Can digital Mind Games be Used to Investigate Children's Reasoning Abilities?

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Abstract: This paper focuses on the use of digital mind games (also called puzzles or brainteasers) to investigate and assess students' logical and reasoning abilities.

It draws on LOGIVALI, a research project whose main objective was that of verifying whether digital mind games can be employed with the aim of understanding and evaluating primary school children's reasoning abilities.

Within the project, supported by the Italian Ministry of Education, the LOGIVALI TEST, a norm-referenced test, was designed and produced. In order to perform the validation and standardization of this test, a large- scale in-field experiment, involving more than 50 teachers and 500 primary school students (4^{th} and 5^{th} grades) was carried out.

Students, during school hours and under teachers' control, were asked to play individually with five mind games that had been carefully selected among mainstream free and Open Source software products. The choice of the games was made on the basis of some key criteria among which: ease of use (interface and design features); suitability to the target population and to the envisaged educational setting (e.g. level of difficulty - time required); disciplinary competences–independence (e.g. not requiring specific mathematics or language competencies); type of feedback offered during the gaming sessions. Following the playing sessions, students were tested by means of a detailed, custom made, evaluation test aimed at shedding light on the children's actual possession of the reasoning abilities required to solve the games at hand.

At the core of the paper the LOGIVAL TEST is described and account is given of the specific abilities investigated in the test and of the methodology adopted to carry out the test validation and standardization. The major results of the project are also proposed, which, basically, account for the suitability of mind games to assess specific relevant reasoning abilities as far as the target population (pupils' age level 8-10) is concerned.

Keywords: Games-based learning, mind games, reasoning skills, evaluation, primary education, Technology Enhanced Learning.

1 Introduction

This paper focuses on the use of digital mind games to investigate and assess students' logical and reasoning abilities, which are actually "transversal" to the very majority of learning tasks and therefore highly influencing on the students' global achievement (Rohde and Thompson, 2007; Robertson and Miller 2009).

Many authors recognize that the educational use of digital games has a significant impact on children's cognitive skills (Whitebread 1997; Amory et al. 1999; Jenkins 2002; Mc Farlane et al. 2002; Kiili 2007), but mind games, which are also called puzzles or brainteasers (Mitchell and Savill Smith 2004, Prensky 2001; Schiffler 2006) are not frequently studied from the point of view of learning outcomes (Facer et al. 2007) and few studies investigate the specific cognitive abilities they cover (Milovanovic et al. 2009, Shih & Su, 2008)

In past years, ITD CNR (the Institute of Educational Technology of the Italian National Research Council) has carried out a number of in-field experiments in primary school classes (some of which on a long term basis) by focusing exactly on mind games and reasoning skills.

The very ultimate aim of such experiments was that of promoting the development of strategic and reasoning abilities in primary school students. To this purpose, the cognitive abilities involved in such games were investigated (Bottino & Ott 2006) and the main design and interface features that make digital mind games more or less suitable to the intended use were examined (Bottino et al. 2009).

Such experiences highlighted the pedagogical potential of mind games to support and foster reasoning skills and showed that their use under certain conditions may also affect performance in curricular subjects such as mathematics (Bottino et al. 2007). Moreover, the observation of the pupils while playing suggested the idea that digital mind games could be used to investigate if and to what extent children possess the reasoning skills involved in the game's solution. As a matter of fact, for instance, it was noted that very often the same child, while dealing with different mind games, seemed to be stuck in front of tasks of the same level and type of difficulty.

A new project called LOGIVALI was then started, which, by taking a "diagnostic", perspective, was explicitly aimed at verifying the suitability of mind games to evaluate to what extent the children possessed those reasoning/ cognitive skills that previous experiences had pointed out as being crucial to reach the game's solution.

In the following, a brief overview of the LOGIVALI project is proposed by focusing on the games used and on the abilities taken into account because they had emerged as important/relevant during previous in-field experiments; the overall research methodology that led to the building up, validation and standardization of the LOGIVALI TEST (which is actually the main output of the project) is then illustrated and, in the end, the main research results are presented and discussed.

2 Context: the LOGIVALI project

The LOGIVALI research project was carried out in the years 2007-2008 by ITD-CNR, in close cooperation with psychologists of the National Health Service and researchers of IRRE Lombardia (Regional Institute for Educational Research of the Italian Ministry of Education) and, of course, with the teachers of the classes involved; it was promoted and financed by the Italian Ministry of Education through its branch which is in charge of the evaluation of school system (INVALSI - Istituto Nazionale per la VALutazione del Sistema educativo di Istruzione e di formazione). The project involved more than 500 students and 50 teachers in two regions of northern Italy: Liguria and Lombardy.

