Working Memory Trainings: Effects on Primary School Achievements

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1. Introduction

The relationship between working memory and complex cognitive processes has been investigated repeatedly. It seems that working memory capacity can be considered as a substantial determinant of children's scholastic achievements. Some studies suggest that well-designed training of working memory can be means of improvement in the area of educational performance. This article seeks to present the most significant research on that matter.

The most common way to conceptualize working memory (WM) refers to its functions. It is thought that WM can be defined as a complex system responsible for the short-term storage and processing of information in mind. The best-known model of working memory was proposed by Baddeley and Hitch [1]. According to the classic version of their theory, WM consists of three components. Two of them: phonological loop and visuo-spatial sketchpad, have a slave nature and are mainly responsible for a short-term storage of information. The last one, called central executive, is thought to be a supervisory system and performs the following tasks: monitoring and coordinating cognitive processes, inhibition of unwanted information from ongoing processing, and controlling slave systems of WM.

In view of those functions, it is highly probable that WM is engaged in higher cognitive processes and plays an important role in complex cognitive tasks requiring reasoning, language and reading comprehension or problem solving. What should be mentioned is that WM is considered to have limited capacity. It is assumed that individual differences in those terms might be responsible for individual differences observed when performing more complex cognitive tasks. Thus, many psychologists have tried to assess WM capacity and examine its relation with high-level cognitive processes and real-life tasks.

Many studies have demonstrated strong positive correlation between working memory capacity and intelligence, especially fluid intelligence [2]. Working memory is also already well-known to be linked with scholastic achievements. A brief overview of research on relationship between WM and scholastic achievements shows that correlation between those two variables can be observed within two major areas of education – language comprehension and mathematics [3,4]. There are some promising studies demonstrating that WM training can lead to the improvement in WM capacity that influences scholastic performance. It seems reasonable to overview current studies on WM training in primary school children with the special reference to the possible scholastic effects of those influences.

2. An overview of research on Working Memory trainings

First of all, it is important to underline that the major aim of WM trainings in children is not only to improve their WM but also to transfer this gain to complex cognitive processes and real-life tasks. According to Shipstead, Redrick and Engle [5], possible effects of WM training can be defined as "near–transfer" and "far-transfer". "Near-transfer" refers to the improvement of performance in tasks similar to the training tasks. "Far-transfer" is much more consequential because it signalizes improvement on tasks that are much more different from the training tasks. This kind of transfer can appear due to similarity of cognitive processes underlying both tasks' performance. In the following subsections "far transfer" effects connected with education will be discussed.

2.1. Working memory training in children with special educational needs

The vast majority of research on WM training refers to the population of children for whom WM capacity is a limiting factor in everyday life or for school performance, especially to children diagnosed with ADHD or dyslexia. Research conducted by Klingberg and colleagues [6] demonstrated that gains of WM training in school children diagnosed with ADHD transfer to significant improvement in reasoning and attention. What is more, training also helped to reduce ADHD symptoms. This training lasted 5 weeks and consisted of tasks based on the method "Cogmed" - videogame-alike tasks designed to train WM, which adjust the level of difficulty to reinforcing expertise of each individual participant. It is important to mention that teachers' rating did not show any difference in children's behavior, so it is questionable whether any kind of educational improvement was obtained. There is also little evidence that training can lead to long-term changes in cognitive abilities.

On the other hand, there is also some evidence that WM training may not affect intelligence scores. Holmes and colleagues [7], after 20 days of WM training of school children diagnosed with ADHD by previously described "Cogmed" tasks, observed an increase on WM capacity that persisted over 6- month period. At the same time, this gain did not enhance intelligence level. It seems that the issue of the influence of the WM training on intelligence should be still kept under discussion and requires further investigation.

In the area more directly related to educational performance, two studies report particularly optimistic conclusions. Research conducted by Alloway and Alloway [8] among children identified as having "learning disabilities" showed significant post-training improvement not only in WM capacity but also influenced crystallized intelligence and academic attainment, particularly in the area of vocabulary and numerical operations. Concurrent conclusions were presented in another study [9] based on "Cogmed" WM training and focused on children with reading comprehension problems. The improvement of WM capacity caused by training appeared to influence children's reading comprehension development. The aforementioned implications suggest that special cognitive training can be used as means of improving children's educational competences.

