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The Relationship Between Working Memory and Academic Outcomes: An Empirical Review

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Abstract: Most students struggle with their academic performance, as the most basic cognitive ability in studying working memory is expected to correlate positively with academic performance. As there are few studies about this, this article aims to review the relationship between them and as a reference for future research. The hippocampus store memory, which plays an important role in working memory. The influence of academic performance on working memory can be divided into some different aspects: creativity, reading literacy and math ability. As for creativity, there are many different results suggested by scientists. For example, working memory linked with creativity positively, greater creativity associated with low working memory. Moreover, working memory has been shown to help with math and reading performance. The unique recovery of working memory is an important factor in mathematical fluency. Working memory is associated with tasks such as reading comprehension and math problem-solving, which illustrates the impact and contribution of working memory to academic achievement. This review contributes to the understanding of academic achievement from the perspective of working memory to a great extent.

Keywords: working memory, creativity, reading literacy, math ability, working memory

1. Introduction

The vast majority of students nowadays suffer from learning process and their academic performance. Moreover, many psychological disorders in children are triggered by mental health problems, and these may lead to poor academic performance [1]. Therefore, academic performance can be one of the factors which affect students' future life. Memory is almost the most basic and significant cognitive process in learning. Many previous studies showed that learning ability is linked with working memory which allows the person to temporarily hold a limited amount of information as already for imitated mental use [2]. Children with poor working memory capacity limit experience issues meeting the weighty working memory requests engaged with numerous classroom activities, such as reading, listening and spelling [3, 4]. Furthermore, another also says that it enables individual to copy with new situations and is necessary for fundamental aspects of normal behavior like learning, reasoning and language comprehension [5]. Working memory has an impact on students' academic performance by improving their comprehension ability, writing ability and mathematical problem

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solving abilities. Cognitive tasks require sufficient cognitive resource like reasoning, critical thinking and creative problem-solving are more precisely predicted by working memory tasks' performance compared to short-term memory tasks' performance [6]. The present studies tend to investigate one specific factor affecting working memory on a relatively small scale. The purpose of this article is to explore the correlations between working memory and academic performance in some different aspects by reviewing and may help to look for a more effective valid methods to address the study issue of students in the future as well.

2. Methods

Using the database ScienceDirect, Google Scholar and full retrieval by inputting the keywords (and their derivatives) about "academic performance," "hippocampus," "working memory," "creativity", "stability," "subsequence academic skill," and "self-esteem." To understand the definitions of these proper nouns, select and collect some relative papers, and ensure the sources of these papers. Choose the fittest papers to prepare for the following review. The papers keep pace with the time, preferably published in the last three to five years. Also, the participants of the selected studies had to be students. The data in these studies must be true (without tampering). Control the other variables which may occur in the selected studies but no need for the following review. Clarify the logical relationships between variables including hippocampus, working memory and academic performance, then analysis and integrate these present results. Make sure that the review does not misunderstand the meaning of the papers.

3. Literature Review

3.1. What Is Working Memory

In human brain, working memory is stored in the hippocampus that is associated primarily with memory located in the inner mean media region of the tempered blob [7]. As the scientists find that the functional collaboration among hippocampus and cortex and the inversion of information flow provides a physiological basis for memory coding and maintenance [8]. With the damage to hippocampus, the ability of working memory also changes. In neurological patients, low memory capacity and small hippocampal volume measurements on magnetic resonance images coexist [9]. There is some relationship between the damage or the development of hippocampus and working memories and academic performance.

3.2. Working Memory and Academic Outcomes

3.2.1. Creativity

Creativity always acts as a skill which not only a part of the factor of judging intelligence but is closely links to academic performance as well and also the high-level thinking process of the human brain. As Vink claimed that working memory could play different roles in the relationship between divergent thinking and academic achievement, the positive relationship between divergent thinking and academic achievement for students [10]. The ability of creativity, also called divergent thinking, can be defined as the ability to generate different ideas and is generally seen as a cognitive aspect of creative potential [10]. And 'Vink find that students who think more divergent have a positive correlation with working memory. Because of a good working memory, students store more knowledge for them to create more ideas. At the same time, creativity plays an important role in academic performance. Especially student with lower levels of intelligence suggests a stronger relationship between creativity and academic performance, as they may have more chance to use their

