Investigating the Relationship Between School Performance and the Abilities to Play Mind Games

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Abstract: Is there any relationship between school performance and the ability to play digital mind games? This paper tries to answer this key question and in doing so, it draws on a long-term research experiment conducted in primary schools and dealing with the use of mainstream mind games (namely those games that deeply require the enactment of thinking and reasoning skills and are almost independent from knowledge/competence in specific school subjects). It reports on an experiment involving 60 Italian primary school children, which was based on the use of the LOGIVALI Test, a game-based standardized test assessing primary school pupils reasoning abilities. The games adopted in the experiment were five digital mind games (mostly public domain products) falling into the category of "mini-games"; some of them were the computerized versions of well-known board games (e.g. battleship, master mind, domino). The main characteristic common to all the adopted games was that they do not require specific prerequisites in curricular school subjects, beyond very basic literacy and, most importantly, do not imply the possession of specific mathematical skills. During the experiment, the possible relationships between gaming and learning performance of primary school students were investigated; a strong correlation between the students' possession of the reasoning skills necessary to successfully play with mind games and their school performance was found. These considerations corroborate the hypothesis that games exercise a set of specific reasoning abilities that are "transversal" to most curricular activities. The targeted experiment also showed that the great majority of students (including low achievers), independently from the level of their school performance, are very attentive and engaged in game-based learning tasks. These findings, together with the results of other experiments carried out by the authors in different frameworks (but with the same target population and with the same games), concretely support the idea that early interventions to support the development of reasoning abilities carried out by means of engaging and motivating game-based activities can positively impact on students school performance. In a proactive perspective, the obtained results corroborate the idea that a carefully designed, teacher-driven and well-focused use of specific mind games can contribute to sustain and foster students' reasoning and problem solving skills and that these skills may have, in the long run, a positive impact on the students' global school achievement.

Keywords: mind games, transversal skills, game-enhanced learning, technology enhanced learning, primary education

1. Introduction

Digital games are broadly regarded as technologies offering a high potential to foster and support learning (Sandford et al, 2006; Prensky, 2001; Hong et al, 2009; De Freitas & Oliver, 2006; Pivec, 2007). Game-based learning refers to teaching-learning actions carried out in formal and/or informal educational settings by adopting games. It encompasses the use of both games designed expressly for fulfilling learning objectives (educational games) and "mainstream games" -- i.e. those games that are not developed for education (i.e. for fun) when used to pursue learning objectives (Kirriemuir and McFarlane, 2004 p.19). To date a wide number of significant research studies have been carried out that look, from different perspectives, at the actual relationships among different types of digital games and specific learning objectives to be met (Mc Farlane et al, 2002; Mitchell & Savill-Smith, 2004). This paper focuses on mind games, namely those games (elsewhere called brainteasers or puzzles Kebritchi et al., 2010; Milovanović et al, 2009) that deeply require the enactment of thinking and reasoning skills. The paper draws on a research experiment dealing with the use of mainstream mind games in formal educational settings with the aim of fostering primary school pupils' reasoning abilities. Such abilities are defined as "transversal" or "key" and it is widely recognized that they underpin the majority of learning tasks, thus sensibly contributing to enhance global academic achievement (Prensky, 2005; Schiffler, 2006; Carbonaro et al, 2010). The use of digital mind games to support the development/enhancement of transversal abilities and, in particular, those involving reasoning and logical thinking, is still scarcely explored (Rohde & Thompson, 2007) but some authors claim that the use of such games can contribute to enhance school achievement (Robertson & Miller, 2009; Franco et al, 2011).

In the following, drawing on a field experiment involving 60 Italian primary school children we investigate the relationships between the possession of the reasoning abilities required to solve mind games and the school performance at primary school level.

