Can chess training improve Pisa scores in mathematics? An experiment in Italian primary schools.

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An experiment in Italian primary schools.

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Abstract

The practice of chess can improve mathematical ability of children? The research presented in this paper shows that a chess intervention with in-presence lessons and online training can improve significantly the scores of a group of children on the Oecd-Pisa Mathematics Scale. Research has been conducted on 568 pupils of the primary schools in the country of Asti and Bergamo (Italy). Pupils are subdivided in four groups: experimental, control, experimental without pretest, control without pretest. The results seem to indicate a small but statistically significant increase in problem-solving skills on complex tasks by the experimental group and this increase is greater in subgroups that have attended more hours of chess in-presence lessons and have achieved an higher level in online training. In according to others Italian *(Chess in School 2005-2011, Sam - Chess and Math Learning 2011)* and international studies, these results indicates that chess training can be a valuable learning aid that supports acquisition of mathematical abilities, if used in couple to formal learning.

Keywords:
Chess in school, Chess training, Cognitive enhancement, Increasing mathematics abilities.

1. Introduction

Chess is one of the most popular games and it has always been associated with concepts such as intelligence, strategy, reasoning. Chess has been used as a compact and easily controllable task environment to study cognitive processes and abilities such as perception, information management, attention, memory, logical thinking and problem solving (Gobet and Campitelli 2006; Saariluoma, 2001). In particular, many studies have tried to demonstrate relationship between playing chess and mathematical ability (see for example Frank, 1978; Christiaen, 1976; Tudela, 1984; Ferguson, 1986 and 1995; Horgan, 1987; Ho, 2006; Hong & Bart, 2007; Scholtz et al. 2008; Ho, Buky 2008; Barrett & Fish, 2011). According to these studies, systematically playing chess is linked to several abilities that are important in the mathematical problem solving, like the maintenance of a high level of attention and concentration on the task, the focalization on details, the perseveration in the pursuit of objectives, the recognizing of strategic information from situations and its use in planning strategies, the critical reflection on own actions and the prediction of the course of events. These abilities are particularly important in school-age children as they can have a non-marginal impact on achievement in curricular tasks. Also several Italian studies (see Trinchero, 2012) confirm these hypotheses of relationship between chess training and mathematical abilities of children in the primary school, but only for chess training of almost 30 hours per year.

Nevertheless, these findings have also shown that the causal direction of the relationship is uncertain (Gobet and Campitelli, 2002). There are three possible scenarios to support the empirical evidence collected: a) the game of chess actually improves people's intellectual abilities, b) those with better mental abilities play better chess, achieve better results and thus tend to play more; c) there are intervening factors such as motivation towards the task, the ability to consider several alternatives and decide which is the best in a limited period of time, which mediate both the expression of intellectual abilities and ability in the game of chess.

The present study aim to investigates the relationship between blended chess training (a mix of training in presence and computer-assisted, CAT) and mathematical ability in children aged 8 to 10 years. Mathematical ability was detected by means of 7 items token from the Oecd-Pisa inquiry (Oecd, 2009), selected from faceable items by children of eight years and older. The experiment was conducted from October 2012 to May 2013.

2. Method

2.1. Participants

The target group of our investigation was composed by 568 children aged from 8 to 10, attending primary schools in the provinces of Bergamo and Asti (Italy) (see details in Table 2). The sample was divided into four main groups, in according to a Solomon 4-group experimental design (see Campbell, Stanley 1963; Shadish, Cook, Campbell 2002), showed in Table 1, and several subgroup in according to different age of the children, school frequented, duration of the in-presence training, year of the chess training (some groups frequented a multi-year chess training program, as shown in Table 2).

Group	N.	Activities		
G1 (Experimental)	380	Pre-test	Blended chess training (in presence + CAT)	Post-test
G2 (Experimental without pretest)	32	-	Blended chess training (in presence + CAT)	Post-test
G3 (Control)	115	Pre-test	Ordinary school activities	Post-test
G4 (Control without pretest)	41	-	Ordinary school activities	Post-test

TABLE 1. The experimental design

Details of the participants is showed in Table 2.

