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Effects of Logical Verbal Training on Abstract Reasoning: Evidence from a Pilot Study

Marta Pellegrini¹ - Lucia Donata Nepi² - Andrea Peru³

¹ Università degli Studi di Firenze - Department of Education and Psychology (Italy)

² Università degli Studi di Firenze - School of Humanities and Education (Italy)

³ Università degli Studi di Firenze - Department of Neurosciences, Psychology, Drug Research and Child's Health (Italy)

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marta.pellegrini@unifi.it
lucia.nepi@unifi.it
andrea.peru@unifi.it

EFFETTI DI UN TRAINING LOGICO VERBALE
SULLE CAPACITÀ DI RAGIONAMENTO ASTRATTO:
RISULTANZE DA UNO STUDIO PILOTA

ABSTRACT

Cognitive enhancement refers to any type of improvement in cognitive performance following structured interventions. Research evidence demonstrates the effectiveness of specific programs to improve cognitive abilities, such as logical reasoning, deployment of attentional resources, working memory, and metacognitive strategies such as self-monitoring, modelling, and peer-tutoring. In recent years, many studies have evaluated the effects of various cognitive enhancement programs to enhance these functions. This paper aims to investigate the value of the Logical Intelligence Enhancement Program (LIEP; Calvani et al., 2017) in providing primary school students with effective strategies for the improvement of high cognitive skills related to issues of a logical nature and problem solving. For the study, two fourth-grade classes of an ordinary Italian primary school were involved in an experimental investigation. The results clearly confirm that the program has potential to empower learners to develop cognitive abilities / logical reasoning. Although needing further substantiation, the findings from this study may be useful for both educational and scientific purposes.

Keywords: Abstract reasoning; Cognitive abilities; Cognitive enhancement; Cognitive training; Logical reasoning.

1. INTRODUCTION

For many years expressions such as «logical thinking» and «logical intelligence» have been of increasing interest in the educational field both on a theoretical level and on an empirical level.

The debate about the development of logical thinking during childhood (Piaget, 1936), as well as the structure of intelligence (Kent, 2017) is a theoretical issue that goes well beyond the aims of the current paper, but the point we would like to raise here is that in recent decades, research in the cognitive neurosciences has shed new light on neuroplasticity. It is now widely acknowledged that experience may influence the synaptic organization of the brain. The implications for education are so evident that Doidge (2007, p. 20) claimed: «Everything having to do with human training and education has to be re-examined in light of neuroplasticity». Indeed, recent evidence demonstrates that education is an influential factor in the modulation of inter-individual differences in cognitive performance (Piras *et al.*, 2011).

Encouraged by findings such as these, many different types of interventions have been developed to enhance cognitive abilities, usually referred to as cognitive enhancement programs. In this vein, cognitive enhancement is defined as «the amplification or extension of core capacities of the mind through improvement or augmentation of internal or external information processing systems» (Bostrom & Sandberg, 2009, p. 311). It is relevant to note that interventions of cognitive enhancement are quite different from any therapeutic treatment carried out to compensate for a deficit. Using a specific training, cognitive enhancement interventions improve abilities such as reasoning, working memory, and self-regulation, also called executive functions by Diamond (2013). In recent years, many studies have evaluated the effects of specific programs or activities to enhance these functions (Shiell, 2002; Diamond & Lee, 2011; Moreau & Conway, 2013; Baron *et al.*, 2017). Various interventions have been shown to improve cognitive abilities, such as computerized training, cognitive training (e.g. Feuerstein's Instrumental Enrichment; Feuerstein, Falik, & Rand, 2006), school curricula, but also activities of different nature (e.g. aerobics). Although these activities appear diverse, they share some features that seem critical for cognitive enhancement: challenging objectives for the pupils, repeated and systematic practice, mediation of the materials by an adult also using feedbacks, activation of metacognitive strategies, and peer

learning (Diamond & Lee, 2011). Some of the elements described (metacognitive strategies such as self-verbalization and self-questioning, modeling, peer tutoring, and feedback) were also identified by Hattie (2009) as factors that are usually effective for academic achievement in school.

In view of these considerations, the present study aimed to investigate the value of the Logical Intelligence Enhancement Program (LIEP) developed by Calvani, Francot, Peru, and Zanaboni (2017) to provide primary school pupils with effective strategies to improve cognitive abilities. Furthermore, it intended to evaluate whether any possible effect observed could depend on the nature of the material used in the training. Namely, whether a verbal training could improve visuospatial reasoning. To address these questions, two fourth-grade classes of an ordinary Italian primary school were involved in the experimental investigation reported below.

