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EFFECT OF CENTRAL EXECUTIVE WORKING MEMORY INTERVENTION ON WORKING MEMORY CAPACITY, FLUID INTELLIGENCE AND MATHEMATIC SKILLS AMONG MIDDLE SCHOOL STUDENTS

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Abstract: The central executive working memory is responsible for the overall control of the working memory system via focusing, dividing and switching attention in a flexible manner. The present research investigated whether Central executive working memory intervention would enhance Working Memory capacity, Fluid Intelligence (Gf) and mathematic skills among middle school students. The present research adheres to True Experimental Research Design (pre test- post test - control group). Based on two criteria, 44 students were selected as samples (Non probability – purposive sampling) among the research population of 315 middle school students. 1) 50 % to 60% in math in previous year's annual exam. 2) No psychological abnormalities, neurological pathologies, cognition deformities or learning disabilities. Pre tests were administered and scored. 22 Students who scored high were in the control group and 22 students who scored less were assigned to the treatment group. Treatment group was subjected to 5 weeks intense Central executive working memory Intervention. The intervention had 6 components, namely, backward digit span, backward word span, computation, trial making, n-back and random generation. Then post tests were administered and scored. Data analysis revealed three facts. 1) Central executive working memory Intervention significantly enhanced WM capacity, Gf and mathematic skills of the treatment group. 2) Control group did not produce improvement at the post test measures of WM, Gf and math. 3) There produced a highly significant enhancement in the post tests measures of WM, Gf and math of treatment group when compared to the control group. Hence, it is evidently proved that the Central executive working memory Intervention strongly improved the WM capacity, Gf and mathematic skills of middle school students.

Key words: Central Executive Working memory, Working Memory, Fluid Intelligence and Mathematic Skill.

INTRODUCTION

WORKING MEMORY

Working memory is the ability to keep information on-line, typically for a few seconds. Working memory refers to a system for both temporary storage and manipulation of information, which is necessary for a wide range of cognitive tasks.

CENTRAL EXECUTIVE WORKING MEMORY

The central executive is a flexible system responsible for the control and regulation of cognitive processes.
It has the following functions:
Binding information from a number of sources into coherent episodes
Coordination of the slave systems
Shifting between tasks or retrieval strategies
Selective attention and inhibition

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THE CENTRAL EXECUTIVE WORKING MEMORY

The central executive is the component of working memory that has overall attention control of the working memory system.Different sub-areas of central executive working memoryPlanning/problem-solving, Set shifting/switching, Fluency, Inhibition,Working memory, Self-monitoring

FLUID INTELLIGENCE

Fluid intelligence and crystallized intelligence (respectively abbreviated Gf and Gc) are factors of general intelligence. Fluid intelligence otherwise called as fluid reasoning is the capacity to think logically and solve problems in novel situations, independent of acquired knowledge. It is the ability to analyze novel problems, identify patterns and relationships that underpin these problems and the extrapolation of these using logic.

NEED FOR THE PRESENT RESEARCH

There were ample researches conducted on working memory intervention. The present research focus on the central executive working memory intervention. In particular the present research investigates its effects on working memory capacity, fluid intelligence and mathematic skills among middle school students.

LITERATURE REVIEW

WORKING MEMORY, CENTRAL EXECUTIVE WORKING MEMORY TRAINING AND CHILDREN

Judith G. Foy, Virginia A. Mann, 2014

The study examined whether children's working memory could be enhanced by adaptive cognitive training (ACT) and whether training outcomes would relate to behavioral self-regulation, a measure of executive control (EC) and certain pre-reading outcomes (phoneme awareness and letter knowledge). Children from economically disadvantaged communities were randomly assigned to an ACT (n = 23) or a wait-list control (n = 27) group. ACT consisted of an average of 20 minutes per day of adaptive visuospatial working memory training (Cogmed-JM) for up to 25 days at the beginning of the school year. ACT significantly improved performance in near-transfer (untrained visuospatial test) and far-transfer (tests of verbal working memory and behavioral self-regulation). However, ACT had no direct effects on either measure of pre-reading skill. Our findings suggest that ACT may indirectly help children at risk for later reading problems to benefit from instruction opportunities by developing self-regulation and memory skills.

