Children's Performance with Digital Mind Games and Evidence for Learning Behaviour

Rosa Maria Bottino, Michela Ott, and Mauro Tavella

Istituto Tecnologie Didattiche – CNR
Via De Marini, 6, Genoa Italy
{bottino,ott,tavella}@itd.cnr.it

Abstract. This paper investigates the relationship between the possession of some of the reasoning abilities required to play digital mind games and the school performance of primary school pupils. It draws on an in-field experiment involving 60 Italian primary school children; the experiment was based on the use of the standardized test LOGIVALI which foresees ten one-hour gaming sessions with five mind games. The pupils were divided in three groups according their school achievement (high, medium and low achievers) and their performance at the test was studied; a substantial consistency was found between school achievement and ability to solve the adopted digital games. A closer insight was also given into the specific reasoning abilities actually possessed by the three different categories of pupils, thanks to the fact that the LOGIVALI test also allows a finer distinction among the different types/levels of reasoning abilities required to perform the proposed gaming tasks.

Keywords: Game-based learning, reasoning abilities, mind games, primary education, students' performance.

1 Introduction

Computer games are broadly regarded as emerging technologies offering a high potential to foster and support learning [1]. One of the key issues to be investigated to nourish this general claim is the relationship between academic performance and the use of computer games in relation to different disciplines, educational settings and underpinning cognitive tasks. At present few studies have been carried out with this objective, even if its importance is increasingly acknowledged [2], [3].

A number of significant research studies have been carried out that look, from different perspectives, at the actual relationships among types of games, learning objectives to be met and learning population to be addressed (i.e. which kind of games better serve the scope of fulfilling specific learning objectives and how this can be done in specific learning contexts and with a specific target population [4], [5].

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This paper focuses on mainstream [6] mind games[1] when used in formal educational settings with the aim of fostering primary school pupils' reasoning abilities, those "transversal" abilities that are recognized as underpinning the majority of learning tasks and sensibly contributing to enhance global academic achievement [9], [10].

With the ultimate aim of understanding whether early interventions in the area of reasoning skills conducted by means of mind games can contribute to noticeably enhancing school performance [11], this paper investigates the possible relationships between the possession of some of the reasoning abilities required to solve mind games and the school performance of primary school pupils. It draws on an in-field experiment involving 60 Italian primary school children and it is based on the use of the LOGIVALI Test, a game-based standardized test assessing primary school pupils reasoning abilities [12]. In the following, after introducing the LOGIVALI Test, the paper presents the methodology adopted to carry out the in-field experiment and discusses some of the obtained results, with a view on future trends and possible new research objectives.

2 The LOGIVALI Test

The LOGIVALI Test is a norm-referenced test that follows a custom set-up, specific methodology with the aim to investigate and assess the possession of some specific logical and reasoning abilities by the target population; to this end, the test employs five digital mind games selected on the basis of previous in-field research experiments [13]. In the following the types of games adopted and the considered abilities are briefly illustrated, and the administration methodology adopted to standardize the test is summarized.

2.1 LOGIVALI Test: The Games Adopted

The test is grounded on the use of five mind games that fall into the category of "mini-games", that is "games that take less than an hour to complete [7]; they do not require specific prerequisites in curricular school subjects, beyond vey basic literacy and, most importantly, do not imply the possession of specific mathematical skills; some of the games are the computerized versions of well known board games (e.g. battleship, master mind).

Figure 1 shows screenshots of the games adopted in the LOGIVALI Test; reference are provided on their availability, since all of them are Open Source or free (two as limited demo-trials).

[1] The term mind games is used in this paper to define games that are elsewhere called brain teasers or puzzles [7], [8]; they differ from brain training games in that they require at an higher extent to devise and enact problem solving strategies to reach the game solution.