The main objective of the project, as said above, was that of verifying the suitability of mind games to detect and assess the actual possession/enactment of a number of key reasoning abilities by primary school students. The main final output of the project was the LOGIVALI TEST that, following a custom set-up, specific methodology, employs digital games to evaluate primary school students' reasoning abilities.

2.1 The games adopted

Five mainstream digital mind games were chosen among the around a hundred games that had been used in the previous research experiences.

The selection procedure, of course, entailed taking into account both the usability and ease of use of each game together with its suitability for children of the target age and it was also checked that they did not require the possession of specific prerequisites in the field of arithmetic or language (only very basic abilities were demanded). A further key criterion regarded the span of time required to finish the game; only those games that need a relatively low span of time to be completed were chosen since this guarantees that in a limited number of playing sessions the children, being engaged in repetitive play over time, become confident with each game and may move towards the game solution by following a multi-trial and multi-level approach. As a matter of fact, games that could be played at increasing levels of difficulty were considered so that pupils could afford the progressive deployment of the abilities involved step by step.

While playing with these games students are involved in a "game cycle" (Garris et al., 2002) in which the recurring judgment-behavior-feedback loops can lead them to fully comprehend the game rules and to better cope with the game demands and constraints thus also allowing them to fully exploit/enact the required abilities.

In this light, all the adopted games fall into the category of "mini-games", that is "*games that take less than an hour to complete (often far less), and whose content is simple and one-noted*" (Prensky 2005); adventure mind games were, instead, discarded since they often, as underlined by Becker (2007), require a substantial and prolonged time investment which stretches play well beyond the span of a typical single-class unit.

The process of games selection was carried out by also accurately taking into account the type and the level of the cognitive abilities involved in their solution. Previous experiences had evidenced that different games, despite the different tasks they propose, may show to a higher or lower extent a significant similarity as far as the required cognitive abilities are concerned. Following these indications, during the games selection process, particular attention was also devoted to choosing those games that showed a certain degree of similarity and also those where the actual cognitive abilities in play could come out and be detected more effectively and easily.

To give an overall/general idea of the selected, and actually used, games (most of which are well-known board games that therefore do not need further explanations) Fig. 1 presents one screenshot for each of them; the URL where specific description is provided and from where they can be downloaded is also reported, since all of them are Open Source, free or shareware products (two of them in a restricted demo-version that, nevertheless, offers enough playing schemes and that was therefore judged as well suiting our scopes).