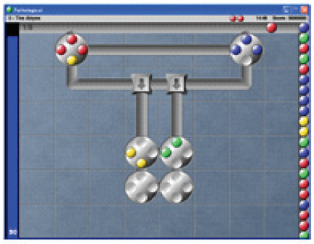
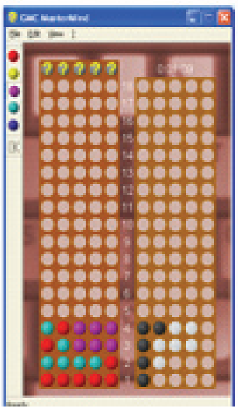
2. Background

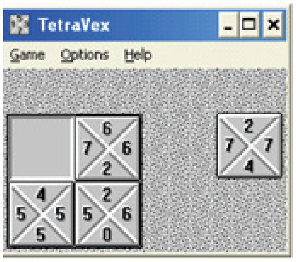
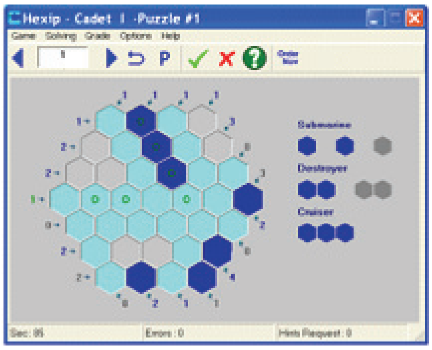
This paper reports and discusses the results of a field experiment conducted in twenty Italian primary schools classes (60 children in 4th and 5th grades) in the Lombardia region. Actually, the experiment was based on the use of the LOGIVALI (LOGIcal thinking eVALuatIon) Test, a game-based norm referenced test assessing the reasoning abilities of primary school pupils (Bottino et al, 2010). In the following before presenting in details the experiment and the related methodology, we briefly summarize the basic concepts underpinning the LOGIVALI test.

2.1 The Logivali test

The LOGIVALI test is a game-based, norm-referenced test that follows a custom set-up, specific methodology to investigate and assess the possession of some specific logical and reasoning abilities. The test is grounded on the use of five digital mind games (Bottino et al, 2010) that fall into the category of "mini-games", that is "games that take less than an hour to complete" (Prensky, 2005). The five games adopted in the LOGIVALI test (Table 1) do not require specific prerequisites in curricular school subjects, beyond very 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, mastermind and domino).

Table 1: LOGIVALI games: screenshots and short description

 Pathological	The Pathological game is a puzzle game consisting of marbles and wheels. The marbles are of different colours and roll along paths. Each wheel has four slots which are to be filled in with marbles of the same colour: to do so, the user clicks on the wheel to rotate it. When the wheel is completed, the marbles vanish and the wheel turns dark. Pathological is organized in progressive difficulty levels that correspond to different schemas. In order to complete each schema it is necessary to take into consideration not only the colour of the ball that is coming but also the colours of the next ones (left-hand side of the screenshot). http://pathological.sourceforge.net
 Tree Tent	TreeTent is a single-player puzzle game in which the goal is to work out where the computer has positioned a certain number of tents on a board where a certain number of trees appears. A tent can only be found in a cell horizontally or vertically adjacent to a tree, tents are never placed adjacent to each other, and for each tree only one tent can be positioned on the board. The numbers along the right and lower sides provide a clue as to the number of tents in that row or column. The player can make inferences on the content of each square by placing either a tent or grass (light green colour) in the cell. When this is done, a small pellet appears in the square. Clicking on the tick in the toolbar validates the player's inferences: if the guess is correct the small pellet disappears, otherwise the system provides an error warning. http://www.yoogi.com/treetent.htm
 GMC Master Mind	The goal of MasterMind is to guess a sequence of coloured pegs that the computer has selected at random. The player start making guesses by filling the holes at the bottom row of the left-hand column with coloured pegs chosen from the range available in the top-left corner. Each time a row is completed, the program gives feedback on the attempt in the right-hand column: a black peg means that the player has correctly positioned a peg of the right colour, while a white one means that a peg of the right colour has been chosen but is not in the right place. The feedback provided by the program does not reveal which individual peg colours/positions are correct within each attempt. At each attempt, the player need to process all the feedback received up to a given point in the game in order to decide what to do next. http://gmoerth.freeservers.com/mm/index.htm

