Attention and Working Memory

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Abstract—The ability of attention and working memory are two very important cognitive functions. There is broad agreement that working memory is closely related to attention. There has been a lot of research in the past that tries to explain the relationship between the two. So far it seems that their relationship is closely related as well as very significant, while one affects the other. This article outlines several theoretical options for conceptualizing this link and evaluates the views of the authors coming to the same conclusion. Essentially, the purpose of the literature research is to show the interdependence of the two fundamental cognitive functions through mechanisms or daily processes - which require working memory and attention – as well as through neurodevelopmental disorders or diseases. In some of the articles listed, the working memory and attention have been divided into components that help to see the relationship between them too.

Keywords—Working memory, attention

1 Introduction

According to Kokkalia and Drigas in recent decades the concept of working memory has been widely used by various scientific fields (such as cognitive psychology, cognitive science and neuroscience). The term "working memory" was adopted in 1960 by Baddeley and Hitch. Working memory is referred to as a system necessary to have certain things in mind and is considered necessary when performing the complex functions of logic, perception and learning. Working memory functions as one of the key cognitive skills that includes a number of components that are responsible for the various forms of processing as well as the temporary storage of information, which is linked to academic and professional achievement. Essentially working memory consists of four elements of limited capacity. The model proposed by Baddeley and Hitch includes the central executive unit, a limited-capacity alert system that tunes the working memory and controls the flow of information from long-term memory. The executive central unit is supported by two auxiliary systems: 1. the phonological loop and 2. the visual-spatial sketchpad, which are used to store and process phonological and optical spatial information, respectively. Poor working memory is the source of many problems like learning difficulties. The evaluation of the problem is provided by a test called Battery Standardized for Children, the early

identification and intervention becomes necessary as well as the training of working memory is done through tools such as Cogmed [1].

Segalowitz & Frenkiel-Fishman explain that attention and cognitive control are multidimensional constructs involving a variety of cognitive functions related to neurobiological substrates. The researchers attempted to fractionate attention by identifying five main component processes underlying the attention tasks. These five are monitoring, energizing, inhibiting, contention scheduling adjustment, and if-then logic control. The components occur in various combinations in a variety of types of attention demanding situations such as maintenance attention in slow-changing situations, concentration attention during fast situations, sharing attention when different cognitive activities must be executed at the same time, suppression of attention and shifting attention focus when a complex activity frequently presents changing demands [2].

Finally, Roodenrys et al with the attention control model incorporate the supervisory control system (SAS) of working memory. This is enabled in attention control modes. Examples of SAS surveillance include tasks involving 1. planning, 2. decision making, 3. overcoming a typical strong response, and engaging with tasks that are difficult to grasp [3].

2 The Relationship Between Attention and Working Memory

Deutsch and Deutsch, who made a literature review about behavioral findings of attention, commended mechanisms for many of these features. Many experiments and theories were presented that had been investigated the phenomenon of selective attention compared with perception. In this framework stressed that the nervous system retains information that is received separately. Also, in this way the confusion is avoided too. This is explained by the filter theory. The existence of the filter helps to select messages with specific characteristics and then proceed to the central analysis mechanism. In this way, the remaining messages with other features are excluded. However, the creation of other discrimination filters has also required the selection of wanted from unwanted messages. Finally, the neurophysiological evidence proposed a shifting reference standard. The results demonstrated a neural blockage of unwanted messages which fluctuated in the lower sensory levels. On the other hand, the wanted messages analyzed at the highest sensory level [4].

Drigkas and Kariotaki made a review study collecting information on theories and models of attention. The first part of the research lists a variety of theories in which previous researchers linked attention to various factors. More specifically, different types of attention, and working memory can be associated with perception, eye movement, metacognition tasks, and emotion. Moreover, the types of consciousness are affected by attention as well as the capacity of visual working memory depends on the inhibition of distraction, the top-down and bottom-up processes are considered a factor of top-down attention and of course the connection of working memory with attention was emphasized. In the second part of the research, after the previous ones were abandoned, it included models of attention such as the noisy Perceptual

Template Model that predicted the influence of a visual task to the attention or the Novel Recurrent Neural Network Model and the autonomous robot control system. Thus, it is understood that attention is an important human cognition that could be enhanced and trained as a metacognitive task for mental flexibility and self-conscious. The external attention deemed necessary for selecting sensory information instead of internal attention is needed for working memory contents [5].