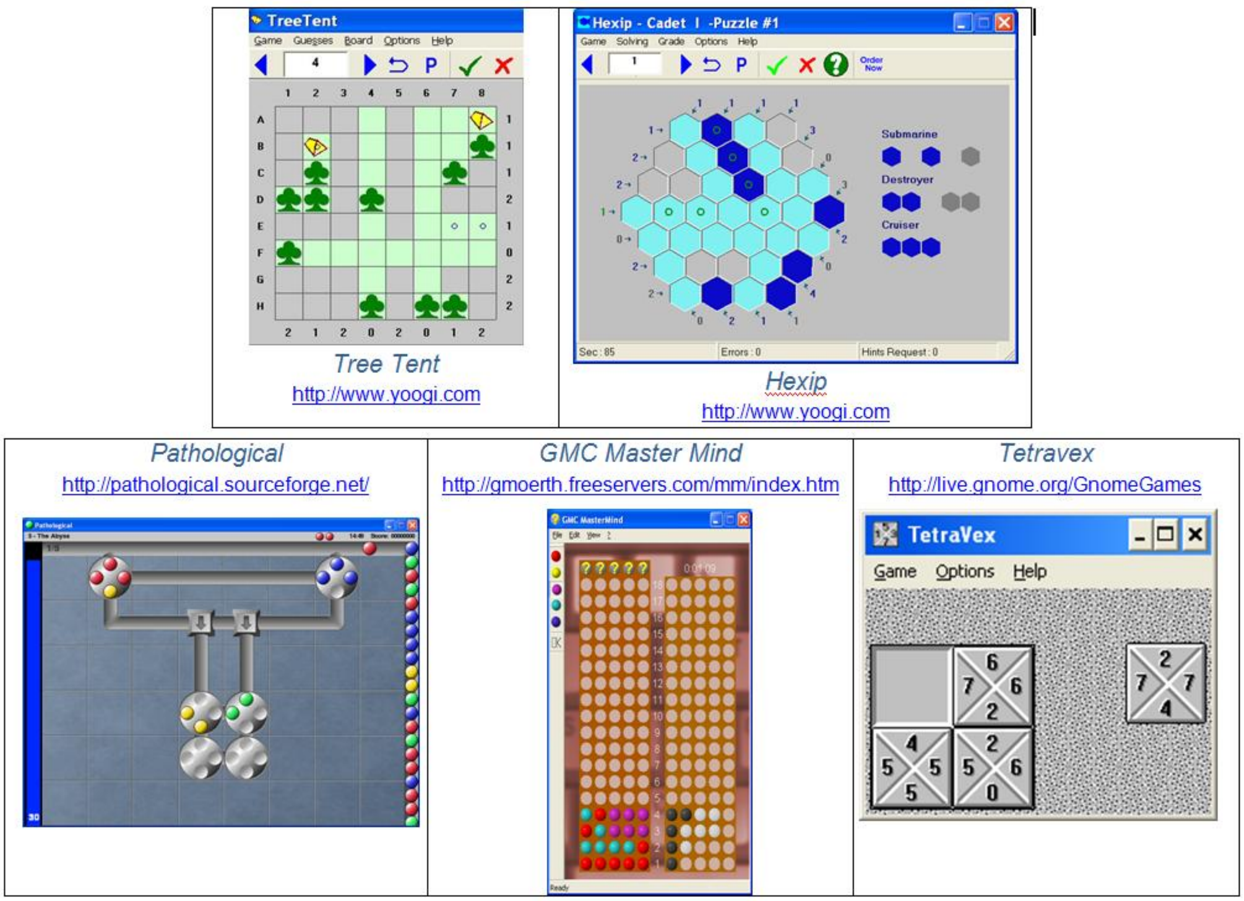

Fig.1 The five games used: examples of screenshots and Internet addresses

2.2 The abilities considered

As previously said, the in-field experiments carried out over the course of time gave us the opportunity to analyze a number of different mind games and to select those that we considered more appropriate to understand and assess the solution process adopted.

The experience acquired in monitoring pupils while playing and the detailed analysis of the mind games at hand also allowed us to identify a set of reasoning abilities that can be considered as essential for the solution of such mind games. As a matter of fact, each game was analyzed and the various abilities figured out were compared and put into relation. Thus, a set of abilities was identified as common to the games considered even if in each game they assumed a specific meaning (connotation).

Such abilities are those investigated through the LOGIVALI TEST. Of course, they are only a subset of the abilities required to deal with the games at hand. As a matter of fact, for the purpose of our work, we decided to concentrate on a restricted number of specific reasoning abilities identified as crucial.

In the outline reported hereunder such abilities have been synthetically named and briefly described.

Ability 1 "*knowing the rules of the game*": to know the rules underlying a given game and to be able to apply them in concrete game situations.

Ability 2 "*first level reasoning*": to be able to make an inference taking into consideration a single given datum. For example, in a battleship-type game such as Hexip (see figure 1), this ability can be described as the ability to be able to correctly identify, in a proposed schema, whether a box (or a set of boxes) contains a ship segment or if it is empty taking into consideration the number outside the row (or one of the diagonals) to which such box belongs.

Ability 3 "*second level reasoning*": to be able to make an inference taking into consideration two given information or game constraints. Considering again the Hexip game, this ability can be exemplified as being able to correctly identify whether a box (or a set of boxes) contains a ship-segment or if it is empty taking into consideration two data (e.g. the numbers outside the row and one of the diagonals to which the box belongs, the number outside the row and the dimensions of the ships to be placed in, etc.).

Ability 4 "*third level reasoning*": to be able to make an inference taking into consideration more than two given information and game constraints. For example, in the game Master Mind (see figure 1) this means to be able to consider all the feedback previously obtained to make the successive guess.

Ability 5 "*managing uncertainty*": to be able to establish whether the data available at a given moment of the game are sufficient to decide whether a certain guess or a given configuration is correct or not. In the Hexip game this means, for example, to be able to evaluate whether it is possible to be sure of the content of a given box. In MasterMind this ability can be seen as being able to establish if the color or the position of one or more balls can be uniquely determined.