 Tetravex	Tetravex is a domino-like game which is played with tiles that are divided into four triangles each marked with a number from 0 to 9. The goal of the game is to drag the tiles in the right-hand board into the left-hand board and position them so that any two adjacent tile numbers are the same. http://live.gnome.org/GnomeGames
 Hexip	Hexip is single-player game whose goal is to find the position of ships within the hexagon-shaped board (dark boxes contain ships, light boxes are empty). The game provides information on the number of boxes occupied by ships both on the horizontal and diagonal rows of the board (the numbers outside the hexagon). The player can make inferences on the content of each box by colouring it either with light colour or with dark colour, in this case a small pellet appears in the box. Clicking on the tick in the toolbar validates the player's inferences: when an attempt has been validated, the small pellet disappears if the inferred content is correct; otherwise the system provides an error warning. http://www.yoogi.com/hexip.htm

The overall administration methodology of the LOGIVALI Test includes the following steps:

- Teachers explain the games to the students.
- 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.
- Teachers monitor students at work during the playing sessions, but abstain from intervening with suggestions and help.
- 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. Each sub-test is composed of eight exercises, each containing multiple items in the form of multiple-choice questions (Serradell-Lopez, 2010) or, when possible, practical drills (e.g. "fill in the schema with the needed moves").

The test takes into account a limited number (six) of specific reasoning abilities identified as "crucial" (Bottino et al., 2007) although they are, obviously, only a subset of the abilities required to deal with the games at hand.

The six abilities investigated through the LOGIVALI Test are:

- *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.
- *Ability 6* "operatively applying reasoning abilities": to be able to implement into the game the results of own reasoning (actions should follow thoughts).

As to the ability of making inferences, in the LOGIVALI test, it is not considered a unique monolithic skill but it is regarded and treated as an ability varying in difficulty according to the number of different data, information and constraints to be dealt with. In particular, the test differentiates the abilities to make inferences according to the need for taking into account one, two, and three or more data (abilities 2, 3 and 4). On the basis of the results obtained with the involved sample population (around 500 primary school students) the test was standardized and the reference norms were defined on a percentile ranking basis. In (Bottino et Al., 2010) the whole LOGIVALI test validation and standardization procedure is presented. During such procedure, it emerged that the number of correct answers progressively decreased in the three stages: Ability 2 (80% of correct answers); Ability 3 (63% of correct answers); Ability 4 (46% of correct answers). This confirmed that the three abilities should be considered as increasingly complex abilities for the target population.

3. Methodology

As mentioned above, for the purpose of the present study 60 pupils out of twenty Italian primary schools classes (4th and 5th grades) in the Lombardia region 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 based on the scores obtained, 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: one for each group A, B and C.

The LOGIVALI test was administered during school hours to all the students in each classroom and, in each class, the students chosen as representatives of the three groups, were individually monitored by teachers.

Detailed results were recorded (score obtained by each student subdivided by sub-test and by entailed ability, plus attribution of the position in the "percentile" scale) and carefully analyzed.

In order to monitor students at work, teachers were provided with "made on-purpose" monitoring sheets where they were asked to record relevant data on each student's behavior, in particular on their autonomy, engagement and attention.

The available data for each student thus consisted in:

- Scores at the LOGIVALI test (global score and individual scores in each single sub-test)
- Percentile analysis of performance
- Qualitative data on: autonomy, engagement and attention

For the scope of this study, all the data available through the LOGIVALI test were analyzed and compared with each student's data on school performance. It was thus possible to make some inferences on the possible correlations between students' performance in playing/solving mind games and that attributed in school tasks. In order to obtain a complete view of each student's profile, behavioral aspects (derived from monitoring sheets analysis) were also considered and the correlations with the above mentioned performances were further studied.

