The Logical Intelligence Enhancement Program (LIEP) for the improvement of cognitive abilities. Preliminary findings

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Abstract
The Logical Intelligence Enhancement Program (LIEP) is a program specifically addressed to students aging from 6 to 12. It consists of a series of exercises of different types (verbal inferences, understanding of graphs and tables, series of digits, etc.) and increasing difficulty, properly devised to activate and train the abilities of logical reasoning. Hopefully, such an enhancement should result in an improvement of academic achievements, especially in low proficiency learner students. Here we report on a study carried out on a large cohort of fifth-grade students. The results demonstrate the effectiveness of LIEP in improving students' cognitive abilities and abstract reasoning.

Il Logical Intelligence Enhancement Program (LIEP) è un programma di potenziamento cognitivo, per studenti tra i 6 e i 12 anni, articolato su esercizi di ragionamento di varia tipologia (inferenze verbali, grafici e tabelle, serie numeriche, etc.) e in ordine di difficoltà crescente. Gli esercizi proposti mirano a sviluppare efficaci strategie di *problem solving* (modellamento del docente, lavoro cooperativo, feedback, etc.) con auspicabili ricadute positive sugli apprendimenti, specie per gli alunni con bassi livelli di apprendimento. Il presente studio ha coinvolto una

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ampia platea di studenti di quinta primaria. I risultati ottenuti dimostrano che il LIEP ha le potenzialità per sviluppare le capacità cognitive e di ragionamento astratto

Keywords: cognitive enhancement; logical reasoning; cognitive abilities; cognitive training

Parole chiave: potenziamento cognitivo; ragionamento logico; abilità cognitive; training cognitivo

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1. Introduction

Cognitive enhancement may be 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). Besides therapeutic implications, the possibility to extend mental capacities is of great relevance for educational purposes. Thus, not surprisingly, in the last decades, in the field of education, several types of interventions have been developed to enhance cognitive abilities such as reasoning, working memory, and self-regulation in school children of various ages (Diamond, 2013; Diamond & Lee, 2011). These interventions, often indicated with the umbrella term "Cognitive Enhancement Programs", encompass a wide range of methods that can be classified into three major categories (Coggi & Ricchiardi, 2015; Dewey & Bento, 2009): direct methods, that aim to stimulate cognitive processes by presenting learners with properly devised, intrinsically motivating, tasks not related to any school subjects (Feuerstein, Feuerstein, & Falik; 2006; Haywood & Brooks, 2013), programs that require the activation of mental operations related to a specific disciplinary domain, for example CAME - Cognitive Acceleration in Mathematics Education (Goulding, 2002; Seleznyov, Adhami, Black, Hodgen, & Twiss, 2021) and CASE - Cognitive Acceleration through Science Education (Adey, 1999; Oliver & Venville, 2015; Shayer, 1999), and methods based on infusion approach, in which cognitive stimulation is activated and reinforced during the learning of the disciplinary contents through taxonomy of thinking and metacognitive reflection, e.g. ACTS - Activating Children's Thinking Skills (McGuinness, 1999; Dewey & Bento, 2009) or the Fenix Program in Italy (Coggi & Ricchiardi, 2015).

A deeper analysis of the "Cognitive Enhancement Programs" is well beyond the aims of this paper. What is relevant to note here, is that some of these programs – for example the Feuerstein's Instrumental Enrichment (Feuerstein, Rand, Hoffman, & Miller, 1980), and Tools of the Mind (Bodrova & Leong, 2001) – have been evaluated through rigorous experimental studies and proven effective in strengthening abstract reasoning and metacognitive skills (Baron, Evangelou, Malmberg, & Melendez-Torres, 2017; Higgins, Hall, Baumfield, & Moseley, 2005; Shiell, 2002), finally resulting into an improvement of the academic performance of students at various school levels.

