Does Chess Instruction Enhance Mathematical Ability in Children? A Three-Group Design to Control for Placebo Effects

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Abstract

Pupils' poor achievement in mathematics has recently been a concern in many Western countries. In order to address this issue, it has been proposed to teach chess in schools. However, in spite of optimistic claims, no convincing evidence of the academic benefits of chess instruction has ever been provided, because no study has ever controlled for possible placebo effects. In this experimental study, a three-group design (i.e., experimental, placebo, and control groups) was implemented to control for possible placebo effects. Measures of mathematical ability and metacognitive skills were taken before and after the treatment. We were interested in metacognitive skills because they have been claimed to be boosted by chess instruction, in turn positively influencing the enhancement of mathematical ability. The results show that the experimental group (participants attending a chess course) achieved better scores in mathematics than the placebo group (participants attending a Go course) but not than the control group (participants attending regular school lessons). With regard to metacognition, no differences were found between the three groups. These results suggest that some chess-related skills generalize to the mathematical domain, because the chess lessons compensated for the hours of school lessons lost, whereas the Go lessons did not. However, this transfer does not seem to be mediated by metacognitive skills, and thus appears to be too limited to offer educational advantages.

Keywords: chess; mathematics; transfer; education.

Introduction

Recently, pupils' poor achievement in mathematics has been the subject of debate both in the United States (Hanushek, Peterson & Woessmann, 2012; Richland, Stigler, & Holyoak, 2012) and in Europe (Grek, 2009). Policy makers and researchers have investigated several alternative methods and activities with the aim of improving the effectiveness of mathematical teaching. Teaching chess in schools is one of these activities. Chess has recently become part of the school curriculum in several countries, and several large studies and educational projects involving chess are currently ongoing in Germany, Italy, Spain, Turkey, the United Kingdom, and the United States. Moreover, the European Parliament has expressed its positive opinion on using chess courses in schools as an educational tool (Binev, Attard-Montalto, Deva, Mauro, & Takkula, 2011).

Chess as Educational Tool: The available Evidence

Several studies have tried to demonstrate the potential benefits of chess training on various cognitive abilities such as attention (Scholz et al., 2008), development of spatial concepts (Sigirtmac, 2012), general intelligence (Hong & Bart, 2007), and metacognition (Kazemi, Yektayar, & Abad, 2012). Other studies focused on academic variables, such as reading and mathematics (Christiaen & Verhofstadt-Denève, 1981).

Recently, several studies have investigated the positive influence that chess could exert on children's mathematical abilities (Barrett & Fish, 2011; Kazemi et al., 2012; Sala, Gorini, & Pravettoni, 2015; Scholz et al., 2008; Trinchero, 2012; Trinchero & Sala, in press). Barrett and Fish (2011) examined the effect of chess instruction on adolescents receiving special education services, using TAKS (Texas Assessment of Knowledge and Skills) scores in mathematics. The chess-treatment group showed an overall better performance than the control group. In Kazemi et al. (2012), the same pattern occurred with a sample of typically developing male students from primary and secondary schools. Scholz et al. (2008) examined the possible benefits of chess instruction on a sample of primary school children with learning disabilities (IQ between 70 and 85), with disappointing results. Finally, Sala's and Trinchero's studies (Sala, Gorini, & Pravettoni, 2015; Trinchero, 2012; Trinchero & Sala, in press) focused on the effect of chess instruction on primary school children's mathematical problem-solving ability. In these studies the chess-treatment groups systematically outperformed the control groups.

The Lack of a Placebo Group

Following the above overall positive results, the view of the chess community has been that chess practice increases academic performance because chess is an intellectually demanding and stimulating game (Bart, 2014; Garner, 2012; Root, 2006). Such optimistic view has been challenged, *ante litteram*, by Gobet and Campitelli's (2006) review of the literature regarding the effectiveness of chess instruction in enhancing children's academic and cognitive abilities. Gobet and Campitelli highlighted that – in spite of some the promising results reported in the reviewed experiments – the benefits of chess practice were yet to be clearly established, because of the poor experimental design used in most studies. In particular, most studies did not control for placebo effects – that is, effects that are not due to the treatment per se but that are due to other, uncontrolled aspects of the experimental design. Potential mechanisms behind placebo effects include instructors' motivation, the state of excitement and attention induced by a novel activity, and teachers' expectations.

