Malleability of Working Memory Through Chess in Schoolchildren—A Two-Year Intervention Study

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Abstract

Working memory is the ability to actively maintain information in conscious awareness, carry out cognitive operations on it, and produce an outcome. Working memory holds a small amount of information in the mind and is used in the execution of cognitive tasks, in contrast to long-term memory, which is extensive. Many important cognitive behaviors, such as reading, reasoning, and problem-solving, require working memory because for each of these activities, some information must be maintained in an accessible state while new information is processed and potentially distracting information is ignored. While the effect of chess training on intelligence and academic performance has been examined, its impact on working memory needs to be studied. This study, funded by the Cognitive Science Research Initiative, Department of Science and Technology, Government of India, analyzed the effect of 2-year chess training on the working memory of children. A pretest–posttest with control group design was used. The randomly selected sample consisted of 88 children in the experimental group and 90 children in the control group for the baseline and first-year assessments. Children of both genders studying in school (grades 3 to 9) comprised the sample. At the second-year assessment, there were 80 children in the experimental group and 77 in the control group. The experimental group underwent weekly chess training for 2 years, while the control group was actively involved in sports and extracurricular activities offered by the school. Working memory was measured by two subtests of Wechsler Intelligence Scale for Children—Fourth Edition (WISC-IV) INDIA. The children were trained using *Winning Moves* curriculum, audiovisual learning method, hands-on chess training and recording the games using score sheets, and analyzing their mistakes. They were also trained in Opening theory, Checkmating techniques, End-game theory, and Tactical principles. Analysis of covariance revealed that the experimental group had significant gains in working memory compared to the control group. The present study supports a link between chess training and working memory. The transfer of skills acquired in chess training to the improvement of working memory could be attributed to the fact that while playing chess, children evaluate positions, visualize new positions in their mind, evaluate the pros and cons of each move, and choose moves based on the information stored in their mind. If working memory's capacity could be expanded or made to function more efficiently, it could result in the improvement of executive functions as well as the scholastic performance of the child.

Keywords: Chess training; cognitive development; executive functions; schoolchildren; working memory

1. Introduction

Working memory refers to a mental workspace that is involved in controlling, regulating, and actively maintaining relevant information to accomplish complex cognitive tasks (Miyake & Shah, 1999). It is the small amount of information that can be held in mind and used in the execution of cognitive tasks, in contrast to long-term memory, which is the enormous amount of information saved in one's life. It has often been related to intelligence, information processing, executive function, comprehension, problem-solving, and learning in people of all ages (Cowan, 2014).

Research evidence has linked performance on working memory tasks to vocabulary acquisition (Engel de Abreu, Gathercole, & Martin, 2011), early academic success in reading (Gathercole & Alloway, 2008; Stevenson, Bergwerff, Heisera, & Resinga, 2014), mathematics (Arndt, Sahr, Opferman, Leutner, & Fritz, 2013), and comprehension (Seigneuric, Ehrlich, Oakhill, & Yuill, 2000). Furthermore, working memory ability measured when the child begins formal education strongly predicted success in reading, spelling, and mathematics, compared to IQ scores (Alloway & Alloway, 2010) and short-term memory ability (Engle, Tuholski, Laughlin, & Conway, 1999).

A study carried out by Joseph, Easvaradoss, Kennedy, and Kezia (2016) assessed the impact of chess intervention on the general intelligence of children and analyzed the cognitive functions that contributed to IQ gain. Significant increases were observed in IQ, and regression analysis indicated that nonverbal reasoning, language, and memory significantly contributed to the dependent variable IQ. Similar findings have been reported by Grabner, Stern, and Neubauer (2007). Since working memory is a better predictor of academic performance than IQ, it is imperative that research assesses the impact of programs that develop working memory. Rajah and Sundaram (2011) established that brief computer-aided intervention for improving neuropsychological functions such as attention and working memory has had a positive impact on the cognitive and academic skills of children who were average in academic performance.

However, research on the impact of chess training on working memory is not available. Chess is a game that involves working memory. While playing chess, the child mentally manipulates an enormous quantum of information, drawing on information stored in the long-term memory and the data at hand. For example, the child concurrently uses blindfolded thinking (i.e., visualizing the positions of the chess game without looking at the board or picturing moves that have not occurred at all on the board), recalls and evaluates case studies of many typical positions while playing a chess game, connecting it to the game at hand. The outcomes of these mental operations are utilized to evaluate the positions, weigh various options, assess each potential move, and make the optimum choice with the best outcome.

In the present study, it is hypothesized that systematic chess training would significantly increase working memory in children. The objective of the study was to assess the impact of a 2-year chess training program with weekly sessions on the working memory of school-going children.