Ability 6 "*operatively apply reasoning abilities*": to be able to solve a given game step by step.

Previous abilities have to do with a specific step or move in a game. This last ability is related to the capacity to be able to proceed autonomously until the solution is reached.

In the LOGIVALI TEST, as will be explained more in detail subsequently, the abilities from 1 to 5 are tested through "closed" questions where pupils have to choose an answer among a set of given options. To test Ability 6 students are asked to complete themselves a given game schema.

It was assumed that there was a difficulty progression between abilities 2, 3, 4 and that they can be seen as different levels of the same reasoning ability: the capability of reaching a conclusion taking into consideration a set of data. We nevertheless judged it useful to distinguish between these levels and to consider them separately. As a matter of fact, we often observed that while pupils were quite easily able to process one or, to a lesser extent, two pieces of information, they often showed difficulties when it was necessary to take into account more information and that the passage from two to three (or more) data was crucial.

3 Methodology

Once the abilities to be considered had been identified and the games had been selected, the LOGIVALI TEST was produced and tried out with a representative sample population. It, then, underwent validation and a standardization procedure so that it can now be used to the purpose of shedding light on the actual possession of the considered reasoning abilities by children of the target age (4th and 5th grade students).

The test encompasses five different sub-tests, one for each of the games employed. Each sub-test is composed of eight exercises, each containing multiple items in the form of questions (e.g. where the answer is to be chosen among different alternatives) or, when possible, practical drills (e.g. "fill in the schema with the needed moves"). Each of the test items (question or drill) was conceived so that it could be considered directly related to the enactment of one of the considered abilities.

Table 1 shows the correspondences item/ability in the case of the sub-test for the game Hexip; the number in the matrix indicates which items of the test correspond to that specific ability (e.g. items 1.1, 1.2 and 1.3 correspond to ability 1).

	Exercise 1 N item	**Exercise 2 N item**	**Exercise 3 N item**	**Exercise 4 N item**	**Exercise 5 N item**	**Exercise 6 N item**	**Exercise 7 N item**	**Exercise 8 N item**
Ability 1	1.1/1.2/1.3		3.1					
Ability 2		2.1/2.2	3.2					
Ability 3				4.2	5.1/5.2			
Ability 4				4.1		6.1/6.2	7.1/7.2	8.1/8.2
Abilità 5					5.1			
Ability 6		2.2	3.2	4.2	5.2	6.2	7.2	8.2

TABLE 1: Correspondence ability /test items for the Game Hexip

The overall administration methodology adopted implies that:

a) teachers explain the games to the students;
b) students play individually with five digital mind games; each game is used twice, in two different one-hour playing sessions to be held in the school computer lab;
c) teachers monitor students at work during the playing sessions, but abstain from intervening with suggestions and help;
d) after completing the two playing sessions with each game, each student individually takes a specific test on that game (sub-test); tests are administered by the teachers who also are in charge of making students aware of the fact that no curricular evaluation is foreseen for the tests but that they are contributing to a research project.

In detail: each sub-test is administered immediately after the two playing sessions where the children have the opportunity to play one of the games; the order in which games are presented to the students is fixed: it was established *a priori* following a number of criteria including perceived difficulty of the games, similitude/difference among tasks, interface attractiveness, etc… For each sub-test to be completed, students have at their disposal one hour during normal school time; teachers are in charge of administering the test and monitoring the process.

To avoid, as far as possible, non-homogeneity in the way teachers carry out the overall process, specific guidelines and detailed sheets (one for each game at hand) were produced aimed at supporting the three tasks of: explanation of the game, monitoring of the work and administration of the test.

4 Results

A validated and standardized test (LOGIVALI TEST) was the main outcome of the project. The validation procedure was aimed at verifying both the test reliability and validity, namely whether the test is self consistent and can be considered able to measure what is required: in the case at hand, if it is able to account for the individual differences existing among children as to the considered reasoning abilities. To this end, first of all, the suitability of the sample population (size and composition) was verified, subsequently the test's internal consistency was analyzed and, finally, its ability to measure what it claimed to assess was investigated.

4.1 Suitability of the sample population

A global number of 26 classes and of 52 teachers participated in the experiment and the test was then proposed to a global number of 540 children. Considering that some students were not present at all the phases of the project (playing and test sessions), in the end the actual sample population was considered as being made up of 502 pupils, which, in the case at hand, resulted to be a suitable sample size. Among the subjects involved, 236 were female and 246 were males; all of them attended the 4th or the 5th grade of primary school, in two subsequent school years (2007 and 2008).