G1 (Experimental)

Subgroup	N.	School	N. Classes	Chess training
G1a4-11-1	44	Alberico da Rosciate (Bergamo)	2 (grade 4)	11 hours in presence (first year of training) + CAT
G1g4-10-1	49	Ghisleri (Bergamo)	2 (grade 4)	10 hours in presence (first year of training) + CAT
G1g3-10-1	41	Ghisleri (Bergamo)	2 (grade 3)	10 hours in presence (first year of training) + CAT
G1r4-10-1	25	Rodari (Bergamo)	1 (grade 4)	10 hours in presence (first year of training) + CAT
G1d4-10-1	37	Diaz (Bergamo)	2 (grade 4)	10 hours in presence (first year of training) + CAT
G1p5-16-1	52	Papa Giovanni (Bolgare -Bergamo)	3 (grade 5)	16 hours in presence, 2 hours per week (first year of training) + CAT
G1p4-8-2	56	Papa Giovanni (Bolgare - Bergamo)	3 (grade 4)	8 hours in presence, 2 hours per week (second year of training) + CAT
G1c5-14-3	11	Castelnuovo don Bosco (Asti)	1 (grade 5)	14 hours in presence, 2 hours per week (third year of training) + CAT
G1c4-14-2	28	Castelnuovo don Bosco (Asti)	2 (grade 4)	14 hours in presence, 2 hours per week (year of training) + CAT
G1b5-14-2	18	Buttigliera (Asti)	1 (grade 5)	14 hours in presence (second year of training) + CAT
G1b4-14-2	19	Buttigliera (Asti)	1 (grade 4)	14 hours in presence (second year of training) + CAT

G2 (Experimental without pretest)

Subgroup	N.	School	N. Classes	Chess training
G2c	13	Capitanio	1 (grade 6, 7, 8)	15 hours in presence, 1,5 hours per week (first year of training) + CAT
G2s	19	Sacro Cuore	1 (grade 3, 4)	15 hours in presence (first year of training) + CAT

G3 (Control)

Subgroup	N.	School	N. Classes
G3a	45	Alberico da Rosciate	2 (grade 3)
G3r	29	Rodari	2 (grade 3)
G3d	41	Diaz	2 (grade 3)

G4 (Control without pretest)

Subgroup	N.	School	N. Classes
G4	41	Papa Giovanni (Bolgare)	2 (grade 3)

TABLE 2. Details of the participants

Participants were not randomly selected. We construct a reasoned sample, by including classes in the experimental group on the basis of their grades (3, 4 and 5) and their previous experiences of chess training (first, second or third year of training, see Table 2).

2.2. Study design

The study duration was one school year (from October 22, 2012, to May 3, 2013). The classes in experimental groups (G1, G2) have received chess lessons in school hours. At the same time of in-presence course, the pupils were invited to do (at home) a computer-assisted training (CAT) on the Web *(www.europechesspromotion.org* and *www.scacchiedu.it)* that provided 12 levels of training, developed by the Piedmont Regional Fsi Committee and Alfiere Bianco amateur sports company in collaboration with the Italian Council of Research (Cnr) of Rome. The chess contents of the CAT was the same of in-presence lessons (CAT activities are a reinforce of in-presence lessons), and the activities are subdivided in Demonstration (the pupil see how to do a move), Practice (the pupil try to do the move and receive a feedback) and Learning Test (the pupil solves problems that implicate the knowledge of that move and receive a feedback). The classes in control groups (G3, G4) have received the planned regular lessons, and had not access to chess CAT.

Table 3 shows the Oecd-Pisa items used in the study. Item were selected to be faceable from children of grade 3, and of different levels of difficulty, as estimated by Oecd-Pisa.

Item	Oecd-Pisa item code	Math abilities involved	Estimated difficulty (from Oecd-Pisa)	Score	Analogy with chess ability
10	M145Q01	Calculate the number of points on the opposite face of showed dice	478 (Level 2)	0/1	Calculate material advantage
11	M806Q01	Extrapolate a rule from given patterns and complete the sequence	484 (Level 4)	0/1	Extrapolate checkmate rule from chess situation
12	M510Q01T	Calculate the number of possible combination for pizza ingredients	559 (Level 4)	0/1	Explore the possible combination of moves to checkmate
13	M520Q1A	Calculate the minimum price of the self-assembled skateboard	496 (Level 3)	0/1	Calculate material advantage
14	M159Q05	Recognize the shape of the track on the basis of the speed graph of a racing car	655 (Level 5)	0/1	Infer fact from a rule (e.g. possible moves to checkmate)
15	R040Q02	Establish the profundity of a lake integrating the information derived from the text and from the graphics	478 (Level 2)	0/1	Find relevant information on a chessboard
16	M266Q01	Estimate the perimeter of fence shapes, finding analogies in geometric figures	687 (Level 6)	0/1	Find analogies in chessboard situations

TABLE 3. Oecd-Pisa items used in the study

Table 4 shows the chess items used in the study. Item were selected to inquiry several chess abilities that was object of the course.