More recently, a meta-analysis (Sala & Gobet, 2016) has lent further support to Gobet and Campitelli's conclusions. In that meta-analysis, 24 studies passed the selection criteria, with 40 effect sizes. The overall effect size of chess instruction was moderate, with $g = 0.34$. It was also found that studies with at least 25 hours of chess instruction were more likely to have a positive effect on mathematics, reading, and cognitive abilities ($g = 0.43$) than studies with less than 25 hours treatment ($g = 0.30$). Only one study (Fried & Ginsburg, n.d.), which was interested in perceptual and visuo-spatial skills, included a placebo control group. This study showed no difference between the chess group and the placebo group, which consisted of attending counselling sessions. Unfortunately, Fried and Ginsburg's (n.d.) study did not investigate the effect of chess instruction on children's mathematical ability. Therefore, this study cannot corroborate or disprove any claims about the effectiveness of chess in enhancing mathematical abilities.

The lack of a placebo control group – i.e., a group attending other activities non-related to chess – has thus been identified as the most serious flaw of the previous studies in the field. These studies often compared the practice of the game of chess to regular school activities. However, chess practice may exert a moderate positive influence on children's academic just because it is a novel activity in their curriculum that is fun, and this may induce a state of increased attention and motivation.

From an educational (and practical) perspective, this might be irrelevant. Policy makers and educators might be interested in the effectiveness of chess instruction, regardless of any chess-specific or non-chess-specific element causing the improvement in pupils' academic skills. Assuming this "whatever works" perspective, the only element of interest would be the size of the effect – i.e., *how much* children attending chess courses improve their academic skills, such as mathematical literacy.

Nonetheless, evaluating whether the benefits of chess practice on children's academic skills are due to elements specific or non-specific to the game of chess is an important theoretical question. In fact, assuming that skills acquired in chess lead to benefits in domains such as mathematics clearly implies the presence of far transfer. Far transfer occurs when a set of skills acquired in one domain (e.g., chess) generalizes to other domains (e.g., mathematics) that are only loosely related to the source domain.

The Problem of Transfer in Chess

Since transfer is a function of the extent to which two domains share common features (Thorndike & Woodworth, 1901), far transfer rarely occurs, as shown by substantial research in education and psychology (Donovan, Bransford, & Pellegrino, 1999; Gobet, 2015a,b). Moreover, in line with Thorndike and Woodworth's (1901) hypothesis, several studies have shown that chess players' skills tend to be context-bound, suggesting that it is difficult to achieve far transfer from chess to mathematics. In her classic study, Chi (1978) demonstrated that chess players' (both adults and children) memory for chess positions did not extend to the recall of digits. Chess players outperformed non-chess players in remembering chess positions, but no difference occurred with lists of digits. The same result was obtained in a study carried out by Schneider, Gruber, Gold, and Opwis (1993). Waters, Gobet, and Leyden (2002) found that chess players' perceptual skills did not generalize to visual memory of shapes. More recently, Bühren and Frank (2010) found that chess grandmasters did not outperform chess amateurs in the economic game known as beauty contest. Finally, Unterrainer, Kaller, Leonhart, and Rahm (2011) found that chess players' planning abilities did not transfer to the Tower of London, a test assessing executive function and planning skills.

The Present Study

The research on the transferability of chess players' skills to other domains offers a complementary perspective to the research on the benefits of chess instruction on children's academic (e.g., mathematics) achievement. Whilst the latter has provided encouraging results, the former has offered results that seem to preclude any generalizability of chess-specific skills.

A possible explanation may be that chess instruction shares with the domain of mathematics some general features, such as quantitative relationships (e.g., the value of the chess pieces) and problem-solving situations (e.g., tactics), which can in turn generalize to mathematics. However, this transfer can occur only when these skills are at the beginning of their development, and hence still generalizable. Put simply, children studying the four operations may take advantage of an activity (i.e., chess) dealing with the calculation, for example, of the pieces' values. By contrast, it is hard to believe that knowing advanced chess techniques, such as Lucena's method in Rook endgames, might be beneficial for college students' skills in calculus or combinatorics. In the former case, there may be an overlap between the domain of chess and mathematics, in the latter there is none. This may explain why the studies dealing with the effect of chess instructions on children's mathematical ability have provided positive results, whilst studies regarding the generalizability of chess masters' skills have showed no effect.