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divergent thinking rather than their intelligence. However, other research shows that one interesting characteristic of individuals with greater creativity is that they often exhibit unique associations of creativity measured by divergent (CMDT) thinking with attentional processes. Some of these associations are common to subjects with low working memory capacity (WMC) [11]. This can be explained by the attraction of students. For example, patients with schizophrenia will be improved their creativity and reduce their working memory capacity. Scientists carried out this research from the point of view of neuroscience by using Functional Magnetic Resonance Imaging and found that it is caused by Gama amino butyric acid and glutamate. The other study claims the opposite ideal that individuals with a high working memory (WM) performance are more likely to ignore distractions and adpot effective strategies to deal with various tasks [12]. And the research found that working memory does not correlate with divergent thinking but with insight and ability of problem-solving. Although there are lots of different conclusions about the interaction between working memory and creativity, the methodology of this research seems to be similar. Scientists evaluate divergent ability by dividing that into fluency, flexibility and originality and test the ability of closed-ended creative problem-solving and insight problem-solving. The differences between them may be that the participants come from different countries and ages. Also, some hypotheses have not been proven, and further research is needed to confirm them. As for the influence of academic performance on a creativity, there is little study to look at the relationship between them specifically. One study predicts future academic performance by using creativity, showing that creativity actually affects academic achievement. Whereas Kuncel and Hezlett's study suggested that though a high level of creativity may be linked with high-level academic performance, fluency, flexibility, and originality are not essential for academics which be associated with high-level intelligence. And they also added creativity work more visibly in academic performance at a later age [13]. Regarding working memory and the correlation between divergent thinking and academic performance, no moderation effect was found, and it may be explained that there can be much cognitive ability to control divergent thinking and working memory [10].

3.2.2. Reading and Mathematics Literacy

Tashauna et al. comprehensively analyzed memory by studying how working memory affects and helps children who are typically developing in reading and math, examining individual differences in reading and math achievement. This study hypothesizes that WM will predict reading and math achievement statistically . And to account for the differences associated with each memory process, the study also examined the potential role of WM. The objective of this study was to examine the contribution and impact of two different memory processes (recollection and working memory) on children's academic performance. This study looks at memory more holistically than other studies examining executive memory associated with academic achievement. The results showed that all measures related to WM, including reading fluency, mathematical fluency, reading comprehension, and calculation, were positively correlated with it. In keeping with previous studies of WM's importance in math and reading achievement, Tashauna et al. found that WM did contribute to four measures of academic achievement [14].

After controlling for intelligence quotient (IQ) and age contributions, WM was shown to help math and reading performance. These results are consistent with previous research on WM's contribution to math and reading achievement. WM's unique recovery is a big factor in mathematical fluency, especially when outside of IQ. Furthermore, WM contributes to all four measures of academic achievement. This finding is consistent with past Swanson and Beebe-Frankenberger's exploration of WM's contribution to mathematics and Bourke and Adams' discovery of achievement in reading [15, 16].

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3.2.3. Academic Achievement

Academic achievement is assessed through standardized tests of language comprehension, arithmetic operations, math problems, and teacher assessment [17]. Some studies that include a sample of students with learning difficulties have found that WM is associated with tasks such as reading comprehension and the solution of mathematical problems to varying degrees, which illustrates the impact and contribution of WM to academic achievement. Nevertheless, other studies of children with learning difficulties have not found this association.

There is much evidence for the effect of WM on reading ability, such as its contribution to paragraph comprehension and overall cognitive skills. The reading ability consists of recognition, comprehension, memorization and speed and requires WM support. According to Titz and Karbach's research, it can be concluded that WM contributes to academic achievement to a large extent [18]. Therefore, to improve academic achievement, it is necessary to focus on the progress and development of WM. Otherwise, academic achievement will likely remain the same or low, whether or not in a good educational environment.

4. Implications

To begin with, the hippocampus is the physiological basis of working memory, and once the hippocampus is damaged, working memory will also decrease. Furthermore, working memory has a great influence and relationship with creativity, mathematics and reading literacy. These relationships directly or indirectly lead to the fact that working memory affects students' academic achievement. Intelligence can explain academic achievement in most cases. Working memory, on the other hand, is only indirectly related to academic achievement.

An interesting finding in the study of divergent thinking and learning achievement is that divergent verbal thinking is responsible for predicting mathematics, but divergent visual thinking is responsible for predicting reading comprehension[18]. While previous studies have shown that both divergent verbal thinking and divergent visual thinking can predict mathematical achievement, this study shows that divergent visual thinking does not have the ability to predict mathematical achievement and only divergent verbal thinking can predict mathematical achievement. Maybe these two studies chose different methods and different measures that produced completely opposite results. Meanwhile, since mathematical problems are generally presented orally, divergent thinking contributes to the solution of these mathematical problems, which may be the basis for the results obtained in this study. Future research should take these two opposite results as hypotheses, test them in a variety of ways, and further analyze the association between divergent thinking and academic performance.

Although Tashauna et al.'s research confirms WM's contribution to math and reading performance, it still has limitations. In the complex systems involved in WM, they only took rough WM tasks. Previous WM studies have discussed the association between all three WM systems and reading achievement. However, mathematical achievements were not examined. Future research should examine their contributions to reading and math skills based on a detailed WM task. In addition, the selection of the study sample was not wide enough, and most of them were Caucasian and upper-middle-class families, which directly led to the fact that the results of the study were not generalized. In future relevant research, it is necessary to pay attention to these issues and select a suitable sample with a wide range of people, which is more convincing and representative of the research results.

