Evaluating the Effects of Working Memory Training on Children: a Review of Literature

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Abstract. Working memory (WM) involves the cognitive activity of temporary information processing in the human brain. With the development momentum of WM in psychological research, we have carefully reviewed various WM training programs to evaluate the effectiveness of WM. However, the findings in this research area have led to an unresolved conclusion that has cast doubt on the effectiveness of current training methods. This article is a review of the latest research on children's working memory training. It provides a critical perspective on the impact of working memory training on children's cognitive development. The review and analysis show that the current findings are not sufficient to constitute evidence to prove that in typical children, there is a direct link between working memory training and children's cognitive development. However, it is worth noting that the positive effects of WM training can be confirmed in studies of children with learning disabilities.

Keywords: Working memory training; Transfer effect; Cognitive functions; academic performance; children.

1. Introduction

Working memory training and its influence on child development had received a wide range of research attention since the concept was initially proposed. Working memory (WM) denotes short-term memory capacity that affords temporary storage, control, and management of information in higher-order cognitive activities. This human attribute is assumed to aid in executing several cognitively demanding tasks simultaneously, such as solving arithmetic problems or understanding semantically complex texts. Some studies have proved significant associations between WM and higher-order cognitive performances, for example, poor performance results are found to be related to lower capacity in WM [1][2][3]. It can be inferred from prior studies that if one's WM capacity improves through training, his/her cognitive development will benefit accordingly, possibly resulting in a more rewarding life experience than it would otherwise be.

2. Working Memory Training and Transfer Effect

The notion of WM indicates that human attentional resources, in general, are limited. If deliberate training could effectively increase the WM capacity, there should be transfer effects that can also be applied to untrained cognitive abilities [4]. Thus, WM training might result in both near-transfer and far-transfer effects if this inference is valid [5]. When WM training is task-specific, it will lead to skill enhancement of this particular task, which is called the near-transfer effect. (e.g., improved visuospatial WM capacity followed by training on a verbal WM task). In contrast, if capacities that are not closely associated with the cognitive attribute under training also benefit from the WM training, far-transfer occurs. (e.g., beneficial effects of WM training on improvement of academic performance such as higher math scores) [5]

As is envisaged, if improvement in children's WM capacity is realizable, there will be far-transfer effects on a wide range of cognitive capacities or skills that children may be struggling (e.g., ability to plan, reason, and behavioral or logic inhibition). Thus, the concept of transfer effect could be regarded as the potential of WM training to optimize problem-solving in real-life scenarios, as the improvement in WM is expected to transfer to other real-world attainments (e.g., improved attentional skills, good performance in an Intelligence Quotient (IQ) test, and good school attainment). Thus, the focus of this paper is to assess whether the near-transfer and far-transfer effects do occur along with WM training, in particular in terms of its contribution to aid children with learning disabilities.

3. Current Working Memory Training Methods

As WM training is gaining attention for its beneficial potential, an array of finely tuned training methods have been developed to improve WM capacity. Morrison and Chein [6] reviewed several frequently employed training methods which were categorized into two types: strategy training and core training.

Strategy training is designed to enhance memory capacity concerning specific types of information and messages, for example, WM retrieval and WM maintenance training. These methods are expected to improve individual performance in tasks that require long-term information storage. Different from strategy training, core training is the method aiming to enhance one's overall WM capacity using the repetition scheme. These trainings aim to improve overall cognitive abilities.

A common feature of WM training programs is the design of eliciting participants' engagement with cognitively demanding workloads in which rapid and simultaneous WM processing is triggered. The two training types mentioned above are often the foundation of current commercial programs. In these programs, a set of tasks are combined to facilitate human cognitive development in aspects that are examined and developed in WM training research. For example, the program named Cogmed comprises multiple tasks with a focus on visuospatial and verbal memory enhancement, in which participants practice their skills multiple times a week for several weeks. Nine tasks are included with a total of 25 sessions, and each session will last around 30-45 minutes [7]. Another notable WM training program is Jungle memory [8]. This program features multiple layers of progress in children. Users taking part in the 8-week program have one access to three tasks per day. The way these programs achieve their aims is by maximizing desired outcomes on the whole. However, since the result of all these programs tend to overlap, it is difficult to pin down the exact components of the task design that are impacting WM the most.

4. A Review of Existing Research on Working Memory Training on Children

4.1 WM Training on Typical Children

There is three meta-analysis research focusing on children specifically. Redick et al[7] evaluated the potential of WM training to facilitate academic attainments of school kids. It is found that evidence for a facilitating relationship is not salient except for the positive signal released by the first few research articles. Based on that, the researchers further selected experiments reported to have a positive WM transfer effect to search for convincing evidence supported by a large sample size, active control group, and used objective measures. However, these methodologically rigorous studies suggest that WM training is inefficient in contributing to children's academic standings such as maths, spelling, and reading. For example, Alloway et al. [9] examined the training tasks used in the Jungle Memory program. The treatment group had four training sessions per week while the passive control group received none training and the active control group received one session per week. After the training, the treatment group did not have a larger improvement in post-test results than two other control groups in terms of the two administered measures of spelling and maths, and aa subset of participants who completed the academic tests at an 8-month follow-up was also observed the same nonsignificant results.