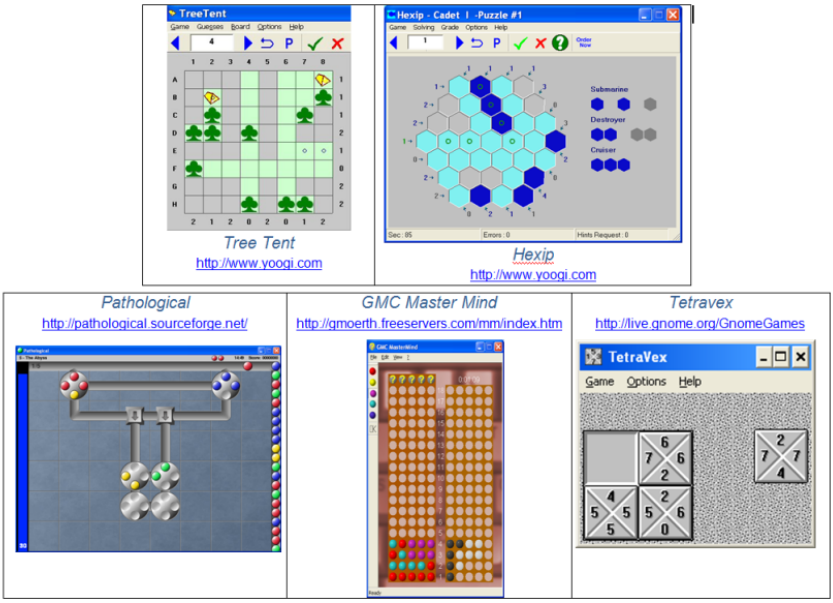

Fig. 1. The five games adopted in the LOGIVALI Test and related reference

2.2 LOGIVALI Test: The Considered Reasoning Abilities

The experience acquired during previous projects [14] and the detailed analysis of the mind games at hand allowed us to identify a set of reasoning abilities that we considered as essential for effectively playing with the adopted games. For the purpose of our work, it was decided to consider a restricted number (six) of specific reasoning abilities identified as crucial although they are, obviously, only a subset of the abilities required to deal with the games at hand.

The following six abilities (which we have identified as common to the five games even if in each of them they may assume a specific connotation) are those investigated through the LOGIVALI Test:

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.

Ability 3 "second level reasoning": to be able to make an inference taking into consideration two given information or game constraints.

Ability 4 "third level reasoning": to be able to make an inference taking into consideration more than two given information and game constraints.

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 is correct or not. This requires flexibility in reasoning and meta-cognitive awareness.

Ability 6 "operatively applying reasoning abilities": to be able to implement into the game the results of own reasoning (actions should follow thoughts); this entails approaching the solution of a given game step by step by showing the capacity to be able to proceed autonomously until the solution is reached.

An important finding emerged during the LOGIVALI project is that the ability of making inferences on the basis of given data cannot be considered as a unique ability but it is necessary to distinguish on the basis of the number of different data, information and constraints to be dealt with. The standardization procedure of the LOGIVALI test evidenced that a reasonable way to do this is to differentiate the abilities to make inferences taking into account one, two, and three or more data (abilities 2, 3 and 4). As to their relative difficulty, it emerged that the number of correct answers progressively decreased: Ability 2 (80%); Ability 3 (63%); Ability 4 (46%). This confirms that the three abilities can be considered as increasingly complex abilities for the target population. This finding is consistent with the empirical observations we have often made during the experimental work with students: pupils usually are able to process one information, but they often show difficulties when it is necessary to take into account two or more information and the passage from one to two (or more) data is crucial. The standardization procedure of the LOGIVALI test showed that all the abilities considered are different and that, at a more general level, all the entailed abilities, even if distinct, are related to a common cognitive area, that of logical reasoning.

2.3 LOGIVALI Test: Structure and Administration Methodology

The LOGIVALI 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 multiple choice questions [15] 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. The standardization procedure of the LOGIVALI test involved 26 primary school classes (4^{th} and 5^{th} grades) of a sample of schools in two Italian regions. The LOGIVALI project involved around 540 students and 52 teachers.

The administration methodology of the LOGIVALI Test 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.
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, 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.

2.4 LOGIVALI Test: Validation and Standardization

The test validation procedure was aimed at verifying both the test reliability and validity, namely if the test is self consistent and can be considered able to measure what 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) has been verified, subsequently the test internal consistency has been analyzed and, finally, its ability to measure what it was claimed to assess was investigated. On the basis of the results obtained with the involved sample population the test was standardized and the reference norms were defined on the percentile ranking basis. In [12] the whole test validation and standardization procedure is presented.

3 The In-field Experiment Based on the LOGIVALI Test

The experiment, aimed at assessing primary school students' reasoning abilities and grounded on the game-based LOGIVALI Test, was carried out in twenty Italian primary schools classes (4^{th} and 5^{th} grades) of the Lombardia region; it was held during school hours within the school computer laboratory.

The students involved in the experiment were globally around 500; for the purpose of this study 60 pupils were selected and monitored while individually playing with digital mind games. The students were classified in three groups according to their school achievement (school actual results plus teachers' judgments): group A (high achievers); group B (medium achievers); group C (low achievers). The target group of 60 students comprised three students per class (out of 20 classes), one student for each group A, B and C.

The LOGIVALI test was administered and the performance of each student at the test was computed according to the percentile ranks determined by the test, namely:

- from 0 to 25: *poor* performance
- from 26 to 50: moderately low performance *(fair)*
- from 51 to 75: moderately high performance (*good*)
- from 76 to 99: *very good* performance

Data on pupils' performance at the test were analyzed and compared with the level of school achievement; further on, since the LOGIVALI test also allows a finer distinction among the different types/levels of reasoning abilities required to perform the various gaming tasks, a closer insight was given into the six specific reasoning abilities considered to investigate to what extent they were actually possessed by the three different categories of pupils.

4 Results

A substantial consistency exists between school achievement and the students' performance at the test.