Item	Chess ability	Score
19	Explain checkmate situation	0/1
20	Identify checkmate situation	-3/+2
21	Establish if a move is allowed for a piece	-2/+2
22	Identify castling situation	0/1
23	Calculate material advantage	0/1
24	Identify common elements in three chess situations	-3/+3
25	Identify pawn promotion	0/1
26	Identify the possibility of stalemate	0/1
27	Identify checkmate situation	0/1
28	Identify checkmate-in-one-turn situation	0/1
29	Reconstruct sequence of chessboard events	0/1
30	Identify common elements in three chess situations	-3/+3

TABLE 4. Items relative to chess abilities

G1 group (experimental) and G3 group (control) has performed a pre-test a week before the chess course and a post-test one or two week after the conclusion of the in-presence course. Both tests were fed by computer. The CAT was contemporary to in-presence lessons, and was a reinforcement of these and an opportunity to put into practice the concepts seen in class.

Pre-test and post-test used the same items in order to guarantee comparability of the results and to exclude differences in items difficulty. This can lead to a noticeable testing effect (see Campbell, Stanley 1963; Shadish, Cook, Campbell 2002). The adoption of two group (one experimental, G2, and one for control, G4) that haven't do the pre-test but only the post-test has allowed to evaluate the incidence of test effect on final results.

Chess lessons were based on a method especially designed for children of 8-11 years which already has been used in the research Sam - Chess and math learning 2011. Contents of the lessons are: the chessboard, the coordinates, the pieces and the rules of movement, the catch and the defense of themselves, the checkmate, the mini-games (e. g. King and two Rookies vs. King), the games, the relative value of the pieces and the material advantage, the castling move, the develop of the pieces, the stalemate, tactics for use pieces in coordinate manner and the vision to recognize these episodes on the board. Complete teaching material are available at the address www.europechesspromotion.org.

For each lesson, the trainer explain rules with a wall-chessboard for a maximum of 15 minutes, then the pupils do mini-games in pairs or games with mates and trainer to put in practice the theory explained. The lessons also included exercises (about 15 minutes) where the pupils should evaluate what piece is threatened and how to defend it, what piece is threatened and can capture, what is the most favorable exchange, what is the better piece to capture in a chess situation. Pupils received an immediate feedback and an evaluation in chess ability.

2.3. Statistics

Initial (pre-test) and final (post-test) scores in mathematics and chess have been calculated for each pupil. Then the gain for each pupil has been calculated, in terms of difference between post-test score and pre-test score. We compared the gain of the experimental group (and subgroups) and the gain of the control group with univariate Anova (Analysis of variance). Calculations were performed using the statistical software package IBM SPSS ver. 20.

3. Results

3.1. Process of the study

Feedbacks from pupils and from teachers were positive. All the experimental classes was interested in learning chess basics and in using chess CAT software. Table 5 shows the mean of achieved level (the maximum is 12) for each subgroup.

			Achieved level in online game	
Subgroup	Players	% on the subgroup	Mean	St. dev.
G1p4-8-2	53	95%	5,38	4,17
G1g4-10-1	48	98%	5,75	4,36
G1d4-10-1	35	95%	5,86	4,71
G1g3-10-1	38	93%	6,08	4,48
Whole G1	313	82%	6,72	4,46
G1a4-11-1	43	98%	7,16	4,66
G1p5-16-1	50	96%	7,36	4,26
G1b5-14-2	3	17%	8,00	4,00
G1r4-10-1	20	80%	9,00	3,96
G1c4-14-2	14	50%	9,43	3,98
G1b4-14-2	6	32%	10,33	2,16
G1c5-14-3	3	27%	11,00	0,00

TABLE 5. Sw usage for each group and achieved level in online game

In the schools of Castelnuovo don Bosco and Buttigliera (subgroups G1c4-14-2, G1c5-14-3, G1b5-14-2, G1b4-14-2) the use of the CAT software was subject to payment (fee € 4) and this can explain the reduced proportion of users. Nobody of the pupils used the CAT before this training.