An alternative explanation has been suggested by Kazemi et al. (2012), according to which chess instruction improves children's metacognition – i.e., the ability to monitor one's own cognitive processing (Brown, 1987; Flavell, 1979) – which, in turn, enhance their mathematical ability. Kazemi et al. (2012) found that youngsters who attended a chess course outperformed the control group not only in mathematical ability, but also in metacognitive skills. Once again, unfortunately, this study did not control for possible placebo effects.

In any case, since metacognitive skills have been claimed to be one of the most important predictors of mathematical ability (Desoete & Roeyers, 2003; Veenman, Van Hout-Wolters, & Afflerbach, 2006), and since playing chess is an activity for which the self-monitoring of one's thinking processes is essential (De Groot, 1965), Kazemi et al.'s (2012) hypothesis is plausible. Obviously, the null hypothesis – i.e., chess instruction has no effect on children's mathematical and/or cognitive abilities, and the observed benefits are marginal and only due to placebo effects – may be valid too.

Since there is a need, in this field of research, to clarify whether the observed positive influence of chess practice is due to placebo effects or to chess training itself, we ran a three-group design study. Beyond the usual experimental and control groups – attending a chess course and regular school activities, respectively – an active control group was added to control for potential placebo effects. Moreover, the participants of this study were given – along with a test of mathematical ability – a questionnaire assessing metacognitive skills, in order to evaluate whether metacognition is the link connecting chess instruction to the improvements in mathematical ability, as proposed by several authors in the field.

This work thus investigates (a) whether chess instruction enhances children's mathematical ability, (b) whether this effect is mediated by metacognition, and (c) whether the effect of chess instruction on the above two variables is genuine or due to placebo effects.

Method

Participants

Fifty-two fourth graders in three classes of a primary school in Italy took part in this experiment. The mean age of the participants was 9.32 years (*SD* = 0.32). Parental consent was asked and obtained for all the participants.

Material

A six-item test was designed to test participants' mathematical ability (range score 0 – 6). The items used were all from the Italian version of the IEA-TIMSS international survey among fourth graders (Mullis & Martin, 2013), a test with good psychometric properties. These items were chosen because they measure not only procedural mathematical knowledge (e.g., 3 + 7 = ?), but also problem-solving ability. In fact, all the items required solving a mathematical problem starting from a given set of data. An example of such items is provided in Figure 1.

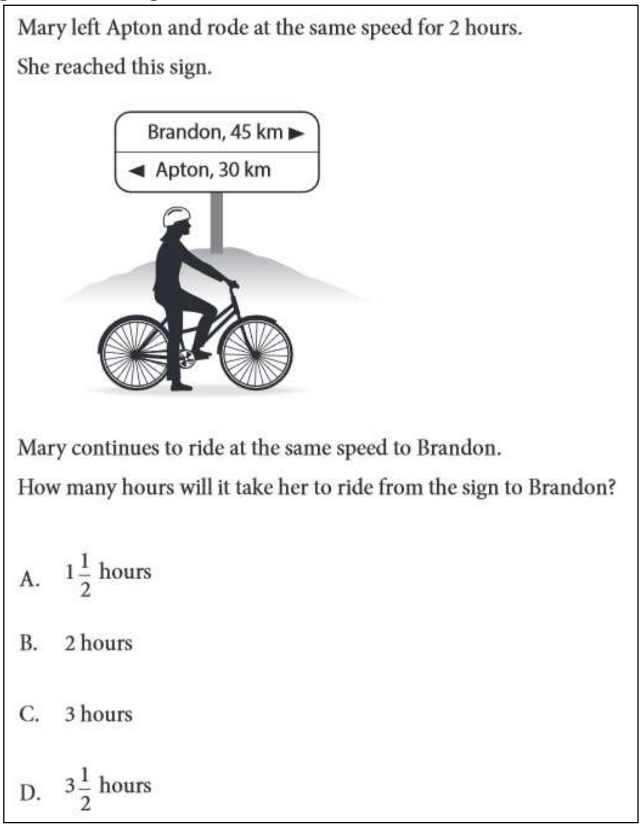

Figure 1. An example of the items used in the test of mathematical ability.

To assess participants' metacognitive skills, we used the Italian version of Panaoura and Philippou's (2003) questionnaire (15-item version; range score 15 – 75). Participants were given 45 minutes for completing the battery of tests.

Design

The three classes were randomly[1] assigned to three groups:

- One class attended 15 hours of chess lessons during school hours, along with regular school activities (experimental group).
- One class attended regular school activities only (control group).
- One class attended 15 hours of Go[2] lessons during school hours, along with regular school activities (placebo group).