As a matter of fact, Figure 2, where dark parts stand for low performances (actually 2 levels of low performances: poor and fair) and light parts for high performances (actually 2 levels of high performances: very good and good) shows that:

- Only students in Group A show prevailing high performances at the LOGIVALI test (light parts in the figure) with respect to the other two categories where dark parts are prevailing; more than half of the students of this group perform at the two highest levels.
- The very majority of the students in group C perform at low levels (fair and poor); most performances of these students are at the lowest level.
- Students in group B performances are comparable to those of students in group C if we consider dark and light parts but performances at the fair level prevail on performance at poor level.

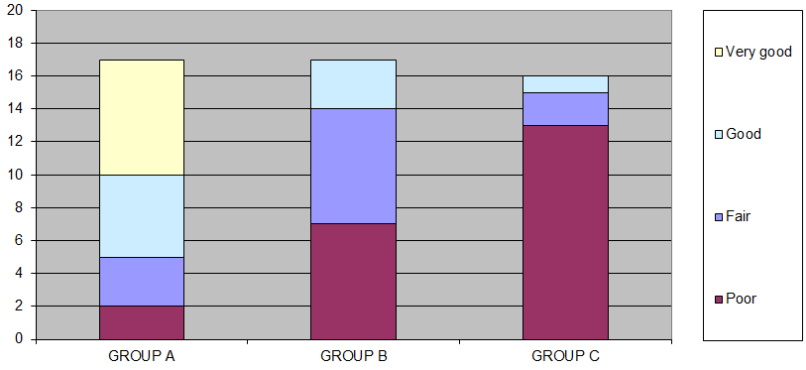

Fig. 2. Performances of the three groups of students at the LOGIVALI Test

High achievers show better performances in each of the abilities.

The structure of the data doesn't allow us to directly compare the performances of the three groups of students in the different abilities: our data are, in fact, based on the calculation of the percentiles which varies in the different abilities (treated as independent) as a consequence of the different number of correct answers given by the

sample population. Notwithstanding this, if we look singularly at the six considered reasoning abilities, we see that high achievers always perform better than the other two groups; this is true for all the abilities in play, despite reasonable differences linked to the intrinsic level of difficulty of each reasoning skill considered. A closer insight (Fig. 3) in the three abilities of the test related to the capacity to make inferences on the basis of given data (namely Ability 2, 3 and 4), we see that performances of high, medium and low achievers are always scaled (with the prevalence of good performances for high achievers and of poor performances for low achievers).

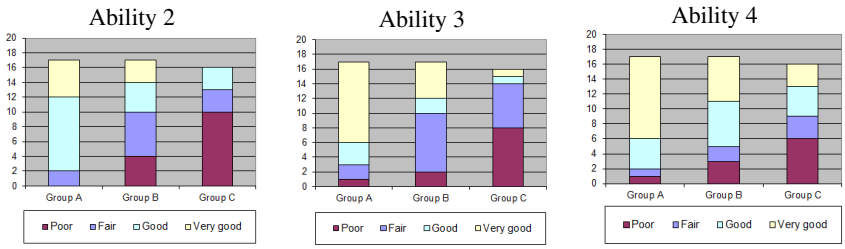

Fig. 3. Performances of the three groups at the three "core" abilities considered

Students in group C appear to have difficulties also in Abilities 5 and 6, while students in group B and those in group A have higher performances. As to Ability 1, which actually deals with a simplest cognitive task, namely the recalling of the game rules, the difference among the performance of the students in the three groups is narrower, probably due to the lower amount of cognitive load required.

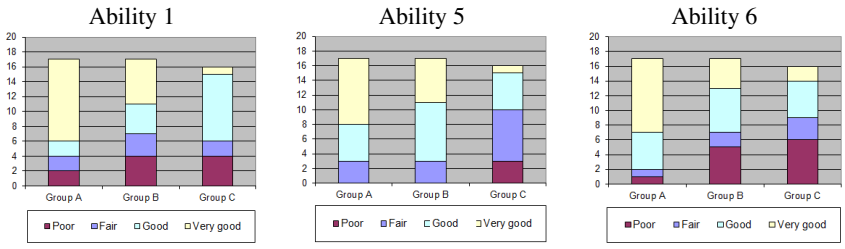

Fig. 4. Performances of the three groups at the three "other" abilities considered

Differences in performances can also be compared to the level of attention and autonomy students showed during the use of the games. For this reason, during the project, considered pupils have been singularly monitored by the teachers while playing and observations sheets were filled in. The analysis of such sheets will allow to have a closer look at the relationship between attention and level of autonomy showed by pupils and their school performance.

5 Conclusive Remarks

The first results of the experiment showed that a substantial consistency can be found between school achievement and ability to play and solve games. Not surprisingly, high achievers' performance on the test was far better with respect to that of the other pupils; conversely, low achievers performance was quite poor.

These former findings, on the one hand, seem to support the idea that at primary school level there is a relationship between school achievement and ability at mind games, and, on the other hand, they also seem to suggest that early intervention aimed to develop and exercise pupils reasoning abilities through games and motivating activities can have an impact on their learning behavior.

This suggests as a possible future line of intervention aimed at improving reasoning abilities by employing mind games that allow a fine graduation of reasoning tasks and that are able to conveniently scaffold the pupils' identification and processing of relevant data.

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