Recently, in the Italian scenario, the SApIE association (https://www.sapie.it) developed the Logical Intelligence Enhancement Program (LIEP; Calvani, Peru & Zanaboni, 2019). This intervention program is specifically addressed to students aging from 6 to 12, attending the five grades of primary school and the first grade of secondary school and goes along with the Visual Intelligence Enhancement Program (VIEP; Calvani & Zanaboni, 2018) for children between 3 and 12 years old, mainly based on visuo-spatial rather than verbal exercises. Taken together, VIEP and LIEP aim to represent a comprehensive training program for the development of logical reasoning abilities in preschool and primary school children, either typically developing or with developmental delays.

In particular, LIEP consists of different types of exercises such as verbal inferences, series of digits, understanding of graphs and tables, which are known to subsume inductive and deductive reasoning (Christou & Papageorgiou, 2007; Johnson-Laird, 1999; Johnson-Laird, Byrne & Schaeken, 1992; Klauer & Phye, 2008). Students are to solve the various items, proposed in order of increasing difficulty, by working individually or in a

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pair with a classmate as well as in a class session provided by the teacher. According to the metacognitive approach, the strategies to be used to solve each problem represent a key feature of the program having the same, if not more, relevance than the problem itself. The main strategies at work in each session of the LIEP program are four: modelling, peer learning, students' verbalization, and teacher's feedback.

Through modelling, teacher verbalizes thoughts aloud while answering an item, thus providing students with effective ("torch") strategies for solving the task. After having listened to the verbalization of strategies that drove teacher's solutions, students will be engaged in their practice tasks and apply the strategies previously acquired by searching for the solution with a classmate, according to the principles of peer learning (Topping, 2005). Teacher pairs children according to ability and compatibility and the pairs of students are changed regularly. During students' verbalization, teacher will promote a collective reflection on the activity so that students can share their experience and co-operate to accomplish the goal (Dominowski, 1998). Then, teacher provides the class with his/her feedback to ensure that everyone has fully understood the activity and is ready to go ahead (Hattie & Timperley, 2007). Each LIEP session involves various activities of different levels of difficulty, in order to provide students with a challenging and rewarding experience that will support their motivation to learn (Namaziandost, Esfahani & Ahmadi, 2019).

In view of all the above, LIEP should have potential to develop children's logical reasoning. Previous findings from our group (Pellegrini, Nepi, & Peru, 2018) seem to support this hypothesis. In that study, two fourth-grade classes of an Italian primary school in Tuscany were engaged in a two-month LIEP program. The effectiveness of LIEP in improving participants' ability of abstract reasoning was evaluated by comparing their pre- vs. post-training performance of a selected sample of Raven Progressive Matrices. A significant improvement, which tended to be more evident among low proficiency learners, was recorded, thus indicating that the program has potential to foster learners' abilities of logical reasoning. However, the relatively small sample of participants and the absence of a control group suggest caution before drawing firm conclusions. Hereafter we report on a study that aimed to extend those preliminary findings on a larger (and a bit older) sample of participants also assessed on a more rigorous way.

2. Methods

2.1 Participants

The study was approved by the Ethics Committee of the participating schools and carried out according to the strictest ethics guidelines (WMA declaration of Helsinki, 2013). A total of 203 pupils (108 females and 95 males), aged ten- to eleven-years-old, members of ten fifth-grade classes in four state Italian primary schools, was enrolled in the study. The schools were selected simply based on accessibility, and willingness to participate. Two schools (for a total of 4 classes) were located in small towns near Firenze, Tuscany, while the other two schools (for a total of 6 classes) were located in the peripheral area of Palermo, Sicily. For the classes from Tuscany, a coin toss was used to decide which of them would serve as the experimental or control group (2 classes each), while all the classes from Sicily served as the experimental group. Students participated with parental consent and were naïve as to the purpose of the study. They were informed that participation was not

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mandatory, and they had the right to decline at any time. A particular emphasis was put on the fact that all the data collected would be kept confidential. None of the students, however, refused to take part in the study, nor dropped out of it. Based on the marks obtained in three subjects (i.e., Maths, Italian, and Foreign Language) in the intermediate evaluation during the current scholastic year, participants could belong to one of three categories: high (average mark higher than 8.5 out of a maximum value of 10), medium (average mark < 8.5 but > 7), and low (average mark not higher than 7) proficiency learners labelled as High, Medium, and Low, respectively. Children with disability could benefit from a simplified version of the program and the assistance of their support teacher; their results, however, were not included in the analyses. Teachers were eligible to participate, on the basis of uninfluenced, voluntary consent, provided they did not have any previous experience with the LIEP program.