2. METHODS

The study was approved by the school ethics committee and carried out according to the strictest ethics guidelines (WMA declaration of Helsinki, 2013). Students participated with parental consent. However, before starting the experimental investigation, all the participants were informed about the general aims of the study and clearly told that participation was not mandatory, and they could withdraw from it at any time without problems. Furthermore, a particular emphasis was put on the fact that all the data collected would be kept confidential. It is worthy to note that none of the students refused to take part in the study, nor dropped out of it.

2.1. *Participants*

A total of 51 (23 F, 28 M) pupils, aged nine- to ten-years-old, members of two fourth-grade classes in an ordinary Italian primary school, were enrolled in the study. The school was selected simply based on accessibility and willingness to participate. The actual composition of the two classes was substantially comparable in terms of gender, race, disability, and level of proficiency.

Based on the final marks reported in the previous scholastic year, participants were subdivided into three categories: students admitted to the next year of study with an average final mark higher than 8 (out of a maximum value of 10) were considered to be high proficiency learners and labelled as High; students with an average final mark ranging from 6.5 to 8 were considered to be medium proficiency learners and labelled

as Medium, and students with an average final mark lower than 6.5 were considered to be low proficiency learners and labelled as Low.

In addition to the students, also teachers participated on the basis of uninfluenced, voluntary consent, provided they were absolutely naïve regarding the LIEP. However, one month prior to the start of the experimental investigation, teachers responsible for the classes enrolled in the study were introduced to the program by one of the authors.

2.2. Instruments and procedure

Following a typical repeated measures design, the study consisted of three different phases: a pre-test before students received any training; a three-month training program consisting of ten two-hour lessons during which students were presented with the LIEP material; a post-test carried out one month after the end of the training program.

In both pre- and post-tests, two sets (labelled set A and set B, respectively) of 15 items selected from the first four series of items (i.e. series A-D) of the Raven's Progressive Matrices (Raven, 1938), served to measure the participants' ability of abstract reasoning. It may seem pleonastic to mention, but Raven's Progressive Matrices is one of the most commonly used, *cultural-bias-free*, instruments to estimate non-verbal, fluid intelligence.

To ensure that the level of difficulty was the same for each test set, items were paired together across sets. In particular, set A was composed of the following items: A3, A8, A11, B6, B7, B12, C3, C6, C7, C10, C11, D3, D6, D7, D9, while set B was composed of the following items: A4, A7, A12, B5, B8, B11, C4, C5, C8, C9, C12, D4, D5, D8, D10. However, according to a chiasmatic pattern, in each class, half of the participants were presented with set A at the pre-test and with set B at the post-test, while the opposite was true for the other half.

In both the pre- and post-tests, a time limit of 20 min was allowed to complete the task. The tests were administered by one of the authors in the presence of the class teacher in a single class session. Students with disabilities could benefit from the assistance of their support teacher. *Figure 1* shows an example of items used in the tests.

Regarding the training, only verbal items from the LIEP program (Calvani *et al.*, 2017) were used. In particular, items from Level 1 Form (i.e. form for pupils aged six-to ten-years-old) served as examples and practice trials, while items from Level 2 (i.e. form for pupils aged ten-to twelve-years-old) served as the true didactic material. *Figure 2* contains examples of the items used during the training.

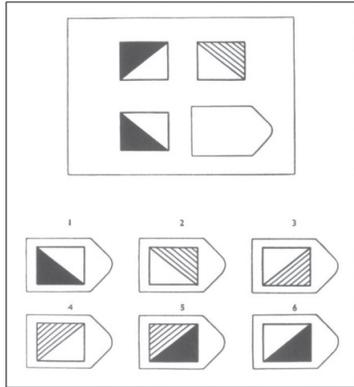


Figure 1. – Example of items used in pre- and post-test.

Level 1 Form

Logical order

Two girls (Francesca and Roberta) and two boys (Aldo and Davide) make a run.

- Aldo arrives before Roberta
- Francesca arrives before Davide
- Davide comes second

Put the children's names in the correct order.

DAVIDE
ROBERTA
ALDO
FRANCESCA

Logical associations

Giovanna, Lucia and Marta can buy a gift. They can choose only one gift in the list: a doll, price 40 euros; a construction set, price 60 euros; a tennis racket, price 70 euros. Knowing that:

- Marta does not like sports
- Lucia cannot spend more than 50 euros

Match each name with the gift chosen.