The research approach adopted in this study basically followed the paradigms of "mixed research methodology" (Burke et al., 2007; Burke & Onwuegbuzie, 2004); in fact, a combined use was made of both quantitative and qualitative approaches.

Actually, as said above, the performance of each student at the LOGIVALI test was assessed according to the percentile ranks determined by the test; subsequently, the obtained quantitative data on performance at the LOGIVALI test were compared with available data on each student's level of school achievement.

Data recorded by teachers in the monitoring sheets and referring to students' autonomy, engagement and attention were, instead, analyzed by employing qualitative research methods, in particular the "direct observation" research method (Herbert, 1995).

4. Results

The ultimate aim of the conducted experiment was that of understanding if, at early school levels, digital mind games can be used to elicit and support the development of those reasoning abilities that underpin learning tasks that students are likely to face throughout all their school careers. This hypothesis, if confirmed, could pave the way for well-targeted and effective interventions using games to sustain the development of reasoning skills, starting from the early stages of school education.

Having in mind this ultimate objective, in the following we outline the key results of the experiment that shed light on:

- the actual relationship between the students' performance at the LOGIVALI test and their school achievement;
- the students' attitudes during game play.

4.1 The relationship between school achievement and ability to play mind games

The results of the test lead to the key finding that:

A substantial consistency exists between school achievement and the ability of playing mind games, as demonstrated by the students' performance at the game-based LOGIVALI Test.

In particular:

Looking at the global performances at games (overall results of the LOGIVALI test, encompassing the results of the five sub-tests, we see that performances of high and low achievers are very different (in favour of high achievers) while the medium group is situated half way between the two

Results proposed in Figure 1, 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) show that:

- Only students in group A (high achievers) 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 (low achievers) perform at low levels (fair and poor); most performances of these students are at the lowest level.
- Performances of students in group B (medium achievers) 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.

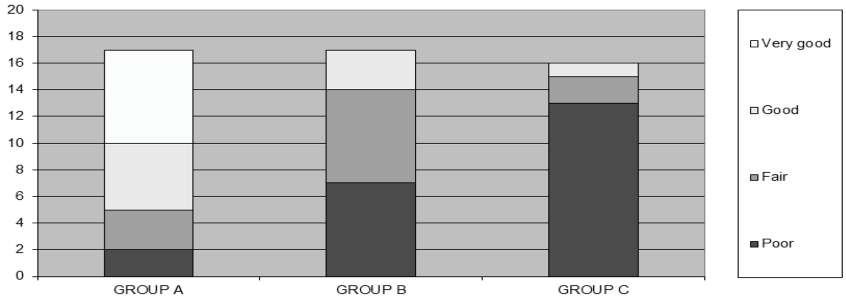


Figure 1: Performances of the three groups of students at the LOGIVALI Test

As to the ability of recalling the game rules (Ability 1) the performance of the three groups are scaled.

As shown in Figure 2, very good performances decrease sensibly from Group A to group C. If we look at the two big blocks (dark and light parts) we see that high achievers perform far better with respect to the other two groups, whose performance is still comparable, but with a prevalence of very poor performance for low achievers. This is true despite what emerged from the LOGIVALI Test standardization procedure, namely that

Ability 1 is the simplest one among the abilities tested by the LOGIVALI test and that it involves lower cognitive load.

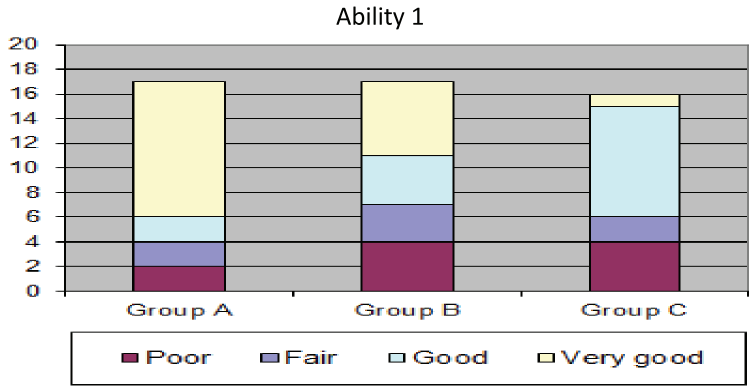


Figure 2: Performances of the three groups at the ability of recalling the game rules

As to the inferential abilities (core abilities 2, 3 and 4 of the LOGIVALI test) 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).