2.2 Measures and Procedure

In accordance with a standard pre- vs. post- design, the study consisted of three different phases: a pre-test administered one week before students received any training; a two-month training program during which students were engaged on LIEP tasks; a post-test administered one week after the end of the training program. A distal and a proximal measure were selected in order to evaluate the near-transfer effect of LIEP on verbal reasoning directly trained by the intervention as well as the far-transfer effect on visuospatial reasoning. In both pre- and post-test phases, participants were to perform two tests: the first one (i.e., LIEP test) is a properly devised test (Di Martino & Pellegrini, 2019), strictly inspired by the LIEP program. It consists of 22 items on verbal reasoning, similar but not identical to the items used during the training. Because of this, the participants' performance on this test can be taken as a proximal, direct measure of the effects of the training. In turn, the second test – a selection of 15 items from the first four series (i.e., series A-D, see Pellegrini et al., 2018 for details on the materials used in this test) of the Raven's Progressive Matrices 1938 – one of the most commonly used, cultural-bias-free, instruments to estimate non-verbal, fluid intelligence – can be considered to be a distal, indirect measure of the effects of the training on the abilities of abstract reasoning. Finally, to further evaluate the effects of the training on students' academic achievements, we also considered the participants' performance on Maths section of the national examination INVALSI (Istituto nazionale per la valutazione del sistema educativo di istruzione e di formazione) carried out at the end of the fifth grade of primary school (https://invalsi-areaprove.cineca.it/docs/2019/05_Matematica_Fasc_1.pdf).

2.3 Intervention

The LIEP program for fifth-grade students consists of a series of activities and exercises mainly related to verbal and mathematical reasoning. One month before the beginning of the intervention, the teachers responsible for the classes enrolled in the study were introduced to the LIEP program by one of the authors through a half-day session training focusing on three main processes: a) how to use the teacher's guide for the program; b) how to implement the program; c) how to adapt the program for students with disability who benefit from the assistant of a support teacher. In particular, for each type of exercise, the guide provided the teachers with a series of

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scripts that will be helpful to analyse the items in proper way and give students the appropriate feedbacks. The whole intervention is organised in 15 one and a half hour sessions carried out in order of increasing difficulty from the easiest to the most difficult. Although there is some flexibility in the implementation of the sessions, the maintenance of a schedule of two sessions per week is strongly recommended to ensure the completion of the program within two months (in our case, between March and April 2019). Table 1 shows examples of the items used during the training.