Baddeley initially suggested a model that was later extended due to the need for explanations of other phenomena. In this way, it is designed and implemented the fourth component, the episodic buffer. The working memory is the cognitive function that used in cognitive science in which information is stored for complex processes. The first component, phonological loop is a system of temporary verbal storage and processing, which is necessary, for example, in the immediate maintenance of a sequence of digits. The visual-spatial sketch is a parallel visual system for storage and processing. The fourth and new element, the episodic buffer, is a new working memory model, which is used to combine information from various sources to form integrated units of visual, spatial, and verbal information, in chronological order [6].

Redick and Engle investigated the relationship between working memory capacity (WMC) and the ability to control attention. More specifically, the researchers conducted three types of tasks such as dichotic listening, Stroop and antisaccade. Firstly, the research has been reported in previous studies that focused on working memory capacity, WMC-spans (LS) and WMC-spans (HS) too. In line with this point, the current view explored whether differences in WMC correspond to differences in the three attention functions measured by the Attention Network Test (ANT). The development of the Attention Network Test (ANT) divided the attention into three parts, the alerting network, orienting function and executive control. The main goal of the experiment was to clarify if working memory is related to the three functions of ANT. The participants in the study were 18 to 35 students whose attention was measured by the OSPAN task. Twenty-six individuals had WMC - HS, twenty-eight colleges had WMC - LS and two of them were removed due to low performance (span group). The results of the present experiment were calculated by ANOVA and showed that WMC is directly related to executive control. This is explained by the fact that the span group had differences only to the executive control as opposed to WMC - HS and WMC - HS which differed in alerting attention and orienting attention too. This proves that when the capacity of the working memory is high then the attention control is at high levels respectively [7]

Schweizer and Moosebrugger reported an investigation that working memory and attention is a predictive element of intelligence. So, the two cognitive processes seem to work under interaction. In a sample, 120 people aged 19 - 45 years old, working memory was assessed with Exchange Test and Swaps Test while attention was evaluated with three types of Frankfurt Adaptive Concentration - Performance Tests (Fact, Fact - SR, and Fact - E). Finally, the intelligence was measured with Advanced Progressive Matrices (APM Raven) as well as Zahlen – Verbindungs - Test (ZVT). The results of this study stated the close relationship between the two cognitive functions and the contact of working memory, attention, and intelligence. Most specifically the central executive function of the working memory was contributed to

intelligence. On the other hand, the attention was related to ZVT intelligence as well as APM intelligence. Notwithstanding, the ZVT was a higher prognostic factor for working memory than APM intelligence. This is an important reason in which working memory is not known to what extent it is essential for intelligence [8].

Randal & Engle introduces a bibliographic review of research related to working memory capacity, fluid intelligence, and executive attention. Essentially, a variety of different tasks have been tried on people with low–span and high–span. The first means that people had low performance in the execution of tasks such as reading and the high - spa means the opposite. This research mentions studies through which it tried to understand the mechanisms that are responsible for the capacity of working memory in various tasks, such as reading. So, one of the experiments was to retrieve named animals the low–span recovered fewer names than high–span people. The conclusion is that the differences in the capacity of the working memory also show differences in the ability to control endogenous attention. Another study, using the anti-shock task, showed a correlation between the ability to attention control and the capacity of working memory. More specifically, it was necessary the attention control in antisaccade procedure. The people with a low–span made more mistakes. Furthermore, there were much research showed that working memory and fluid intelligence is useful in the ability to delete information when it is not useful. This ability is based on attention control [9].

Ash, Vogel and Oh explained that the process of attention must go through two stages (perceptual and post perceptual) which are separated in the working memory. A variety of research demonstrates the relationship between working memory and attention. Therefore, this article analysed this relationship by explaining the ways in each process. Initially, the process of selective attention works during the sensory and post perceptual stages. At the same time, the working memory is affected by these specific stages. Also, the documented interactions proved that attention can act as a gatekeeper to working memory by helping to decode information. In this way, the data are determined which will occupy a small space in the working memory. In addition, the same attention processes, that help identify new information, are also used to maintain information about spatial working memory. Many procedures involved in working memory. In conclusion, it is understandable that the relationship between working memory and attention is multifaceted [10].