Joni Holmes & Susan Elizabeth Gathercole, 2014

Working memory skills have been shown to be enhanced by adaptive training in several randomized controlled trials. Here, two field trials were conducted in which teachers administered working memory training to their own pupils in school. Twenty-two children aged 8–9 years participated in Trial 1. In Trial 2, 50 children aged 9–11 years with the lowest academic performance completed training. They were matched with a group of 50 children who were not trained. Following training, children in Trial 1 improved significantly in both trained and untrained working memory tasks, with effect sizes comparable to those reported in research studies. Improvements on the trained tasks in Trial 2 were comparable, and training was associated with significantly greater progress at school across the academic year in maths and English. These findings indicate that teacher-administered training leads to generalized and robust gains in working memory and educationally significant gains in academic performance.

Joni Holmes, Susan E. Gathercole and Darren L. Dunning, 2014

Working memory plays a crucial role in supporting learning, with poor progress in reading and mathematics characterizing children with low memory skills. This study investigated whether these problems can be overcome by a training program designed to boost working memory. Children with low working memory skills were assessed on measures of working memory, IQ and academic attainment before and after training on either adaptive or non-adaptive versions of the program. Adaptive training that taxed working memory to its limits was associated with substantial and sustained gains in working memory, with age-appropriate levels achieved by the majority of children. Mathematical ability also improved significantly 6 months following adaptive training. These findings indicate that common impairments in working memory and associated learning difficulties may be overcome with this behavioral treatment.

Rachel J. Gropper, Howell Gotlieb, ReenaKronitz, Rosemary Tannock, 2014

The feasibility and effectiveness of working memory (WM) training in college students with ADHD or learning disabilities (LD).A total of 62 students (21 males, 41 females) were randomized to a 5-week intensive WM training program or a wait-list control group. Participants were evaluated before treatment, 3 weeks after completion, and at 2-month follow-up. The criterion measures were standardized tests of auditory-verbal and visual-spatial WM. Near transfer measures included other cognitive tasks; far transfer measures included academic tasks and behavioral rating scales. Results:Intent-to-treat analysis revealed that participants receiving WM training showed significantly greater improvements on the criterion WM measures and self-reported fewer ADHD symptoms and cognitive failures. The follow-up assessment indicated that gains in WM were maintained, as were improvements in cognitive failures. Computerized WM training is a feasible and possibly viable approach for enhancing WM in college students with ADHD or LD.

Dunning DL1, Holmes J. 2014

Adaptive computerized training has been associated with significant enhancements in untrained working memory tasks, but the nature of the cognitive changes that underpin these improvements are not yet fully understood. Here, we investigate the possibility that training stimulates the use of memory-related strategies. In a randomized controlled trial, participants completed four tests of working memory before receiving adaptive working memory training, non-adaptive working memory training with low memory loads, or no training. Open-ended interviews about strategy use were conducted after the administration of untrained working memory tasks at two time points. Those in the adaptive and non-adaptive groups completed the assessments before (T1) and after (T2) 10 training sessions. The no-training group completed the same set of tasks at T1 and T2, without any training between assessment points. Adaptive training was associated with selective improvements in untrained tests of working memory, accompanied by a significant increase in the use of a grouping strategy for visuospatial short-term memory and verbal working memory tasks. These results indicate that training-related improvements in working memory may be mediated by implicit and spontaneous changes in the use of strategies to subsegment sequences of information into groups for recall when the tasks used at test overlap with those used during training.

FLUID INTELLIGENCE AND CENTRAL EXECUTIVE WORKING MEMORY TRAINING

Sissela Bergman Nutley, StinaSöderqvist, Sara Bryde, Lisa B. Thorell, Keith Humphreys andTorkelKlingberg 2011

Fluid intelligence (Gf) predicts performance on a wide range of cognitive activities, and children with impaired Gf often experience academic difficulties. Previous attempts to improve Gf have been hampered by poor control conditions and single outcome measures. It is thus still an open question whether Gf can be improved by training. This study included 4-year-old children (N = 101) who performed computerized training (15 min/day for 25 days) of either non-verbal reasoning, working memory, a combination of both, or a placebo version of the combined training. Compared to the placebo group, the non-verbal reasoning training group improved significantly on Gf when analyzed as a latent variable of several reasoning tasks. Smaller gains on problem solving tests were seen in the combination training group. The group training working memory improved on measures of working memory, but not on problem solving tests. This study shows that it is possible to improve Gf with training, which could have implications for early interventions in children.

Mogle et al., 2008

Evidence for a link between storage capacity in WM and fluid intelligence is an important step in our understanding of the basic determinants of intelligence. In particular, such simple tasks allow for relatively straightforward conclusions regarding the core cognitive operations that play a role in fluid intelligence, thereby complementing the data from complex span procedures that tap into a broader range of cognitive abilities, including dual task coordination, resistance to interference, access to secondary memory, etc.