<table>
<tr><th>Logical problems</th><th>Logical equations</th></tr>
<tr><td>Luca saved 400 Euros in 2- and 1-euro coins. The 1-euro coins are double the number of 2-euro coins. How many 2-euro coins does he have?
100 200 300 400</td><td>A bottle of milk is enough to fill up 3 cups. One cup is enough to fill up 2 small glasses. How many small glasses can be filled from a bottle of milk?
2 4 6 8</td></tr>
<tr><th>Flags test</th><th>Logical inferences</th></tr>
<tr><td>If I said the flag is green, blue, and yellow, one colour would be wrong. If I said the flag is yellow, red, and grey, two colours would be wrong. If said the flag is blue, rose, and grey, two colours would be wrong. If I said the flag is red, rose, and purple, three colours would be wrong. The flag is (mark all the colours of the flag):
White Blue Black Rose Red Green Purple</td><td>A cookbook claims: “If a cook doesn’t have fresh eggs of the day, he can’t make mayonnaise”
To prove the cookbook is wrong, you need to find:
▪ at least one cook who failed to make mayonnaise with fresh eggs of the day
▪ at least one cook who failed to make mayonnaise with eggs not of the day
▪ at least one cook who succeeded to make mayonnaise with eggs not of the day
▪ at least one cook who succeeded to make mayonnaise with fresh eggs of the day</td></tr>
<tr><th>Numerical inferences</th><th>Matrices and graphs</th></tr>
<tr><td>Find the missing number in the series:
10 16 22 ? 34 40</td><td>Fill in the matrix with missing data:<table><tr><td></td><td>Football</td><td>Volley</td><td>Total</td></tr><tr><td>Boys</td><td>6</td><td></td><td>9</td></tr><tr><td>Girls</td><td></td><td>9</td><td>14</td></tr><tr><td>Total</td><td>11</td><td>12</td><td>23</td></tr></table></td></tr>
</table>

Table 1: Examples of items used during the training

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All the sessions follow the same procedure: the teacher introduces an example item on an interactive whiteboard and verbalises each step of the solving process, thus modelling the comprehension strategy. Then, students work in a pair to solve a series of problems similar to the example. Finally, the teacher gives a feedback to the class by discussing different solution strategies and analysing the most common errors made by the students. Such a procedure is repeated for each type of exercises (4-6 per session in order of increasing difficulty) included in each session. Finally, each session ends with the pairs of students who are asked to develop a new, original, exercise similar to those just solved.

3. Results

Of the 203 participants, 57 were excluded from the analysis because they missed more than 20% of training sessions and/or because they did not complete pre- or post-test or scored below the chance level (thus demonstrating a lack of motivation). Data from the remaining 146 participants (77 females and 69 males) were analysed as follows. In a first step we wanted to evaluate whether the LIEP training was successful overall by comparing the performances of the experimental and control group as homogeneous as possible. For this purpose, only data from the two Tuscan schools (2 classes for each group for a total of 71 participants) were considered. The main results are summarised in Table 2.

	LIEP (22 items)		**Raven (15 items)**	
	Pre-test	***Post-test***	***Pre-test***	***Post-test***
Experimental group (N=38)	72.0	83.3	55.4	57.4
Control group (N=33)	66.1	71.4	48.3	44.7
Performances expressed in % of hits				

Table 2: Results by group

For each participant the pre- vs. post-test performances on both LIEP and Raven task were entered in two separate repeated measures ANOVA with Time (pre vs. post) as the within-subjects factor and Group as the between-subjects factor. In all the analyses, Bonferroni correction for multiple comparisons was applied, and a p-value of <.05 was considered to indicate statistical significance. As to the LIEP task, results were straightforward: the factor Time was significant [$F(1,69) = 50.410$; $p < .001$)] because both groups ameliorated their performance in the second session. More interestingly, the interaction Time by Groups was also significant [$F(1,69) = 6.705$; $p = .012$)], because such an amelioration was more evident among experimental than control participants. However, the between-subjects factor Group was also significant [$F(1,69) = 5.477$; $p = .022$)], likely reflecting the heterogeneity among the two groups. On the opposite, neither the main factors nor their interaction reached significance in the analysis of the Raven task.

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Having demonstrated that LIEP was able to modulate students' performance, in the second step we focused only on the performance of participants from the eight classes (2 from the Tuscany and 6 from the Sicily) who served as experimental group and carried out the LIEP training. Thus, once again, the performances of 30 Low, 49 Medium, and 34 High proficiency learners on both LIEP and Raven task were entered in two separate repeated measures ANOVA with Time (pre vs. post) as the within-subjects factor and Group (Low vs. Medium vs. High) as the between-subjects factor with Bonferroni correction for multiple comparisons, and a p-value of <.05 as index of statistical significance. The main results are summarised in Table 3.