Lavie and Fockert investigated the availability of attention during a task that depends on the availability of working memory. So, three different experiments were performed. The first two experiment involved 12 university students who were asked to take a dual task condition and one single task condition. During the tests there was a green singleton on the screen. In the first test, students had to remember specific digits and say if they appeared at the end. Unlike the second test that does not agree with this. The results were detected and showed that in visual tests the attention capture is affected by irrelevant stimuli (singleton) as well as the availability of working memory. In the second experiment, students were involved in visual search tasks that had to recall a series of digits. The mediation was the same. The results showed that working memory is related to whether attention will be affected by the singleton. In the last experiment the participants were ten and followed almost the

same procedure as the second experiment. The results confirmed that the load of working memory can increase the attention capture [11].

Oderauer and Hein initiated the utility of selective attention into the contents of the working memory. That is, the information is selected by selective attention with the help of working memory. The three built-in elements of working memory are the retention of information (LTM) in the immediate access area and the focus on one point (broad focus). The broad focus is in limited capacity than LTM. People can retain a series of elements (broad focus) while additional elements exist in LTM. Four experimental findings serve as evidence for focusing on working memory. The narrow focus serves to select specific information required for each cognitive function. The results of the research showed the same importance in the narrow and broad focus. Besides the article argues that individual differences in working memory determine the function of the broad focus. In contrast to the narrow focus that is not related to the individual differences of the working memory [12].

Theeuwes et al are considering at the case where the functions are not at a different point in the brain but arise from recruitment brain areas of spatial attention and motor control. The maintenance of working memory is related to attention but also the ophthalmic system. This view may be related to the new invitation of Baddeley that connects visual, spatial, and verbal information. Findings from previous research have shown that shifting spatial attention to a particular space means maintaining working memory. Also, focusing on a spatial location increases the likelihood that this information will be transferred to the working memory. Moreover, visual-spatial attention plays a key role in recalling information from visual working memory. Thus, the relation of spatial attention to working memory arises. In other experiments, the external factor affected spatial attention, resulting in the displacement of spatial working memory. In essence, visual working memory and visual attention have been shown to share the same content. Finally, the results of other research showed that attention precedes an eye movement and attention is the vehicle in which information is stored in working memory [13].

Hansen et al investigated the effect of vagal tone on performance during executive and nonexecutive tasks, using working memory and a sustained attention test. Working memory is a central function that is essential for future operations such as decision and making and troubleshooting. Heart rate, as well as heart rate, were investigated, which are important for proper and faster responses. The test used was a continuous performance test (CPT) in which took part 53 people with an average of 23 years of age were controlled. This test divided tasks into executive and non-executive functions. Two tests were presented and measured with the working memory test and the CPT. The procedure followed in the working memory test was to locate the same digits that had appeared earlier. After the works were completed, they were then divided into executive and non-executive works. The groups of participants were divided into low and high heart rates. The results showed that the variation in heart rate was related to work performance and heart rate dysfunction was related to heart rate variability. The differences attributed to qualitative differences between task demands could be predicted by the subjects' cardiac vagal tone [14].

Docherty, Rakfeldt et al investigated schizophrenic communication disorders and lack of working memory and therefore attention. Schizophrenia presents reduced cognitive function and language performance problems. This is because people with this disorder do not have the skill to maintain a speech plan to working memory. There were 48 schizophrenic participants, 24 dipolar and 23 healthy people. Speech control and language performance were measured with a meter that examines vague language references. The working memory was measured with Trails B and Task Set Test. The test results were articulated and given a working memory index. The measures included visual and verbal working memory. The CPT test for attention was also used. The speech of schizophrenic and bipolar patients appeared more disturbed than that of non-psychiatric patients. The ratings in the schizophrenic patients were associated with scores on tests of working memory and attention and were not related to performance on concept formation or verbal fluency tests. In contrast, in the bipolar and no psychiatric individuals, reference performance was associated with concept formation and verbal fluency test scores but was not related to performance on tests of working memory [15].

