system will be used is when you visualize in your mind how the pieces on a chess board would probably be moved over a number of moves ahead as a result of your intended next move.

THE EPISODIC BUFFER

The episodic buffer is the latest addition to Baddeley's working memory model. It was added after research revealed that information from long-term memory can have a profound effect on our working memory capacity. The episodic buffer is a temporary storage, where information from the incoming impressions, the phonological loop and the visuospatial sketch pad are integrated with information from long-term memory. The episodic buffer is considered important for learning because it can use multimodal code to integrate information from different systems into a single representation. Like the other components of working memory, there is a limitation in the amount of information that can be handled simultaneously.

An example of when you use the episodic buffer is when you solve a mathematical problem. In order to calculate five times seven you use the information presented to you, but you must also use information from long-term memory, (the rules for multiplication) in order to calculate the answer.

THE CENTRAL EXECUTIVE

The central executive, or the executive system as it is also called, coordinates and monitors the other systems in working memory. In addition, several aspects of how we use our attention are guided by the executive system. Firstly, the executive system determines our ability to focus attention and our ability to close out impressions that compete for our attention. When you sit at home and watch your favourite programmes you direct your attention to the television screen in front of you. At the same time, you close

out the impressions of your surroundings such as children playing in the next room or a bird chirping outside the window. This puts the executive system to work.

The executive system also controls our ability to divide attention between several tasks simultaneously. An example of when high demands are put on the executive system is if you correct a test while at the same time listening to the news. The executive system is activated even when an automatic mental process is disturbed or fails.

In order for us to make sense of larger amounts of information it is essential that part of the information can be handled automatically, i.e. without conscious mental effort. This is because the executive system must be able to devote resources to higher mental processes such as problem solving and reasoning. For example, if you are an adult, reading is an automatic process which means that while you read there are mental resources left to reflect on the meaning of what you have read. In contrast for a child, reading may be such a mentally-demanding activity that hardly any capacity is left to interpret and take meaning from the text.

The executive system is the part of working memory upon which there has been the least research. From currently available research it seems the executive system serves the functions mentioned above. However, it is probable that there are additional purposes not yet described.