Importantly, the two interventions – i.e., chess and Go courses – replaced part of the hours originally dedicated to

[1] Randomizing participants instead of classes is unpractical in schools, especially when interventions replace part of the curricular hours. The participants were assigned to the three classes according to accidental sampling – i.e., the teachers did not adopt any particular didactic criterion (e.g., the students struggling with math in a particular class).

[2] Go (or Baduk) is an Asian strategic board game for two players. The objective of the game is to surround a larger portion of the board (called *Goban*) than the opponent. To pursue this aim, the two players place *stones* (the game pieces) on the board.

mathematics and sciences. This way, we could confront the effectiveness of chess (and Go) instruction with the traditional way of teaching mathematics or mathematics-related subjects – such as sciences.

The chess and Go lessons followed a pre-arranged teaching protocol, which consisted of the basic rules of the games, tactical exercises, and playing complete games. All these activities focused mainly on problem-solving situations, such as finding the correct move and evaluating the advantages/weaknesses in a particular position. It must be noticed that the two courses (chess or Go) did not deal with or introduce any mathematics-related topics, unless these were part of the respective games (e.g., in chess, a Bishop is worth three Pawns). That is, the two courses had only chess- and Go-related contents. In order to rule out possible extraneous effects related to instructor personality (e.g., Pygmalion effect), the chess and Go interventions were carried out by the same instructor, who is an experienced teacher and both a chess and Go trainer. The tests of mathematical ability and metacognition were administered twice, once before the beginning of the course and once after the end. The experimental design is summarized in Figure 2.

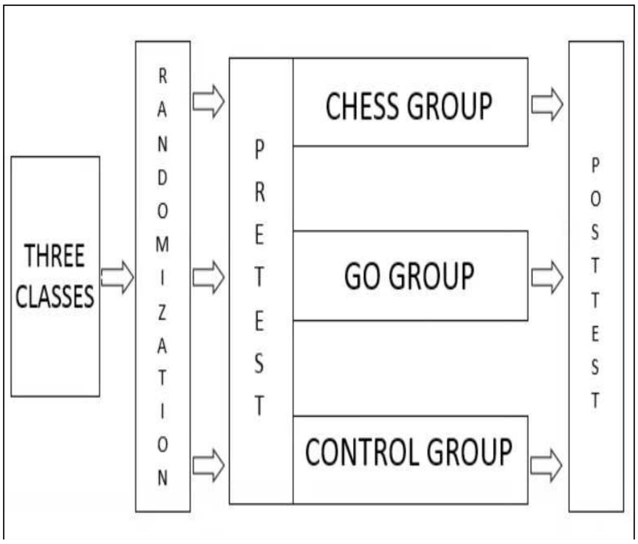

Figure 2. The experimental design.

Finally, the chess/Go trainer, the teachers, the parents, and the children involved reported no unpleasant issues. On the contrary, the people who took part in this project expressed a positive feedback.

Results

Mathematical Ability

No significant differences between the three groups were found in the pretest scores ($F(2, 51) = 1.030$, $p = .365$). A univariate analysis of covariance (ANCOVA) was used to evaluate the role of group (independent variable) and mathematics pretest scores (covariate) in affecting mathematics post-intervention scores (dependent variable).

The results showed a significant effect of the covariate ($F(1, 48) = 21.834$, $p < .001$), and a significant effect of group ($F(2, 48) = 3.371$, $p = .043$). The pairwise comparisons showed that the control group outperformed the Go group ($p = .017$), the chess group marginally outperformed the Go group ($p = .088$), whereas no significant difference was found between the control and the chess group ($p = .487$). The results are summarized in Table 1.

Table 1. Mathematical ability scores in the three groups.

Group	Pretest	Posttest	Adjusted mean
Chess	2.13 (1.26)	2.50 (1.41)	2.30
Go	1.81 (1.08)	1.62 (1.20)	1.63
Control	1.53 (1.13)	2.40 (1.55)	2.60

Note. Standard deviations are shown in brackets.

Metacognitive Skills

No significant differences between the three groups were found in the pretest scores ($F(2, 51) = 0.487$, $p = .617$). A univariate analysis of covariance (ANCOVA) was used to evaluate the role of group (independent variable) and metacognition pre test scores (covariate) in affecting metacognition post-intervention scores (dependent variable).