RESEARCH PROBLEMS

- To investigate whether the central executive working memory intervention will enhance working memory capacity among middle school students.
- To discover if the central executive working memory intervention will enhance fluid intelligence among middle school students.
- At exploring if the central executive working memory intervention will improve mathematic skills among middle school students.

AIM

I. The study aims to investigate whether the central executive working memory training will enhance working memory capacity among middle school students.

II. The study aims to discover if the central executive working memory training will enhance fluid intelligence among middle school students.

III. The study aims at exploring if the central executive working memory training will improve mathematic skills among middle school students.

HYPOTHESES

In the present research it was hypothesized that:

The central executive working memory intervention will enhance working memory capacity among middle school students.

The central executive working memory intervention will enhance fluid intelligence among middle school students.

The central executive working memory intervention will enhance mathematic skills among middle school students.

There will be no improvement in the working memory measure of the control group at the post test when compared to the pretest among middle school students.

There will be no improvement in the fluid intelligence Gf measure of the control group at the post test when compared to the pretest among middle school students.

There will be no improvement in mathematic skills of the control group at the post test when compared to the pretest among middle school students.

At post – test working memory measures, performance of the treatment group will be higher than the control group.

At post – test fluid intelligence measures, performance of the treatment group will be higher than the control group.

At post – test mathematics skills measures, performance of the treatment group will be higher than the control group.

RESEARCH DESIGN

THE PRESENT RESEARCH ADHERES TO TRUE EXPERIMENTAL RESEARCH DESIGN - PRE TEST POST TEST CONTROL GROUP

All the samples were given pretest of central executive working memory, fluid intelligence and mathematics. Pretests were scores. After the initial measures, the samples were divided into a control (non-intervention) group and an intervention group. The control group – treatment group division of the sample was done on a "matched-pairs" basis. Each child in the intervention group was matched with a child in the control group. Care was taken in matching the pairs, so that both children in

Each pair was from the same class. This was done to eliminate any differences in mathematical instruction within each matched pair. It also ensured that the math teachers from different classes could not influence mathematical outcomes by concentrating their teaching on specific areas of the curriculum or changing the amount of the school hours devoted to mathematical instruction. As gender did not prove to be an important factor in the pre-training measures, this was not considered when matching the pairs classes the participants were drawn had children in both the intervention and the non-intervention (control) groups. The intervention group received 5-weeks Central executive working memory training program. Following the Central executive working memory training, all the samples were post - tested. Posttest were scored.

The sample size in the present research is 44.

The sample consisted of 44 healthy children 23 female, 21 male (2 boys were left handers), from middle school. They were all in regular school settings in Chennai.

The following participants' criteria were applied:

- Samples were students who had scored of 50 % – 60 % in mathematics in the previous academic year's annual exam.
- No history of psychological abnormality, neurological pathology, cognition abnormality or learning disability.

MATERIALS

WORKING MEMORY INDEX (WMI) SUBSET OF THE WECHSLER INTELLIGENCE SCALE FOR CHILDREN IV (WISC-IV) was used to measure Working memory and mathematic skills

RAVEN'S STANDARD PROGRESSIVE MATRICES was used to measure fluid intelligence.

INTERVENTION

The children in the treatment group followed the Central executive working memory Intervention at school on working days for five weeks.

The Central executive working memory intervention consists of 6 components, namely:

1. Backward word SPAN (Speed, Parallelism, Activation, environment),
2. Backward digit span,
3. Computation,
4. Trial making,
5. n-back,
6. Random generation.

EXPLANATION OF EACH INTERVENTIONAL TASK

The **backward word recall** task comprised of 50 word list (from 2 letter words to 6 letter words). Each word was spelt at the rate of 1 letter per second and the child repeated it in the reverse order. This is done for all the 50 words.

The **backward digit recall** task comprised of 2 sets of strings of digits. Each set contained 2 digit to 9 digit numbers. Each number was spelt at the rate of 1 digit per second and the child repeated it in the reverse order. This is done for all the numbers in both the sets.

The **computation** task consisted of 40 arithmetic problems. (10 addition, 10 subtraction, 10 multiplication and 10 division problems). Each problems were told orally and the child solved the problem without pen and paper.

The **trial making** task comprised 2 parts. Both parts of the Trail Making task consisted of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered 1 – 25, and the child drew lines to connect the numbers in ascending order. In Part B, the circles include both numbers (1 – 13) and letters (A – L); as in Part A, the child drew lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.). The child should be instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. Both part A and B should be completed within 5 minutes.