3.2. Results for mathematical ability

The results of the mathematical tasks are summarized in Table 6. Here are presented the initial scores and the score gain for whole experimental group, for experimental subgroups, and for the control group. The subgroups are ordered by mean of the score gain. Gain significance (sixth column) refers to Anova between gain of the control group and gain of each single experimental subgroup.

	Initial score		Gain		Gain Sign.
Subgroup	Mean	St. dev.	Mean	St. dev.	
G1b4-14-2	1,74	1,79	0,11	1,88	0,942
G1a4-11-1	1,64	1,20	0,16	1,74	0,763
G1p4-8-2	1,57	1,06	0,27	1,38	0,409
G1d4-10-1	1,14	0,86	0,51	1,37	0,103
G1g4-10-1	1,27	0,93	0,63	1,41	0,023
G1g3-10-1	1,05	0,84	0,66	1,26	0,022
Whole G1	1,37	1,17	0,67	1,51	0,000
G1p5-16-1	1,56	1,30	0,79	1,36	0,003
G1r4-10-1	1,16	0,94	1,04	1,43	0,003
G1c4-14-2	1,68	1,42	1,43	1,17	0,000
G1b5-14-2	0,94	1,43	1,44	2,12	0,001
G1c5-14-3	0,55	0,93	1,73	0,79	0,000
G3 (control)	1,53	1,30	0,08	1,42	-

TABLE 6. Score gain in mathematics ability

There are no significant differences (at p=0.01 level) between means of initial levels neither for whole experimental group vs. control group (Anova, sign.=0.204) nor for single subgroups vs. control group (for the G1c5-14-3 group the significance of the mean difference is 0.016, calculated with Anova). Significant difference are found between score gain of the control group and score gain of whole experimental group (Anova, sign.=0.000). Therefore, not all subgroups have obtained a significant gain. Only subgroups that have frequented almost 14 hours of in-presence lesson, and/or have reached high average levels in the CAT, have achieved a significant amelioration. The exception to this rule is the G1b4-14-2 subgroup. In this class average level in the initial test are higher and the final test was administered in less than optimal conditions (performed in late afternoon and with a teacher who did not explain clearly that the test was connected to the chess course, so the kids have probably not done with the proper motivation).

This result is confirmed by calculating correlation between variables. For whole experimental group, the gain in mathematic is positively correlated with duration of the chess course (r=0.139, sign.=0,007) and with the gain in chess ability (r=0.199, sign.=0,000), and negatively correlate with initial scores in mathematic (r=-0.544, sign=0,000). For the control group the gain in mathematic is negatively correlated with initial scores in mathematic (r=-0.619, sign=0,000).

There is no significant gender differences in gain for mathematic scores neither in experimental (Anova, sign.=0.484) nor in control group (Anova, sign.=0.399).

Table 7 shows the score gain for each mathematic task, for both the experimental and the control group.

		Experim. group Gain			Control group Gain		
Item	Math abilities involved	Mean	St.dev.	Sign.	Mean	St.dev.	Sign.
10	Calculate the number of points on the opposite face of showed dice	0,16	0,59	0,000	0,08	0,56	0,140
11	Extrapolate a rule from given patterns and complete the sequence	0,14	0,54	0,000	0,02	0,58	0,747
12	Calculate the number of possible combination for pizza ingredients	0,10	0,65	0,003	-0,06	0,64	0,309
13	Calculate the minimum price of the self-assembled skateboard	0,12	0,52	0,000	0,08	0,46	0,072
14	Recognize the shape of the track on the basis of the speed graph of a racing car	0,00	0,26	0,842	0,00	0,27	1,000
15	Establish the profundity of a lake integrating the information derived from the text and from the graphics	0,16	0,51	0,000	-0,03	0,41	0,494
16	Estimate the perimeter of fence shapes	0,00	0,45	0,908	-0,01	0,39	0,810

TABLE 7. Gain for mathematic items in the two groups

The significance refers to the difference between pretest and posttest for paired samples and is calculate with Student t-test for paired samples. There are no significant gains (at p=0.01 level) for control group and five significant gains on the item with estimated difficult (Oecd 2009) from Level 2 to Level 4. Item with difficulty at the Levels 5 and 6 obtain no gain, objectively because they are too difficult for the children of the sample.