GIOVANNA		DOLL
LUCIA		TENNIS RACKET
MARTA		CONSTRUCTION SET

Numerical inferences

Find the missing number

1	3	6	10	15	21	?	36
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<p>A. 23 B. 27 C. 30 D. 28</p>																										
<p>Flag test</p> <p>The flag has only one colour. If I said the flag is red and white, only one colour is correct. If I said the flag is blue, red and brown, only one colour is correct. The flag is:</p> <p>A. Blue B. Red C. White D. Brown E. Purple</p>																										
<p>Logical problems</p> <p>Christmas tree baubles</p> <p>Carla and Luisa are preparing Christmas decorations. They have to decorate their Christmas tree with 20 baubles and Luisa hangs up two baubles more than Carla.</p> <p>How many baubles has Carla hung up?</p> <p>A. 9 B. 7 C. 8 D. 10</p>																										
<p>Level 2 Form</p>																										
<p>Logical inferences</p> <p>Every time Neri goes to visit his grandmother, he eats the chocolate she offers him.</p> <p>If Neri eats the chocolate, he has a stomach ache.</p> <p>Today Neri hasn't a stomach ache, then:</p> <p style="margin-left: 20px;">A. He didn't go to visit his grandmother</p> <p style="margin-left: 20px;">B. He went to visit his grandmother</p> <p style="margin-left: 20px;">C. He ate the chocolate</p> <p>He ate the chocolate his grandmother offered him.</p>																										
<p>Flag test</p> <p>If I said the flag is white, blue, black and yellow, there would be two wrong colours.</p> <p>If I said the flag is yellow, red, black and white, there would be three wrong colours.</p> <p>If I said the flag is white and green, there would be two missing colours.</p> <p>If I said the flag is red, blue, pink and white, there would be one wrong colour.</p> <p>The flag is:</p> <p>A. Gray B. White C. Red D. Black E. Blue F. Pink G. Green</p>																										
<p>Matrices</p> <p>The table shows the number of foreign and Italian pupils – males and females - attending a classroom.</p> <table border="1" style="margin-left: auto; margin-right: auto; border-collapse: collapse; text-align: center;"> <thead> <tr> <th style="width: 15%;"></th> <th style="width: 15%;">Italiani</th> <th style="width: 15%;">Stranieri</th> <th style="width: 15%;">Totale</th> </tr> </thead> <tbody> <tr> <td>Maschi</td> <td>5</td> <td>6</td> <td>?</td> </tr> <tr> <td>Femmine</td> <td>6</td> <td>?</td> <td>8</td> </tr> <tr> <td>Totale</td> <td>?</td> <td>8</td> <td>?</td> </tr> </tbody> </table> <p style="margin-left: 20px;">A. In the classroom there are 21 pupils</p> <p style="margin-left: 20px;">B. The Italian pupils are 12</p> <p style="margin-left: 20px;">C. The males are 11</p> <p style="margin-left: 20px;">D. In the classroom there are two female foreign pupils</p> <div style="margin-left: 400px; margin-top: 10px;"> <table style="border: none;"> <tr> <td style="padding-right: 20px;">Vero</td> <td style="padding-right: 20px;">Falso</td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> </table> </div>		Italiani	Stranieri	Totale	Maschi	5	6	?	Femmine	6	?	8	Totale	?	8	?	Vero	Falso	<input type="checkbox"/>							
	Italiani	Stranieri	Totale																							
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<p>Logical problems</p> <p>A fish tank is full of water and its weight is 106 Kilograms.</p> <p>If the fish tank is half full, its weight is 56 Kilograms.</p> <p>How many Kilograms does the fish tank weigh when it is empty?</p> <p>A. 12 B. 26 C. 31 D. 6</p>																										

Figure 2. – Examples of items used during training.

At the beginning of each lesson, the teacher presented an example item on an interactive whiteboard and verbalized aloud each solution step, thus modelling the process of comprehension and promoting self-monitoring. Then, each student – working individually or in pairs – was engaged in solving a series of problems similar to the example. At the end of the lesson, the teacher gave a feedback to the class.