This emerges from Figure 3 where the results at 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) are presented.

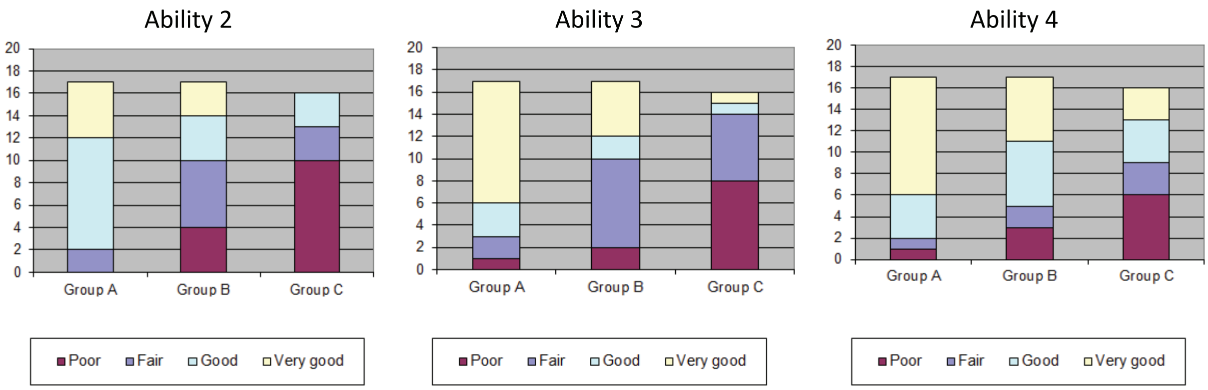


Figure 3: Performances of the three groups at the three "core" abilities considered, regarding inference

The figure shows that in all the three abilities poor performances prevail in group C in all the three abilities and vice versa good performances prevail in group A while medium achievers are always in between the two.

While looking at Figure 3 nevertheless we must consider that the three graphs should be regarded singularly and no direct comparison among the three graphs representing the three different abilities can be done.

The structure of the available 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.

Despite this, if we look singularly at the considered reasoning abilities, we see that high achievers always perform better than the other two groups.
The emerging trend is the same for all the six considered abilities, despite reasonable differences linked to the intrinsic level of difficulty of each one of them, as illustrated below.

As to the ability of "managing uncertainty" (Ability 5) performances of students in Group C are lower with respect to those of students in the other two groups; only Group C show genuinely poor performances while high and medium achievers performances are comparable .

This ability, namely the ability 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, clearly discriminates among the three groups: it appears to be very difficult for low achievers (Figure 4), so that only very few of them perform well. Both the other two groups, instead, appear to be more confident with the task.

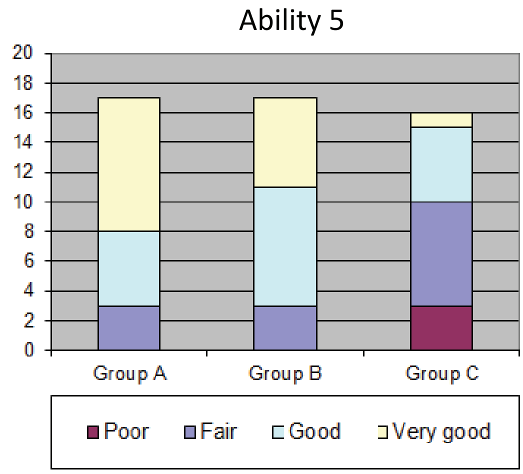


Figure 4: Performances of the three groups at the ability of "managing uncertainty"

As to the ability of "operatively applying reasoning abilities": (Ability 6), performances of students in Group A are higher with respect to those of students in the other two groups. Differences between group B and Group C are found as well, in favour of Group B.