The **n-back** task consisted of 3 parts (A, B, C).

Part A is 0- back. During this task, 10 single digit number is read aloud by the researcher. As each number is read, the child repeats the number again. For example, if 2 was said, the child would say 2. Then if 6 was said, the child would say 6, then if 8 was said the child would say 8 and so on).

Researcher	2	6	8	1	7	4	9	3	5
Child	2	6	8	1	7	4	9	3	5

Table a: n-back (Part A)

Part B is 1-Back. During this task, 10 single digit number is read aloud by the researcher. As each number is read, the child repeats the number before the last number that was said. For example, if 2 was said, the child would say nothing. Then if 6 was said, the child would say 2, then if 8 was said the child would say 6 and so on).

Researcher	2	6	8	1	7	4	9	3	5
Child	Nothing	2	6	8	1	7	4	9	3

Table b: n-back (Part B)

Part C is 2-Back. During this task, 10 single digit number is read aloud by the researcher. As each number is read, the child repeats the number that was before 2 number ago. For example, if 2 was said, the child would say nothing. Then if 6 was said, the child would say nothing, then if 8 was said the child would say 2 and so on).

Researcher	2	6	8	1	7	4	9	3	5
child	nothing	nothing	2	6	8	1	7	4	9

Table c: n-back (Part C)

In the **Random Generation** task each child was asked to speak aloud consonants (i.e. no vowels) in a random sequence. They were told to avoid repeating the same letter sequence, to avoid producing alphabetical sequences, and to try to speak each letter with the same overall frequency. Then letter number sequences were said aloud and theseparately and/or sequentially.The Child repeated it with letter and number.

PROCEDURE

In order to begin the research, an introductory session on psychology, working memory and its importance, fluid intelligence and mathematic skills were rendered.Then samples were given research roll number. Pretest was conducted. Pretest consisted of Working Memory Index (WMI) Subset of The Wechsler Intelligence Scale for Children IV (WISC-IV) to measure working memory and arithmetic, and Raven's Standard Progressive Matrices to measure fluid intelligence Gf. Pretests were scored.The participants were divided into Control group and Treatment group according to their performances in the pretest. The participants who performed lesser in the pretest were in the treatment group and the participants who performed higher were in the control group.The treatment group received 5 weeks of the Central executive working memory intervention in the class room. Every week the training held on first 3 working days for 3 hours each day. Hence, the treatment group received 45 hours of Central executive working memory training. Two days later all the participants from both control group and treatment group attended the post test. The posttest consisted of Working Memory Index (WMI) Subset of The Wechsler Intelligence Scale for Children IV (WISC-IV) to measure working memory and arithmetic, and Raven's Standard Progressive Matrices to measure fluid intelligence Gf. Then, the post tests were scored.

All participants were thanked for their participation.

RESULTS AND DISCUSSION

HYPOTHESIS I

The central executive working memory intervention will enhance working memory capacity among middle school students. Table 1

		Mean	N	SD	t
Pair 1	Working memory pre test	76.73	22	6.12	10.87**
	Working memory post test	86.91	22	3.9	

Note: ** Denotes significant at 0.01 level

Since P value is significant at 0.01 level, the null hypothesis is not accepted at 1 percent level of significance. Hence concluded that there is significant improvement in the working memory measures at posttest when compared to the pretest (t =10.871) table 1. Thus, we infer that the Central executive working memory intervention had enhanced the working memory capacity of the middle school students.

HYPOTHESIS II

The central executive working memory intervention will enhance fluid intelligence among middle school students. Table 2

		Mean	N	SD	t
Pair 2	Gf pre test	45.86	22	3.93	8.07**
	Gf post test	49.82	22	3.26	

Note: ** Denotes significant at 0.01 level

Since P value is significant at 0.01 level, the null hypothesis is not accepted at 1 percent level of significance. Hence concluded that there is significantly higher performance in fluid intelligence (Gf) measure at the post test than the pretest (t = 8.069) table 2. Thus, we infer that the Central executive working memory intervention had enhanced the fluid intelligence (Gf) of the middle school students.

HYPOTHESIS III

The central executive working memory intervention will enhance mathematic skills among middle school students. Table 3.

		Mean	N	SD	t
Pair 3	Math pre test	19.32	22	6.04	9.82**
	Math post test	27.05	22	3.33	

Note: ** Denotes significant at 0.01 level

Since P value is significant at 0.01 level, the null hypothesis is not accepted at 1 percent level of significance. Hence concluded that there is significant improvement in the measures for mathematic skills at posttest when compared to the pretest (t = 9.815) Table 3. Thus, we infer that the Central executive working memory intervention had enhanced mathematic skills of the middle school students.