Furthermore, the authors do not give a detailed and clear definition of children with learning difficulties. The situation varies from children with or without learning difficulties to children. Especially for children with learning difficulties, the extent of learning difficulties and their impact on their current learning can lead to deviations between children's performance on WM tasks and actual results. Future studies should take this aspect into account, categorizing children by the depth

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of learning difficulty or by the learning task they are affected by learning difficulties and then comparing and analyzing the data to arrive at more general results.

Titz and Karbach's research has even shown that WM provides great help and support for academic success beyond intelligence. Therefore, to improve academic achievement, it is necessary to focus on the progress and development of WM. Otherwise, academic achievement will likely continue to remain unchanged or gradually decline, whether or not in a good educational environment.

So we conclude that working memory directly affects reading and mathematics literacy, not academic performance. Based on this conclusion, students should no longer worry about whether their working memory will lead to poor academic performance but should focus on the development and improvement of their reading, mathematical literacy, academic self-esteem, creativity, etc. These factors are the important reasons that directly lead to students' academic performance. Compared with doing a lot of working memory-related training to improve their academic performance, the development of the above factors is more effective in improving students' academic performance. Spending time on working memory without focusing on the most fundamental factors is not only detrimental to academic performance but may also lead to a decline or loss of abilities in other areas. Therefore, while students focus on consolidating knowledge, they should also focus on long-term improvement of reading literacy and other factors.

5. Conclusion

This review aims to explore and analyze the link between working memory and academic performance from the starting point of the hippocampus, the physiological basis of working memory. The significance of working memory for students' academic performance is assessed primarily through creativity, reading fluency, and mathematical fluency.

Working memory is stored in the hippocampus inside the brain, and provides the physiological basis for memory coding and maintenance. There are some relationships between damage or development of the hippocampus and working memory and academic performance, where damage to the hippocampus affects the ability to work memory.

Teresa et al.'s research aims to evaluate the specific contribution of working memory updating to predicting the academic performance of typical developmental children in related learning tasks through four standardized tests of language comprehension and arithmetic and mainly explores the impact of the two working memory updating tasks of keeping track and updating the numerical update task on academic performance. The study found a significant contribution to working memory updating on math ability as well as teacher assessment.

Tashauna et al.'s study, which looked at the effects of two types of memory on academic performance, differed from other related studies in that it was examined in the population of typically developing children. After analyzing the major components of academic performance, the study discusses WM's contribution to each section separately and the associations between them, focusing on the importance of WM for two factors: mathematics and reading fluency. In a large number of relevant studies, students with learning difficulties accounted for the largest proportion of the research sample. So the researchers of the study invited typical developing children as subjects. Based on data from previous studies, they believe WM statistically predicts academic achievement. And in order to explain the different situations related to the memory process, they specifically discuss the potential role of WM on academic performance. This study also used four hierarchical regressions and equations to study the contribution of WM to reading and math-related levels. The WJ III measurement (reading fluency, math fluency, reading comprehension, calculation) found that WM was positively correlated with each other. And for the accuracy of the results, the study entered age into the first step of the equation. The data showed that the total verbal IQ and age associated with

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achievement accounted for 18%, 20%, 10%, and 32% of the differences in reading fluency, paragraph comprehension, math fluency, and calculation, respectively.

Tashauna also examined individual differences in reading achievement and math achievement by studying WM's contribution to reading and math in typically developing children. The study statistically hypothesized that WM would predict reading and math scores. In addition, to account for the differences associated with each memory process, the study also looked at the potential role of WM. The results showed that all four measures related to WM (reading fluency, mathematical fluency, reading comprehension, and numeracy) were positively correlated. Consistent with previous research on the importance of WM in math and reading achievement, WM does contribute to four measures of academic achievement. After controlling for IQ and age contribution, WM has been shown to help with math and reading performance. The unique recovery of WM is an important factor in mathematical fluency, especially outside of IQ.

Furthermore, creativity plays an important role in academic performance. For students with lower levels of intelligence, there is a stronger relationship between creativity and academic performance because they have more opportunities to choose to use their different thinking than their intelligence. However, other studies have shown that an interesting trait of individuals with greater creativity is that they often exhibit a unique connection between CMDT and attention processes. Although a high level of creativity may be associated with a high level of academic performance, fluency, flexibility, and ingenuity are not essential. An interesting finding in the study of divergent thinking and learning achievement is that divergent verbal thinking is responsible for predicting mathematics, but divergent visual thinking is responsible for predicting reading comprehension. The possible reason is that mathematical problems are generally presented orally, and verbal thinking contributes to solving these mathematical problems.

To sum up, future studies should be broad and evenly selected for the appropriate research sample, and the results should be tested by analyzing the data obtained by different methods to test different or opposite hypotheses. It is important to note that a review standard should be established when analyzing data, removing erroneous values and extreme values to obtain accurate results.

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