2. Methodology

The research design used for the study was pretest–posttest with control group design (Edwards, 1985). The independent variable was the chess training program and the dependent variable was the working memory of children.

2.1. Sample

Children of both genders who were studying in schools and falling in the age range between 6 and 14 years (grade 3 to grade 9) were selected. Schools were identified and permission was obtained. Contracts were signed with the school to carry out the study. The children were randomly selected. Informed consent was obtained from the parents and the children. Random sampling within each school was used to form the experimental and control groups. The following procedure was used to select students for the sample

- Name list along with the date of birth of the child was collected from the school.
- Requirement analysis was made for each school.
- Using the random number selection method, the students were initially identified.
- Consent was taken from the parents of all the selected students. Some students were dropped as their parents did not give their consent.
- IQ test (BKT) was done for all students. Based on the IQ scores, children with identical IQ scores were paired, taking into consideration gender and age.
- The children were then randomly assigned into two groups having equal mean of the IQ.
- Further, the Head of the school, assigned the two groups randomly into experimental and control group, by using the Lot system.
- Some of the students, who fell into the experimental group opted out stating unwillingness to undergo regular chess training.

The sample included 178 children, 88 in the experimental group and 90 in the control group at baseline and first-year assessment. The experimental group included 38 girls and 50 boys, and the control group had 33 girls and 57 boys. At the second-year assessment, there were 80 children in the experimental group and 77 in the control group. Children were unable to complete the second year of intervention as they were relocated due to a major flood that occurred in the city.

2.2. Tools

Assessment of working memory was carried out using the WISC-IV (Wechsler Intelligence Scale for Children—Fourth Edition, 2012). The test provided subtest and composite scores that represented intellectual functioning in specific cognitive domains and a composite score that represented general intellectual ability. To ensure accurate assessment, an Indian edition of WISC-IV was used. Scores on the Digit Span subtest and the Letter–Number Sequencing subtest yielded the Working Memory Index.

Digit Span is a core working memory subtest composed of two parts: Digit Span Forward and Digit Span Backward. Digit Span Forward requires the child to repeat numbers in the same order as read out by the examiner, and Digit Span Backward requires the child to repeat the numbers in the reverse order of that presented by the examiner. This subtest is designed as a measure of auditory short-term memory, sequencing skills, attention, and concentration. The Digit Span Forward task involves rote learning and memory, attention, encoding, and auditory processing. Digit Span Backward involves working memory, transformation of information, mental manipulation, and visuospatial imaging. The shift from the Digit Span Forward task to the Digit Span Backward task requires cognitive flexibility and mental alertness.

Letter–Number Sequencing is another core working memory subtest. A jumbled sequence of numbers and letters is read out by the examiner and the child recalls the numbers in ascending order and the letters in alphabetical order. This subtest involves sequencing, mental manipulation, attention, short-term auditory memory, visuospatial imaging, and processing speed.

2.3. Chess Training Methodology

The chess intervention consisted of standardized weekly training sessions of one hour duration, during school hours, over a period of 2 years. Clustering technique was used to form the training groups. The children in the experimental group were grouped or clustered, according to their age, class, and their playing strength throughout the 2-year period. Regular assessments were made to make sure that the children were assigned to the right groups. In each school, there were at least three to four groups and equal number of chess trainers. All children were taught chess, starting from the basics, as per the curriculum.

Chess training was adjusted to the level of the child and the speed with which they understood the concepts. Advanced concepts were taught if the child played well.

The training methodology comprised Winning Moves Chess Learning Program Episodes 1–22 (Joseph, 2008), lectures with the demonstration board, on-the-board playing and training, chess exercise through workbooks (Chess school 1A, Chess school 2, and tactics), and working with chess software. Further children’s games were mapped using chess base software and the brain patterns of the child were understood. They were taught the ideas behind chess openings and exposure to classical games were also given. The children participated in mock as well as regular tournaments.

3. Procedure

Schools were identified and permission was obtained. Contracts were signed with the school to carry out the study. The children were randomly selected based on the inclusion criteria. Informed consent was obtained from the parents and the children. Random sampling within each school was used to form the experimental and control groups. Assessment was done for all students. Based on the IQ scores, children with identical IQ scores were paired, taking into consideration gender and age.

Clustering technique was used to form the training groups of six to eight children. The chess training consisted of once-a-week chess classes conducted for 1 hour during school hours at the end of the day over 2 years. The children were given a standardized Winning Moves Chess Learning Program (Joseph, 2008) and played at tournaments also. The children who formed the control group were actively engaged in sports and extracurricular activities offered by the school.