The results showed a significant effect of the covariate ($F(1, 48) = 47.809$, $p < .001$), and no significant effect of group ($F(2, 48) = 0.367$, $p = .694$). The pairwise comparisons showed no differences between the three groups. The scores are summarized in Table 2.

Table 2. Metacognitive-skill scores in the three groups.

Group	Pretest	Posttest	Adjusted mean
Chess	55.2 (11.0)	57.0 (10.5)	56.3
Go	52.7 (9.2)	54.8 (8.6)	55.8
Control	55.3 (6.5)	58.3 (6.0)	57.6

Note. Standard deviations are shown in brackets.

Discussion

According to the results presented in this paper, chess seems to be more effective in enhancing children's mathematical skills than Go, but not than regular school activities. This outcome – which is consistent with the aforementioned reviews (Gobet & Campitelli, 2006; Sala & Gobet, 2016) – might be discouraging for researchers and teachers who have upheld the implementation of chess instruction in school curricula. However, the fact that the placebo group (Go instruction) underperformed in this experiment – whilst the chess group equalled the performance of the control groups – suggests that some chess-related skills generalized to the domain of mathematics (Scholz et al., 2008), and therefore that the benefits of chess instruction, albeit limited, are not only the mere by-product of placebo effects.

With regard to metacognitive skills, children do not seem to benefit from any advantage from chess instruction. In fact, the participants of the three groups performed equally, both in the pretest and in the posttest, suggesting that metacognition does not represent the cognitive link between chess instruction and mathematical ability.

Strengths and Limitations of the Study

In spite of the long history of research on the benefits of chess instruction on mathematical ability, which started more than thirty years ago with Christiaen and Verhofstadt-Denève (1981), the current study is the first to use a placebo group. In addition to its design, it has several strengths. First, the same instructor taught the experimental and placebo groups. Second, the interventions were implemented during school hours, and replaced part of the lessons dedicated to the teaching of mathematics or mathematics-related subjects (i.e., sciences), in order to compare directly chess and Go instruction to ordinary school teaching. Finally, the design included both a cognitive (i.e., metacognition) and an academic (i.e., mathematics) variable, in order to search for a possible causal link between chess instruction and enhancement of children's mathematical ability.

The study also suffers from a few weaknesses. The sample size was relatively small, which affected statistical power. Randomization was done at the class level rather than the individual level. (However, as remarked in footnote 1, randomization at the individual level is nearly impossible in the context of real schools.) Finally, only one measure of mathematical ability and metacognitive skills, respectively, was used.

Recommendations for Future Research

The present study supports the hypothesis according to which chess skill transfers to mathematical ability. Importantly, because the effect was not observed in the Go condition, this generalization of chess skill does not depend on placebo effects. However, this far transfer seems – when it occurs – to be limited in size, which is in line with substantial previous research in the field (e.g., Donovan et al., 1999). Furthermore, the results of this study do not corroborate Kazemi's et al. (2012) idea that chess instruction fosters children's mathematical ability by enhancing their metacognitive skills.

Given the near-absence of studies controlling for placebo effects in this line of research, it is essential to replicate and extend this work. First, since the duration of treatment seems to be positively related to the effect of chess instruction on cognitive and academic outcomes (Sala & Gobet, 2016), future studies should directly manipulate this variable, in order to understand the optimal duration of chess courses. Second, given that the positive effect of chess instruction does not appear superior to the regular curricular activities, it would be interesting to compare the effect of chess interventions held during school hours with the effect of chess interventions held during extra-curricular hours. Third, there has been little research that has explicitly tried to teach mathematics using chess. Possible examples include illustrating the Cartesian graph with the chess board and introducing the concept of block distance – as opposed to Euclidean distance – with the movement of the King. As it is known that awareness makes transfer more likely (Gick & Holyoak, 1980; Salomon & Perkins, 1989), it is plausible that making explicit the links between chess and mathematics could facilitate transfer. Finally, other activities could be used with the placebo groups, such as other board games (e.g., checkers) and music.

The chess-in-school field of research has been nearly exclusively interested in establishing the presence of benefits of chess instruction for curricular topics (mostly mathematics and reading) and general cognitive abilities (e.g. intelligence and creativity). However, very little research has been carried out on the mechanisms (presumably) leading to such benefits. A crucial aim for this field of research, then, is to develop a detailed causal model explaining the cognitive processes that mediate learning and transfer. With such a model, more precise hypotheses could be tested than it is currently the case.

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