Belleville, Chertkow et al distinguished attention according to three control procedures (divided attention, manipulation capacities and inhibition). Moreover, the working memory has separate executable components (inhibition, updating and switching). People with schizophrenia were found to have been harmed in tasks that measured the inhibition of responses and difficulties in manipulation and inhibition. In addition, it seems that people with mild cognitive impairment end up with schizophrenia because they have memory problems, especially episodic memory. Over time in these individuals reduced executive functions and abilities. There were 76 participants, 19 of whom had schizophrenia, 28 had mild cognitive impairment. The three processes are Alphabetical Recall, Adapted Brown–Peterson Procedure, Hayling Test. People with schizophrenia showed weakened attention to all three elements. People with mild cognitive impairment were harmed to Brown–Peterson. People with both disorders were deficient in all three processes [16].

Buehner et al developed a study which is distinguished the working memory in four components - storage, processing, supervision and coordination. In this framework were created models of attention too like as selectivity aspect of attention. The main goal of the research was to clarify the relationship between working memory, attention and reasoning. The tests were administrated in 135 students of the Philipps –University in Germany. Participants were tested in working memory tasks, attention and reasoning tasks in groups of about 2 to 5 people in a laboratory. Each participant took part in two sessions lasting 3 - 3.5 hours, separated by 1–2 weeks. The shed light on that the coordination and storage are considered important predictors for reasoning. Notwithstanding the supervision and selectivity aspect of attention had little impact on reasoning [17].

Mayer, Bittner et al reported that humans have limited access to visual information storage. Is this restriction due to common nerve sources that have to do with visual working memory and selective attention? There are considered two cognitive functions that seem to be related to information storage. A trial study was conducted in which 18 people participated and followed a procedure using a computer to

memorize objects. In addition, there were 18 participants who followed almost the same procedure. The goal was to discover the brain region that responds to either working memory or attentional demand and those involved in both processes. The research hypothesis confirmed that there are processes that require attention, visual working memory, and common neural and cognitive resources [18].

Ricker, Nieuwenstein et al shed light on one of the storage processes called consolidation. Certainly, attention is important and works through an unknown process in working memory. This procedure is mentioned in the research. Older research has dealt with either short-term memory, perception, or selective attention. The results showed that attention delays were due to the consolidation of working memory. Also, the consolidation has implications for maintenance. This process also needed the attention process to be adequate. It also appears that the consolidation is not related to the long-term consolidation. Nevertheless, the research left several unanswered questions [19].

Wiley and Jarosz focused on the capacity of working memory to solve problems through attention. One of the most straightforward correlations between working memory and problem-solving is mathematical problem-solving tasks. The research had stressed that in order to mathematical problem solving, the information is initially preserved, data is stored and then the recall is done through long-term memory (LTM). In essence, working memory capacity can have either positive or negative effects. This means that capacity certainly plays an important role in attention and consequently in problem-solving. The more one focuses, the greater the capacity, and the easier it is to solve problems. On the other hand, some problem solving may not be successful if we focus on it for a long time, so executive functions are not always necessary to solve problems. Differences in working memory capacity depend primarily on differences in encoding or retrieval related to long-term memory. Secondly, it depends on the ability to limit distraction, thirdly on the ability to handle other mental states, and fourthly on the ability to deal with external interference. In summary, the differences in the capacity of the working memory are evident from problem-solving, attentional focus, and control [20].

Ikkai, Clayton, and Curtis supported their studies that the two substrates of working memory (prefrontal cortex-PFC and posterior parietal cortex-PPC) work with intense activity during working memory tasks, spatial attention and motor intention. Working memory is a very important component so it makes sense to look at neural mechanisms. Three different studies were performed. One related to visuospatial memory, the other with visuospatial attention and the third with motor intention. After being tested by these studies that persistent activity during delayed working memory reflected memory retention, attention, and motor intention, it was found that there is a nervous mechanism. So, it is suggested that PFC and PPC substrates contain a variety of neurons. The two sub-domains of working memory that show activity during the maintenance of a working memory show at the same time the persistent activity during the maintenance of spatial attention and the maintenance of the motor intention [21].

Fougnie explored the perceptual and central attention to distinct processes in working memory (encoding, storage, manipulation). Initially, the article reports that

visuospatial and central attention is different forms of attention. Regarding the encoding of the working memory, some questions were asked for attention: Can the audiovisual attention change during the encoding? Is it also necessary attention to the audiovisual sector? Finally, is the encoding of an optical array caused by optical information? The answers to the questions show that visual attention is not enough for the encoding and it is unclear whether the attention itself is necessary for the encoding of the working memory. However, there is evidence from other studies for a link between central attention and encoding. In addition, it proves that there is a relationship between working memory and attention during storage. Interference between central attention and working memory was mostly restricted to instances in which the contents of WM were being manipulated or updated [22].