As to the sample composition, the analysis conducted by using the log-linear model (adopted to describe associations between variables) showed that the three variables 1) year of test administration, 2) sex of the subjects and 3) class attended are "statistically independent" ($G2(1) = 0.12$, $p = .73$); in this light, the occurrence of one of the three "events" makes it neither more nor less probable that the other occurs and, as a consequence, the available data can be used to make statistical inferences. Actually, some differences emerged, that were nevertheless considered not influencing test results, namely that:

- the sample in 2008 was wider than that of the 2007 (56.0% vs 44.0%, $G2(1) = 11.03$, $p < .01$),
- the sample encompassed a slightly higher number of children in 4th grade than in 5th grade (60.4% vs 39.6%, $G2(1) = 22.74$, $p < .01$)
- a slightly meaningful relation existed between year and attended class ($G2(1) = 4.00$, $p = .05$) the sample being made up of a slightly higher number of 4th grade children in the year 2007 and of 5th grade in 2008

4.2 Test reliability

As to the test reliability, the internal consistency of each one of the six considered abilities was assessed by adopting the Kuder-Richardson-20 measure which is used with multiple-choice items that are scored correct/incorrect (dichotomous choices). Results showed good internal consistency for all the six considered abilities (scores slightly lower than .60 were considered suitable due to the fact that the LOGIVALI TEST comprises, following a precise functional decision, items of different levels of difficulty).

The *item analysis* was also performed by referring to the computation of *item difficulty* and *item discrimination* indexes. Both the indexes accounted for a good reliability of the test. In particular:

As to *item difficulty* no item was found having a value lower than .90 (the acceptable range being between .10 and .90) thus showing that no item should be considered too difficult, while for 13 items the percentage of correct responses was higher than 90%, thereby showing that those answers were too easy.

As to *item discrimination* which actually refers to the capacity of each item of the test to shed light on the individual differences as to the specific ability at hand, it was found that all the items of the test matched at least one of the criteria underpinning the discrimination threshold. In addition it was found that the number of correct answers progressively decreases starting from Ability 2 up to Ability 4, thus confirming, as hypothesized, that the three abilities (2, 3 and 4) can thoroughly be considered increasingly complex abilities for the target population.

As a result of the process of *item analysis* a “validity scale” was produced encompassing 13 items of the test that had resulted both very easy (*item difficulty*) and with a relatively low grade of ability to “discriminate”(*item discrimination*). Considering the 13 items of this validity scale, it emerged that 95% of the entire sample of children gave at least 12 correct answers; it was then decided to exclude from the sample population those subjects presenting lower performance and it was also argued that such a “validity scale” could be used to evidence those children that need specific and particular attention, (regardless of what their scores in the other items of the test are); in other terms when the performance of a subject at the validity scale is lower than 12 this is *per se* indicative of the fact that he/she may have specific problems.

4.3 Test validity

Test validity accounts for the degree of correlation between a test and a criterion (in this case reasoning ability). It entails considering both the *construct validity* (the capacity of a test to measure a construct similar to or different from the one that is measured by other tests) and the *criterion validity* (the correlation between the test and a criterion variable (or variables) taken as representative of the construct).

In the case at hand, the *construct validity* was measured by referring to the results of other tests that were employed during the research, in particular the Raven Progressive Matrices (Raven 1954), the Invalsi test[1] and the Test “Matematica per la Scuola dell’Obbligo – Mathematics for compulsory school” (Amoretti G. et al., 2007).

The *criterion validity* was, instead, measured by referring to the students’ academic achievement on the basis of the scores obtained by the children in mathematics and language.

The Spearmans’ *rho* was adopted in both cases to measure: a) the correlations between the above mentioned other tests carried out in the framework of the project b) the relationship between the two considered variables (academic achievement and test scores).

As to the *construct validity* the related analysis showed that all the coefficients were lower than .70 thus showing that the different tests considered actually account for different constructs (that is, they refer to non- coincident abilities).

As to the *criterion validity* it was shown that there is a moderate correlation (a value comprised between .22 and .53) between the test and the students’ academic achievement (both in mathematics and language); this is true as to all the considered abilities.