Later, a systematic review conducted by Randall and Tyldesley [10] analyzed WM training effects on children aged five to twelve, aiming to investigate the far- and near- transfer effects of notable WM training programs. The effect size of near-transfer indicates positive effects of WM training on participants' verbal and math skills, such as in studies conducted by Kroesbergen et al [11] and Witt [12]. However, the finding is inconclusive regarding far-transfer effects. While various results on numeracy and reading literacy-related research were reported, there are no evidence-based far transfer effects to these skills. Most recently, the meta-analysis conducted by Sala and Gobet [13] examined near- and far-transfer effects of WM training on typical children aged from 3 to 16. A significant near-transfer effect was found in previous studies, but, same as the previous meta-analysis, little far-transfer effects were observed in terms of measurement of fluid intelligence or cognitive control. In synthesizing the findings, Sala and Gobet [13] also acknowledge a change in the subtleties of research methodology and design could yield very different results. As in the three meta-analysis reports, WM training does not saliently lead to strengthened cognitive abilities in children, especially in terms of far-transfer effects, hence might not contribute to improved academic attainments.

However, when considering the results from previous studies, two factors need to be scrutinized. Firstly, the sample size reported in previous studies were not large enough to lead to valid conclusions. For example, Melby-Lervag et al.[14] reported that the mean sample size of the 120 studies in all ages investigating WM transfer effects of nonverbal IQ level was only 22.1 in the control group and 22.4 in the training group. This means that the findings generated by these studies may be unreliable. The study by Klingberg et al.[15] had only seven subjects without a control group but concluded with a large effect size (d = 2.18). Thus, future research should consider a significantly larger sample size to generate more accurate effect-size estimation. Besides, the inclusion of an active control group also needs to be considered. The expectancy effects might also lead to bias on results, as the fact that test subjects are aware of the nature of the test itself could alter the behavior and potential actions they would enact [6]. Thus causing significant impacts, perhaps even more severe than the test itself, on test scores and targeted cognitive process. Participants' perceptions that this training could lead to improved results might also affect their performance in the test. Moreover, if a participant is informed of a delayed post-test in 6 months after the training, he or she might devote extra efforts for improved performance on the post-training assessment [14]. Thus, instead of an 'untreated' control group, an active control group that works as a placebo is needed.

4.2 WM Training on Children with Learning Disabilities

Meta-analysis and systematic research mentioned above have not included studies of WM training on children with learning disorders. Findings of WM training effects on children with learning difficulties and typical children yielded mixed conclusions. Since Working Memory Deficiency (WMD) are often associated with academic underachievement of kids with learning disabilities (LDs) [16], it is essential to discuss the WM training effects on those children in particular.

Alloway et al.[9]found that WM training programs facilitate the spelling ability and fluid intelligence on children with LDs in an 8-week training program, and these impacts were maintained eight months after training. Vugs and his colleagues[17] found that the visuospatial WM, mental flexibility, and inhibition abilities of children aged 8 to 12 years with LDs could be improved significantly after 6-month post-intervention. However, neither verbal WM nor verbal fluency showed noticeable improvement. Also, this research integrated reports from parents and teachers, who also gave positive feedback on a six-month post-intervention behavior rating. However, since there is a lack of control group, it is understandable why there is no apparent effect on the immediate post-test. Further, Chen et al.[16] researched to investigate training on WM updating ability with 58 children with LDs. It is reported that the treatment group outperformed the control group after six-month training, showing a significant near-transfer effect.

The above-mentioned studies share common grounds that WM training for children with LDs is beneficial. However, some studies come up with findings not as optimistic as theirs. Gary et al.[18] conducted five weeks of Cogmed training on children with ADHD and co-existing learning disabilities. In the assessment three weeks later, the trained aspects of these children, including spelling, word reading, mathematical computation, and sentence comprehension abilities did not show any improvement.

Previous studies on WM training and children with LDs yielded controversial conclusions. On the one hand, WM training seems to work well in terms of both near- and far-transfer for these children. The explanation is that people whose cognitive ability is at a lower level might have more potential for improvement before training, so they are likely to benefit from WM training [7]. On the other hand, however, there is evidence against the beneficial effect of WM training. Future research with finely tuned methodology is needed to evaluate further the effectiveness of WM training programs. It is a good start that the positive evidence supporting WM training enlightens us as regards how to help those children with LDs better.

5. Conclusion

In general, WM training programs envisage enhanced cognitive development and performance in human beings as a result of deliberate WM capacity training. As in the meta-analysis reports of WM training on children, it is premature to claim that the positive impact on children's cognitive development imposed by training can be transferred to other untrained capacities, despite the training programs are practically successful and satisfactory to some extent. In other words, WM training might offer the opportunity for the near-transfer effect to take place, but no evidence is found as to whether it is the same case with the far-transfer effect. In the interest of research, methodological issues should be taken into account when drawing conclusions based on the existing studies. However, it is worth noticing that the effect of the far transfer is more salient in the case of children with LDs. An explanation for this might be that individuals whose cognitive ability is at a lower level might have more potential for improvement before training, so they are likely to benefit from WM training. To conclude, the use of WM training to aid children's cognitive development has limited effects.

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