3. RESULTS

Fifty-one (23 female, 28 male) pupils were enrolled in the study, as mentioned above, however only 41 of them met the inclusion criteria: having carried out both pre- and post-test evaluation, having participated in at least 80% of training lessons, and free from neurological or psychiatric problems. Thus, data from ten pupils (i.e. six who missed the post-test and four with from mild to severe mental retardation) were excluded from the analysis which was ran on data from 41 pupils. *Table 1* shows the composition of the sample by gender and level of proficiency.

Table 1. – Composition of the sample by gender and level of proficiency.

	HIGH	MEDIUM	LOW
FEMALES	5	9	3
MALES	11	7	6

Given that two pairs of items (i.e. items A3-A4 and C5-C6 for sets A and B, respectively) turned out to be so easy that no error was recorded, participant performance was scored on 13 instead of 15 items.

Thus, for each participant, his/her score on the pre- and post-tests was inserted into ANOVA with Time (i.e. pre vs. post) as the *within-subjects* factor and Level of Proficiency (i.e. high vs. medium vs. Low) as the *between-subjects* factor with Bonferroni correction for multiple comparisons. The factor Time [$F(1,38) = 6.265$; $p = .017$] was significant, thus demonstrating that the participants' performance improved from pre- (overall performance = 74,7%) to post- (overall performance = 80,9%) test. The factor Level of Proficiency [$F(2,38) = 4.071$; $p = .025$] was significant as well, because overall the Low group performed worse (mean performance = 71,8%) than the High (mean performance = 82,2%) and Medium (mean performance = 7,8%) groups, which, in turn, did not differ from each other. Finally, notwithstanding that the improvement from pre- to

post-test was more evident among low proficient learners than among high and medium proficient learners (see *Tab. 2* for details), the interaction Time-Level of Proficiency, tended toward, but did not reach significance [$F(2,38) = 1.948; p = .157$].

To sum up, findings from our study demonstrated that the training with verbal material from LIEP succeeded in improving participants' ability of visuospatial reasoning as measured by means of Raven Progressive Matrices. Even more interestingly, pupils who benefitted the most from such a training were those with the worst academic outcome (see *Tab. 2*).

Table 2. – Groups' performance.

	PRE	POST
HIGH	81,3%	83,2%
MEDIUM	77,9%	80,8%
LOW	65%	78,6%

4. LIMITS AND CONCLUSIONS

In conclusion, we can say that our results confirm that the program has potential to empower learners to develop cognitive abilities/logical reasoning. Nevertheless, several issues remain to be addressed.

First, our data need to be substantiated by additional evidence from a larger sample of participants. Moreover, future studies should involve students from different classes in both primary and secondary school. Even more importantly, the LIEP should be compared with a different approach to the improvement of logical reasoning rather than with a «no training» condition.

A final point deserves consideration. According to the teachers' reports, pupils found the task fun and challenging, although several items were very easy (and that explains why several participants performed at or near ceiling already on the pre-test). On the other hand, it seems quite obvious that especially among pupils who experience academic difficulty the duration of the training period might play a critical role, so that, the longer (and deeper) the training, the more robust its effects.

Notwithstanding these limitations, the findings from this study may be useful for both educational and scientific purposes and they encourage proceeding with a study on the effectiveness of the LIEP program on a larger scale.

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RIASSUNTO

L'espressione «potenziamento cognitivo» si riferisce a qualsiasi tipo di intervento strutturato indirizzato a favorire lo sviluppo di abilità cognitive. Numerose evidenze sperimentali dimostrano l'efficacia di diversi programmi di potenziamento cognitivo nello sviluppare abilità quali il ragionamento logico, l'allocazione delle risorse attentive e la memoria di lavoro, come pure strategie metacognitive quali l'autoregolazione, il modellamento e l'apprendimento tra pari. Il presente lavoro ha l'obiettivo di indagare la validità del Logical Intelligence Enhancement Program (LIEP; Calvani et al., 2017) per fornire a studenti della scuola primaria strategie efficaci per il miglioramento di alte abilità cognitive relative a problemi di natura logica e di problem solving. Per rispondere a tale obiettivo, due classi quarte di una scuola primaria italiana sono state coinvolte in uno studio sperimentale. I risultati indicano chiaramente che il programma LIEP può essere uno strumento efficace per potenziare le abilità cognitive e il ragionamento logico. Pur nella loro preliminarità, questi riscontri offrono spunti interessanti sia dal punto di vista teorico che delle ricadute didattiche.

Parole chiave: Abilità cognitive; Potenziamento cognitivo; Ragionamento astratto; Ragionamento logico; Training cognitivo.

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