In both cases, the fact that the existing correlation between the LOGIVALI TEST and the three tests and the academic achievement resulted as moderate proves not only, as said above, that the different tests measure different constructs (abilities) but also that, at a more general level, the entailed constructs are related to a common cognitive sphere (logical/reasoning sphere).

4.4 Test standardization

On the basis of the results obtained with the sample population involved the test was standardized and the reference norms were defined; as a consequence, now the reasoning abilities of new subjects matching with the target population (4^{th} or 5^{th} grade) can now be assessed by means of the norm-referenced LOGIVALI TEST.

In order to determine the test “norms” it was necessary to verify in advance whether the two main variables in the sample population (class attended and gender) had significant influence on the abilities tested. To this end, an in-depth analysis was performed by means of the factor analysis, and also the specific index η^2 was employed in order to detect whether the “effect” was to some extent related to the number of subjects adopted as sample population. These analyses showed differences due to one of the variables (the class attended); two different norms were, then, generated one per each of the two considered classes (norms for the 4^{th} class/norms for the 5^{th} class produced)

In order to make the reading of the test result easier, the “test norms” were determined on the percentile ranking basis; this means that subjects are classified according a continuous ranking that goes from 0 to 100 (that is, if one subject ranks at the 80 percentile this means that his/her performance is higher than 80% of the sample population that has taken the same test).

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1 INVALSI is the Italian National Evaluation Institute of the Ministry of Education. The test referred to in this paper evaluated curriculum competences and was carried out by Invalsi on a national basis. In 2004, the test involved more than 71,000 classes and approximately 1,400,000 students.

The percentile ranks are normally considered as follows:

- from 0 to 25: low performance
- from 26 to 50: moderately low performance
- from 51 to 75: moderately high performance
- from 76 to 99: high performance

Following the standardization procedure the LOGIVALI TEST at present provides “norms” for each one of the considered abilities (six in total) and for the two considered classes (4^{th} grade and 5^{th} grade)

5 Discussion and Conclusion

The fact that logical and reasoning abilities can be promoted and investigated through the use of digital games and, in particular, of mind games, is an assumption which is usually generically accepted even if very few research studies explicitly focus on the use of mind games to develop and assess such abilities. Nevertheless, the importance of designing research projects and intervention methods in this field is acknowledged (Cotton, 2003; Wolcott, 2003) and early activities at primary school level appear to be particularly important. As a matter of fact, as mentioned in the introduction to this paper, there is ground to believe that detecting and improving logical and reasoning abilities can have, under certain conditions, an impact on students’ school performance.

The objective of the research project reported in this paper was that of using mind games to investigate and assess students’ logical and reasoning abilities. To this end it was necessary to precisely focalize the field of investigation and to clearly identify the abilities to be examined.

The results of the project demonstrate that digital mind games can be regarded as a suitable environment to detect and analyze children’ specific reasoning abilities. In particular, the LOGIVALI TEST confirms that a variety of identified abilities are involved in the solution of the mind games considered. As a matter of fact, it has been demonstrated that the different scales of the test (one for each of the six considered abilities) de facto measure different abilities (constructs); the fact that among the entailed abilities a moderate relationship exists, suggests that these abilities, although per se different, at a more general level, can be ascribed to the same cognitive area, that of reasoning skills. This is also confirmed by the comparison made between the LOGIVALI TEST and other tests that measure different, but related, constructs like fluid intelligence (Yuan et al. 2006) - Raven matrices and mathematics abilities - Amoretti test.

Moreover, some of the identified abilities (abilities 2, 3 and 4) can be seen as different progressive levels of the general ability of making inferences on the basis of given data. The fact that the LOGIVALI TEST allows one to distinguish among such abilities permit one to better appreciate the differences among the children’s inference capacity. This is important to understand, for example, the difficulty that a child may have in a specific task and to better support her/him in facing it.

It is worthwhile noting, despite prejudices sometimes related to the use of digital games, that the LOGIVALI TEST does not give account of any significant difference between male and female performance.

Last but not least, the abilities required to solve the games can be considered, to some extent, precursors of academic achievement. The matching among test results and academic achievement (based on curricular formal evaluations) proved that school high achievers perform better at the LOGIVALI TEST with respect to low achievers and vice versa.

This last indication introduces an interesting future direction for the research work related to the use of mind games for educational purposes. As a matter of fact, such games can offer an alternative frame of reference to interpret the students' level of achievement especially at early school levels. They can usefully supplement the teachers' observations/judgments and the standard/traditional measures of performance, thus can help to provide pupils with more personalized and informed educational support.