2.2. Working memory training in typically developing children

There is much less evidence on the effectiveness of WM training in typically developing school children. However, recently this topic is gaining more and more attention among cognitive scientists. Witt [10] reports preliminary results of a WM training in primary school children that leads to the improvement not only in WM but also in mathematics (assessed by the number of errors in mathematic task). It is important to notice that applied training was conducted individually and consisted of many tasks of different nature (some of them were game-alike and some resembled cognitive tasks). Due to this fact, it is difficult to assess what kind of cognitive processes played the crucial role in the improvement observed. What is more, control group was only assessed twice and not subjected to any other kind of vicarious influence. These reflections seem to be strong imperfections of presented study, so it should be considered with caution.
Another study on the effectiveness of WM training was conducted by Loosi and colleagues [11]. In this study not only "near" but also "far-transfer" effects of WM training in school children were demonstrated. The training task was designed to engage both storage and processing resources of WM and had an adaptive difficulty. Children significantly enhanced their performance on WM tasks and on reading tasks based on the very well-standardized measure, namely Salzburg Reading Test. However, it should be mentioned that some research showed incompatible outcomes. A good example is a study conducted by Shavelson and colleagues [12], who trained middle school children with "Cogmed" WM training. The results showed post-training improvement in WM tasks but failed to demonstrate any signs of "far-transfer" in intelligence or scholastic attainments. This report may be a counterbalance for the previously reported conclusions and remind us to postpone any conclusive judgment about "far-transfer" effects of WM training until researchers better explore this topic.
Finally, it is worth to mention another study which is not directly connected with the educational area but reports some implications that might pertain to it. Jaeggi and colleagues [13] trained school children by videogame-alike tasks based on the N-back paradigm. Participants were assessed on reasoning tasks (as a indicator of fluid intelligence). It appeared that some WM trained children improved their performance on fluid intelligence tasks while others did not and the gain was closely correlated with the range of improvement in the training tasks. What is important, the difference between groups was also observed after 3-months gap of training. It is a significant notice that "far-transfer" effects of WM training can be long-lasting and consistent over time. What is especially important is that Jaeggi's study showed that the amount of subjects' improvement on the WM task directly influenced transfer to higher cognitive processes like fluid intelligence (that may definitely influence scholastic achievements). The very important question that appear is: why some children manage to show transfer effects and the others fail? Providing unambiguous explanation definitely requires further research.

3. Conclusions

This section summarizes and takes into consideration the most significant findings of the studies on WM training affecting scholastic achievements in primary school children. Conclusions are presented in two sections according to the major area of their possible implications.

3.1. Theoretical conclusions

First of all, it seems to be indubitable that WM trainings in children can be effective and lead to the improvement in WM capacity. Furthermore, this regularity can be observed when assessing WM using various methods (including "far-transfer"), so it definitely cannot be claimed that reported effects are simply caused by the increasing participants' expertise in training tasks.
On the contrary, findings signalizing that higher cognitive processes can benefit from WM improvement should be considered with caution due to the area of discrepancy in empirical reports. Some research presents the transfer effect on intelligence (both fluid and crystallized) and/or scholastic achievements but there are also some studies that failed to yield such effects. The discrepancy might be caused by the following methodological imperfections of the studies. (1) The differences in training tasks and schedule of the training program. (2) An inadequate control group that is not involved in any kind of influence, or conversely, that trained on tasks that engage too much WM. (3) The kind of methods used to assess higher cognitive processes (some of them might be not well-adjusted to children). Without regard for these methodological objections, it occurs that WM training might improve scholastic achievement in the area of reading comprehension and less likely in mathematics.

3.2. Practical conclusions

To cite Jaeggi [13], current findings reveal that WM trainings work, but there is an urgent need to investigate the boundary conditions on transfer, especially in terms of the training time and individual differences of participants. Future research should be aimed at determining factors that moderate the effectiveness of WM training and then – designing the most appropriate training program that leads to general and long-lasting effects and enables all

the participants to benefit from training. Therefore, it might seem that WM trainings, an issue first investigated in the area of cognitive neuroscience and experimental cognitive science, is starting to be more and more attractive for researchers involved in educational science. Perhaps this is the area where researchers should find the way to cooperate with the aim to create the most effective WM training schedule.

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