Assessment of working memory was carried out at baseline, 1 year, and 2 years.

4. Results

The analysis was carried out using SPSS. Analysis of covariance was used to compare the experimental and control groups on the dependent variable and to test the significance of difference between the means following chess training

Table 1: Descriptive statistics for working memory for baseline, first-year, and second-year assessment.

Working Memory	N		Mean (SD)	
	Experimental	Control	Experimental	Control
Baseline	88	90	90.92 (15.201)	90.10 (13.692)
First Year	88	90	97.57 (14.585)	91.64 (12.706)
Second Year	80	77	102.23 (17.023)	96.01 (15.269)

Table 2: Analysis of covariance between experimental and control groups on working memory at first-year assessment.

Source	Type III Sum of Squares	Df		Mean Square	F	Sig.
Corrected Model	14891.816[1]	2		7445.908	66.673	0.000
Intercept	7051.475	1		7051.475	63.141	0.000
Baseline Working Memory	13330.478	1		13330.478	119.365	0.000
EXPCON	1310.777	1		1310.777	11.737	0.001***
Error	19543.735	175		111.678		
Total	1626478.000	178				
Corrected Total	34435.551	177				

[1]R-Squared = 0.432 (Adjusted R-Squared = 0.426).
***p<0.001.

Table 3: Analysis of covariance between experimental and control groups on working memory at second-year assessment.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	19996.418[1]	2	9998.209	69.574	0.000
Intercept	3075.117	1	3075.117	21.399	0.000
Baseline Working Memory	18482.348	1	18482.348	128.613	0.000
EXPCON	929.787[1]	1	929.787	6.470	0.012*
Error	22130.589	154	143.705		
Total	1586433.000	157			
Corrected Total	42127.006	156			

[1]R-Squared = 0.475 (Adjusted R-Squared = 0.468).
*p<0.05.

The results in Table 1 indicate that the working memory of the children who underwent chess training has significantly increased when compared to the control group at the first assessment after 1 year (Table 2, p <0.001) and after the second assessment after 2 years (Table 3, p <0.05). Greater grains have been noted in the first year of training and the working memory index has shown an increase of 11 points across 2 years.

5. Discussion

The results demonstrate that chess training has significantly increased the working memory of the children who underwent the training when compared to the control group.

Children who received chess training appear to have acquired the ability to juggle information while keeping in mind the already known information and the principles and rules of manipulation. In the present study, it was demonstrated that children who had received chess training were able to transfer the ability to hold and manipulate information acquired during the training to tasks requiring similar abilities (namely the digit span and letter–number sequencing tasks).

This effect has occurred after 2 years of chess intervention. Greater grains have been noted in the first year of training and the working memory index has shown an increase of 11 points across 2 years. It is probably the intensive and focused nature of the chess training which was individualized to the child's playing strength that resulted in the clear increase in scores. Further, a multisensory training approach was used, ensuring that effective learning and development of chess playing skill was occurring.

Research has emphasized the encouraging effects resulting from working memory training. They have found a transfer effect on related tasks, such as tasks requiring following instructions, nonverbal reasoning and mathematical problem solving, and tasks involving attentional control (Brehmer, Westerberg, & Backmann, 2012; Holmes, Gathercole, & Dunning, 2009; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008).

Melby-Lervåg and Hulme (2013), on the other hand, reported contradictory findings that working memory training does not generalize to other reasoning tasks. However, these training programs are of short duration, with a mean training duration of 12 hours across all the studies reviewed by them. Clearly a working memory training program of longer duration is required for transfer to be observed.

Many studies have established a link between working memory and academic achievement (Gathercole & Pickering, 2000). In one study, working memory independently predicted the children's achievements in reading and to a lesser extent in mathematics, thereby indicating that working memory was common to the domains of reading and mathematics (Gathercole, Alloway, Willis, & Adams, 2006). Furthermore, working memory tests (digits backward and sentence repetition) appeared to be the best predictors of mathematical test scores and may represent a major cognitive deficit in children with specific defects in mathematics (Rosselli, Matute, Pinto, & Ardila, 2006).

6. Implications

It is evident from the present study that there is a relationship between chess training and working memory. When systematic chess training with proper curriculum is offered, one could expect a significant gain in the working memory, which can lead to educational implications for children. Strengthening working memory through chess intervention could optimize its functioning; the positive outcomes would be seen not only in scholastic functioning but on other cognitive–behavioral attributes as well, leading to holistic psychological well-being in the child. The potential educational gains of interventions using working memory training are valuable and therefore should be explored. Impacting working memory through chess training is thus a significant goal for psychologists, educationists, chess coaches, and cognitive scientists.

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