At present, as a continuation of the LOGIVALI project, the test is being administered to a new sample population of 4th and 5th grade students in order to investigate how the pupils will distribute in the test ranks and how this is correlated with disciplinary performance.

References

Amoretti, G., Bazzini, L., Pesci, A., Reggiani, M. (2007), Test di Matematica per la Scuola dell'Obbligo, in corso di pubblicazione

Amory, A., Naiker, K., Vincent, J., Adams, C. (1999) The use of computer games as educational tools: identification of appropriate game types and game elements, British Journal of Educational Technology, 30 (4), 311-321.

Becker, K. (2007) Digital game-based learning once removed: teaching teachers. British Journal of Educational Technology, 38 (3), 478-488.

Bottino, R.M., Ferlino, L., Ott, M., Tavella, M. (2007) Developing strategic and reasoning abilities with computer games at primary school level. *Computers & Education*, 49 (4), 1272-1286.

Bottino, R.M., Ott, M. (2006) Mind games, reasoning skills, and the primary school curriculum: hints from a field experiment. *Learning Media & Technology,* 31 (4), 359-375.

Bottino, R.M., Ott, M., Benigno, V. (2009) Digital Mind Games: Experience-Based Reflections on Design and Interface Features Supporting the Devlopment of Reasoning Skills, In Pivec M. (ed) , Proc. 3rd European Conference on Game Based Learning, 53-61 , Academic Publ. Ltd-ISBN: 978-1-906638-47-4,

Facer, K., Ulicsak, M., Sandford, R. (2007) *Can Computer Games Go to School?,* [online], BECTA http://partners.becta.org.uk/index.php?section=rh&rid=13768

Garris, R., Ahlers, R.. Driskell, J. E. (2002) Games, motivation, and learning: a research and practice model. *Simulation & Gaming*, 33 (4), 441–467.

Kiili, K. (2007) Foundation for problem-based gaming. *British Journal of Educational Technology*, 38 (3), 394-404.

Jenkins, H. (2002) Game theory, Technology Review, 29, 1-3.

McFarlane, A., Sparrowhawk, A. and Heald, Y. (2002) *Report on the educational use of games* [online]. Cambridge, UK: TEEM. http://www.teem.org.uk/publications/teem_gamesined_full.pdf

Milovanovic, M, Minovic, M, Kovacevic, I, Minovic, J, Starcevic, D (2009) Effectiveness of Game-Based Learning: Influence of Cognitive Style *Communications in Computer and Information Science,* 49, 87-96.
Mitchell, A., Savill-Smith, C. (2004) *The use of computer and video games for learning. A review of the literature,* [online], London: UK Learning and Skills Development Agency. https://www.lsneducation.org.uk/user/order.aspx?code=041529&src=XOWEB.
Prensky, M. (2001) *Digital game-based learning.* New York: McGraw Hill.
Prensky, M. (2005) Educational Games Complexity Matters: Mini-games are Trivial - but “Complex” Games Are Not. An important Way for Teachers, Parents and Others to Look At Educational Computer and Video Games, *Educational Technology*, 45 (4), 1-15.
Raven, J.C. (1954). Progressive Matrices. Firenze: Organizzazioni Speciali.
Robertson, D., Miller, D., (2009) Learning gains from using games consoles in primary classrooms: a randomized controlled study. *Procedia Social and Behavioral Sciences*, 1 (1), 1641-
Rohde, T. E., Thompson, L.A.,(2007) Predicting academic achievement with cognitive ability *Intelligence* 35 (1), 83-92.
Schiffler, A. (2006) *A heuristic taxonomy of computer games* [online], http://www.ferzkopp.net/joomla/content/view/77/15/
Shih Ju-Ling, Su Hui-Yu (2008) Analyzing Children's Cognitive Activities in Digital Problem-solving Learning Games “William Adventure”: An In-depth Case Study. Proceedings of the 16th Int. Conference on Computers in Education (ICCE), 651-658, http://www.apsce.net/ICCE2008/program_Contents_I.html
Whitebread, D. (1997) Developing children’s problem-solving: The educational uses of adventure games, in McFarlane, A. (ed.), *Information Technology and Authentic learning*, London, Routledge.
Yuan, K, Steedle, J., Shavelson, R., Alonzo, A., Oppezzo, M. (2006). "Working memory, fluid intelligence, and science learning" Educational Research Review ,1, 83–98.