3.3. Results for chess ability

Table 8 shows initial scores and score gain in chess tasks for the whole experimental group, subgroups, and control group. The subgroups are ordered by mean of the score gain. All the gains in experimental groups are significant (sixth column of the table, significance is calculated with Anova) in relation to control group, as expected.

	Initial score		Gain		Gain Sign.
Subgroup	Mean	St. dev.	Mean	St. dev.	
G1p4-8-2	5,45	3,39	3,52	3,37	,000
G1d4-10-1	1,51	2,63	5,73	4,34	,000
G1c4-14-2	4,71	4,16	5,86	4,54	,000
G1b4-14-2	4,37	5,14	6,11	4,52	,000
G1a4-11-1	4,23	4,48	6,25	4,11	,000
G1c5-14-3	1,45	3,39	6,27	4,52	,000
Whole G1	3,00	3,98	6,62	4,60	,000
G1g4-10-1	2,57	3,40	7,04	4,92	,000
G1g3-10-1	0,61	1,95	7,20	4,63	,000
G1p5-16-1	2,54	3,85	8,46	4,22	,000
G1r4-10-1	0,92	1,80	8,84	3,70	,000
G1b5-14-2	3,17	4,49	10,17	5,11	,000
G3 (control)	1,17	2,46	0,47	2,10	-

TABLE 8. Score gain in chess ability

There is a big heterogeneity in initial scores of the various subgroups and the subgroups that have lower scores on initial test obtain a greater increase. The gain in chess is positively correlated with the duration of the chess course (r=0.225, sign=0,000) and with the level reached in the CAT (r=0.170, sign=0,003), and negatively correlate with initial scores in chess (r=-0.468, sign=0,000) and with the year of course (r=-0.276, sign=0,000).

There is no significant gender differences in gain for chess scores neither in experimental (Anova, sign.=0.396) nor in control group (Anova, sign.=0.087).

Table 9 shows the score gain for each mathematic task, for both the experimental and the control group.

		Experim. group Gain			Control group Gain		
Item	Chess ability	Mean	St.dev.	Sign.	Mean	St.dev.	Sign.
19	Explain checkmate situation	0,28	0,64	0,000	0,09	0,36	0,012
20	Identify checkmate situation	0,68	1,40	0,000	0,01	0,89	0,917
21	Establish if a move is allowed for a piece	0,95	0,99	0,000	0,07	0,71	0,296
22	Identify castling situation	0,56	0,52	0,000	0,05	0,26	0,033
23	Calculate material advantage	0,21	0,60	0,000	-0,03	0,23	0,103
24	Identify common elements in three chess situations	0,97	1,39	0,000	-0,03	0,77	0,630
25	Identify pawn promotion	0,34	0,59	0,000	0,03	0,26	0,158
26	Identify the possibility of stalemate	0,51	0,56	0,000	0,01	0,31	0,764
27	Identify checkmate situation	0,32	0,60	0,000	0,02	0,30	0,529
28	Identify checkmate-in-one-turn situation	0,40	0,58	0,000	0,04	0,36	0,198
29	Reconstruct sequence of chessboard events	0,36	0,57	0,000	0,08	0,35	0,019
30	Identify common elements in three chess situations	1,05	1,42	0,000	0,07	0,88	0,396

TABLE 9. Gain for chess items in the two groups

The significance refers to the difference between pretest and posttest for paired samples and is calculate with Student t-test for paired samples. There are no significant gains (at p=0. 01 level) for control group while for experimental group the gains are all significant.

3.4. Influence of initial test on final scores

The initial test in mathematics has influenced in negative the final scores of the experimental group. Table 10 compare the final scores of the two groups for the mathematics tasks and for the chess tasks. For the experimental group, the comparison shows that G3 group (experimental without pretest) has a mean in mathematics scores significantly higher (Anova, sign=0.006) than G1 group (experimental with pretest). The other means have no significant difference. This result is probably due to the fact that the kids were bored by having to do twice the same test in a few months.