HYPOTHESIS IV

There will be no improvement in the working memory measure of the control group at the post test when compared to the pretest among middle school students. Table 4

P value is not significant, so null hypothesis is accepted. The control group did not produce significant improvement in the working memory measure at the post test when compared to the pretest (t = 1.021) Table 4. Thus, we infer that students who did not receive the Central executive working memory intervention (control group) did not show enhancement in the working memory measures at the post tests.

		Mean	N	SD	t
Pai	Working memory pre test	78.59	22	6.9	1.02 NS

r 4	Working memory post test	79.68	22	8.12	

Note: NS – not significant

HYPOTHESIS V

There will be no improvement in the fluid intelligence Gf measure of the control group at the post test when compared to the pretest among middle school students. Table 5

		Mean	N	SD	t
Pair 5	Gf pre test	45.68	22	4.37	1.73^{NS}
	Gf post test	44.91	22	4.47	

Note: NS – not significant

P value is not significant, so null hypothesis is accepted. The control group did not improve in the fluid intelligence (Gf) measure in the post test than the pretest (t = 1.733) table 5. Thus, we infer that students who did not receive the Central executive working memory intervention (control group) did not show enhancement in fluid intelligence (Gf) measures at the post tests.

HYPOTHESIS VI

There will be no improvement in mathematic skills of the control group at the post test when compared to the pretest among middle school students. Table 6

		Mean	N	SD	T
Pair 6	Math pre test	20.91	22	5.7	0.18^{NS}
	Math	21.14	22	7.9	

Note: NS – not significant

P value is not significant, so null hypothesis is accepted. In the mathematic skills measures too, the control group produced no significant improvement at posttest when compared to the pretest(t = 0.18) table 6. Thus, we infer that students who did not receive the Central executive working memory intervention (control group) did not show enhancement in the mathematic skills measures at the post tests.

HYPOTHESIS VII

At post – test working memory measures, performance of the treatment group will be higher than the control group. Table 7

	Group	N	Mean	SD	T
Working memory post test	Control	22	79.68	8.12	3.77**
	Treatment	22	86.91	3.9	

Note: ** Denotes significant at 0.01 level

Since P value is significant at 0.01 level, the null hypothesis is not accepted at 1 percent level of significance. The treatment group performed higher than the control group at post test of working memory measures (t = 3.765) Table 7. Hence, we infer that the central executive working memory intervention was effective and it has enhanced the working memory capacity of the treatment group. Whereas the control group did not receive the intervention, hence did not show improvement. Thus we derive that the central executive working memory intervention is effective in enhancing the working memory capacity of middle school students.

HYPOTHESIS VIII

At post – test fluid intelligence measures, performance of the treatment group will be higher than the control group. Table 8

	Group	N	mean	SD	t
Gf post test	Control	22	44.91	4.47	4.16**
	Treatment	22	49.82	3.26	

Note: ** Denotes significant at 0.01 level

Since P value is significant at 0.01 level, the null hypothesis is not accepted at 1 percent level of significance. The treatment group performed significantly better than the control group at the post test of fluid intelligence (Gf) (t = 4.161) table 8. Hence, we infer that the central executive working memory intervention was effective and it has enhanced the fluid intelligence (Gf) of the treatment group. Where as the control group did not receive the intervention, hence did not show improvement. Thus we derive that the central executive working memory intervention is effective in enhancing the fluid intelligence (Gf) of middle school students.

HYPOTHESIS IX

At post – test mathematics skills measures, performance of the treatment group will be higher than the control group. Table 9

	Group	N	Mean	SD	t
Maths post test	Control	22	21.14	7.39	3.42**
	Treatment	22	27.05	3.33	

Note: ** Denotes significant at 0.01 level

Since P value is significant at 0.01 levels, the null hypothesis is not accepted at 1 percent level of significance. The treatment group demonstrated significant improvement than the control group at the post test of mathematic skills measures (t = 3.420) Table 9. Hence, we infer that the central executive working memory intervention was effective and it has enhanced the mathematic skills of the treatment group. Whereas the control group did not receive the intervention, hence did not show improvement. Thus we derive that the central executive working memory intervention is effective in enhancing the mathematic skills of middle school students.

CONCLUSIONS

Therefore, it is evidently proved that the Central executive working memory intervention had enhanced the working memory capacity, Fluid Intelligence and mathematics skills of the middle school students

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