Silk, Bellgrove et al have conducted a survey where the fundamental and closely related cognitive processes (spatial working memory, spatial attention) are based on common mechanisms. There were twenty healthy participants 19-35 years old and took part in a study. The experimental tasks were based on a working memory alone task and a dual-task that integrated a visual search task during the retention interval of the working memory task. According to this study, these two cognitive processes are closely related. The results showed an interaction between brain regions and spatial working memory. This interaction bespeaks that the part of the brain, the supramarginal gyrus, is important for mediating spatial working memory as well as spatial attention [23].

McCabe et al examined the relationship between attentional control and working memory capacity as executive functioning. In this article, the executive function and working memory capacity shared a common underlying attentional ability, which labeled as executive attention. There were many tasks of working memory capacity and executive function, along with multiple constructs of interest such as processing speed and episodic memory. The data of research proved the high degree of similarity between two cognitive abilities, which referred to as executive attention. The results of the study showed a strong connection between working memory capacity and executive functioning constructs contrary to correlations between these constructs and processing speed that were considerably weaker [24].

Rossiter, Stevens et al correlate tinnitus - the perception of sound in the absence of corresponding auditory stimulation - with cognitive functions in their experiments. Two experiments took part in two groups of nineteen people (chronic, moderate tinnitus group, and control group) and are involved in an auditory working memory task as well as a visual divided attention task. It is worth noting that the stress factor was included in some of the experiment tasks. In all the results there were universal differences between the groups. More specifically there are significant differences to the reading span. The above indicates that working memory is affected by chronic tinnitus. On the other hand in the automatic task of recognizing words revealed no significant difference. In general, the phenomenon of tinnitus seems to affect cognition making it poorer and weaker. Finally, covariate analyses proved that differences in task performance were not attributable to the stress factor [25].

Rogers et al investigated the interplay between the inattention and working memory in academic achievements to people with attention-deficit/hyperactivity

disorder (ADHD). The sample included 145 adolescents with ADHD which passed a clinical interview and a teacher interview as well as a questionnaire of strength and difficulties. Therefore, the inattention measured with Strengths and Weaknesses of ADHD symptoms and Normal Behaviour Scale. Secondly, the Auditory-Verbal Working Memory measures with the Digit Span and Letter-Number Sequencing subtests of the Wechsler Intelligence Scale for Children – Fourth Edition and Visual-Spatial Working Memory measured with the Spatial Span subtest and the Finger Windows subtest. The Woodcock-Johnston-III Test of Achievement and The Broad Reading Cluster was used for academic achievement. Essentially auditory working memory can be connected with achievements in reading and mathematics in contrast visual-spatial working memory was only associated with achievement in mathematics. Finally, the research findings implied that working memory plays an important role in the academic failure of adolescents with ADHD [26].

Shipstead et al explained the common grounds of working memory capacity with attention. Their research initiated with definition of working memory which was divided into two types - complex span and visual arrays. What emerges from the analysis is that complex span has a relatively stronger relationship to fluid intelligence. Moreover, found that both types of working memory task have strong relationships to attention control. This indicates that the ability to engage attention in a controlled manner is a critical aspect of working memory capacity, regardless of the type of task that is used to measure this construct [27].

3 Conclusion

The relationship between working memory and attention is evident from previous studies, although they have many distinct functions as well as elements. But how strong is the relationship between the two mental functions? Let us mention typical examples that emerge from the research cited above. So, on the one hand, research proves that selective attention is necessary for the skill of perception (since when we accept a variety of information, we must be able to choose some of this information) on the other hand additional research proves the relationship of perception with working memory. Thus the conclusion is reached that working memory is connected to attention. Also, research revealed the relationship between working memory items (such as capacity) with attention items (such as executive attention), so the relationship between the two functions is visible. This, of course, proves the opposite. More specifically, the attention control process as well as problem-solving require the capacity of working memory. The higher the working memory load, the higher the attention span. Attention is the vehicle that will help store information in our minds (working attention). Even in diseases such as Alzheimer's or disorders such as Attention Deficit Hyperactivity Disorder, when working memory is deficient then attention is also deficient. In addition, adolescents who have failed academically due to inattention have been shown to have a deficient working memory.

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