	Math final scores			Chess final scores		
Group	Mean	St.dev.	Sign.	Mean	St.dev.	Sign.
Experimental (G1)	2,03	1,31	0,006	9,63	4,45	0,213
Experimental without pretest (G2)	2,72	1,61	-	10,66	4,93	-

	Math final scores			Chess final scores		
Group	Mean	St.dev.	Sign.	Mean	St.dev.	Sign.
Control (G3)	1,61	1,19	0,56	1,64	3,31	0,916
Control without pretest (G4)	1,49	1,03	-	1,71	3,36	-

TABLE 10. Influence of initial tests in mathematics and chess for the two groups

4. Discussion

The aim of our study is to investigate the influence of chess training on mathematics abilities, not on an individual level but on the group level. In according to previous research *(Chess in School 2005-2011, Sam - Chess and Math Learning 2011, see Trinchero 2012)* and to our hypothesis, we found a small but clear advantage of the experimental group with respect to improvement of problem solving ability in mathematics. This advantage is greater in subgroups that have attended more hours of chess in-presence lessons and have achieved an higher level in chess online training.

In according to the theories presented in Trinchero (2012), this difference may be due to the increased capacity of the pupils of **reading** and **interpret** correctly the mathematic problems, **apply** their mathematic knowledge and **reflect** on their own actions and strategies, as effect of chess training. How can this happen?

Today's children are often used to divide their attention on more than one activity at the same time. Their attention span is often very short and this can limit their ability to focus on a single problem. Playing chess require exclusive attention and focalization on the problem. The configuration of pieces on the chessboard must be interpreted and analyzed, not only seen. The attention must be focused on single pieces and on the relation between them, on the relative values, on the threats, on the defense and on the possible tactics and strategies to be adopted in that situation *(see the mind's eye concept, Chase and Simon 1973)*. The chess lessons are designed just to make it clear to the students that it is the attention to get them to win at chess.

The same approach carried on math problems could bring the child to ask "What this question asks to me?", "What data are available to answer?", "What ties them together?", "What is my goal at this time?", "What is the relationship between the available data and my goal?", "What do I need and what I don't need to achieve it?", "How do I use what I need to achieve my goal ?", "What are the ways in which the situation can evolve?", "In relation to the ways in which the situation may evolve, what I am doing is correct?", and this reflective mechanism could be the basis of the increased problem solving skills. In chess, children can experience the consequences of their actions and understand how success depends on taking into account the relevant elements present on the board and to use that information to making good decisions. For example, a considerable amount of time was devoted to teaching children how to create / prevent the material advantage and how this can lead to winning or losing matches. The benefit of these activities would not be only on computational skills, but especially on the ability to analyze situations and problems, to grasp the important elements and remain focused in completing the solution process. The children learn that, in the game context, maintain prolonged attention, imagine scenarios and possible game developments, design strategies and put it in practice, can be a fun and rewarding experience. They understood that only their engagement and concentration (or the lack of engagement and concentration of the opponent) could lead them to win, because no aleatory elements can help the chess players. This means also have benefits on the attribution of success to their own efforts, rather than to luck / bad luck or to the difficulty of the task. This increases pupils' motivation to engage in activities that require cognitive effort, self-esteem and confidence in their own abilities: the mathematics is less scary if you learned that with your efforts you can successfully deal with it. The same attention and concentration is applied to mathematics tests, because the children see initial and final test like a part of a fun and motivating chess course and therefore are keen to do them well. The visible effect of these processes is a transfer of chess ability to higher attention and problem solving abilities, that led to an appreciable increase of mathematics skills of the children.

The process of the study went without any problems. We received only positive responses in accordance with other experiences with chess in schools (for example Vail 1995, Trinchero 2012).

The experiment presented has the greater limit in the statistically non-equivalence of experimental and control groups, relative to the number of subjects and in the internal composition of the groups. This limit could be overcome with a random selection of classes in the two groups. The research group is actually working on a new experiment (a project of research called Chess World, performed in Italian and Indian schools, see *www.europechesspromotion.org)* based on this design but with randomly selected groups.

Further research is necessary in order to identify skills which can be improved with chess training and to reveal the underlying mechanisms of action of chess training, but present results are encouraging and outline possible lines of research for future studies.

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