	LIEP (22 items)		**Raven (15 items)**	
	Pre-test	***Post-test***	***Pre-test***	***Post-test***
High (N=34)	64.8	78.1	49.6	55.9
Medium (N=49)	57.1	69.1	47.1	51.0
Low (N=30)	55.8	68.0	44.9	47.8

Table 3: Results by level of proficiency

As to the LIEP, the main factor Time was highly significant [$F(1, 110) = 87.943$; $p < .001$)], while the factor Group tended but did not reach significance [$F(2,110) = 2.888$; $p = .060$)]. On the opposite, the interaction Time by Group was far from significant because all the three groups markedly improved from baseline.
The pattern of results was pretty similar when the Raven task was considered: also in this case, the main factor Time was significant [$F(1, 110) = 5.779$; $p = .018$)] while neither the between-subjects factor Group nor the interaction Time by Group were significant because the three groups ameliorated in a similar way also on this task. Finally, in the third step, we addressed the question whether the performance on any of these tests would correlate with the participants' score on the maths section of the national examination (INVALSI) carried out approximately in the same period of the post-test session. Pearson's test showed positive correlations between INVALSI score and both LIEP ($r = 0.592$) and Raven ($r = 0.347$) score.

4. Conclusions

In the field of education, "Cognitive Enhancement Programs" are arousing increasing interest for the possibility that they offer to enhance cognitive abilities in both typically developing and with developmental delays children. Here, in Italy, besides the classic, worldwide known, programs (e.g., the Feuerstein's Instrumental Enrichment) are now available two other programs developed by the SApIE association with the aim to provide preschool and primary school children with an extensive training program for the development of logical reasoning abilities.
Both these programs, however, need to be validated before being incorporated into any academic curriculum. Promising, albeit preliminary, findings stem from a pilot study recently carried out by our group (Pellegrini et

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al., 2018) on a relatively small sample of fourth-grade pupils. Indeed, a two-month LIEP training program resulted to be capable to enhance students' abilities of logical reasoning as assessed by means of Raven Progressive Matrices.

To expand and corroborate these findings, we next examined a larger (and a bit older) sample of primary school children with a more sophisticated paradigm. First, we wanted to estimate the effects of the training by comparing experimental and control group on a test (i.e., LIEP test) strictly linked to the activities administered during the training period. As expected, although both groups ameliorated their performance from pre- to post-test, such an amelioration was much more evident among students who attended the LIEP program. Otherwise, such an effect did not reach statistical significance when the Raven task was considered, likely because the relatively small size of the sample (i.e., 38 experimental vs. 33 control ss.).

Actually, the effect became evident when a larger sample was considered. Namely, when analysis was run on the whole cohort of experimental participants (i.e., 113 ss.), we observed a significant improvement on both the LIEP and the Raven test. Unlike what recorded in the previous study, such an improvement was spread out among all the pupils, no matter their level of proficiency. Several, albeit not mutually exclusive, explanations can be proposed to account for this inconsistency across studies, ranging from the different sample size to the not homogeneous teachers' evaluation criteria. Taken together, findings from these studies suggest that LIEP program has potential to enhance abstract reasoning in children from fourth and fifth grade of primary school. Does such an enhancement have an effect on the students' academic achievements? Namely, is there any relationship between the students' ability to solve the LIEP items and their performance on more traditional academic tasks? The strong correlation between INVALSI and LIEP post-test score seems to suggest a positive answer to that question.

However, we must recognize that in our study there are significant limitations that remain to be overcome. First, our data need to be substantiated by additional evidence from a larger sample of participants of different grades from a very large number of schools located throughout the whole Italian territory. 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. Finally, in this investigation students were to solve items by working in a pair with a classmate and the pairs of students were changed regularly by the teachers. Given the critical role played by the skill level of the companion, it is possible that the outcome would have been different if the students had worked individually or with different classmates (Lou et al., 1996). To conclude, we can claim that, although in need of further substantiation, our findings confirm the LIEP training as a promising tool to improve the students' abilities of logical reasoning.

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