This ability implies "operatively applying reasoning abilities" namely to be able to implement into the game the results of own reasoning (in the logic that actions should follow thoughts). Here we need to observe that Group A performance is far higher with respect to the one of the other two groups (Figure 5): this could allow arguing that students in this group are more able to "put into practice what they have learnt" (and this attitude/ability could be responsible for their good achievement in curricular activities).

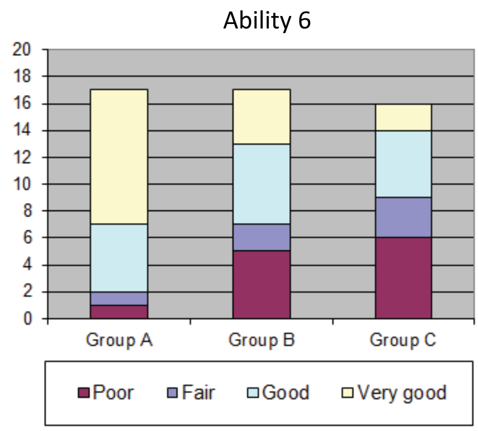


Figure 5: Performances of the three groups at the ability of “"operatively applying reasoning abilities"

4.2 Affective aspects of mind game playing: attention, engagement, autonomy

During the experiment, issues related to children's behaviour such as engagement, attention and motivation were also investigated. This was done by means of made on-purpose monitoring sheets where the teachers and the members of the research group, while observing students at work, carefully recorded data on their attitudes considering a number of common specific indicators, to guarantee comparability.

The first attitude considered was autonomy; in this respect, as shown in Figure 6, it was noticed that, while students in the high and medium achievers group were substantially autonomous most of those in the low achievers group frequently required help and advice although only few of them were considered non-autonomous at all.

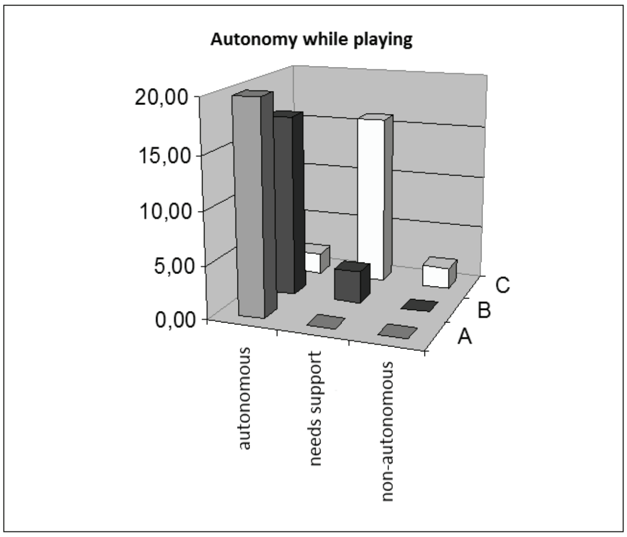
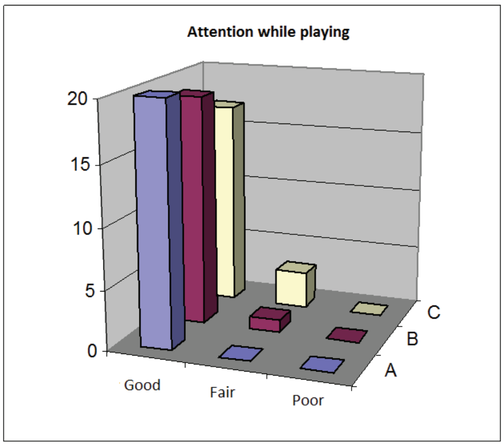


Figure 6: Level of autonomy shown by pupils in the three groups

The examination of the monitoring sheets showed also that all pupils, were fundamentally attentive and engaged while playing (Figure.7); this was true also for a consistent number of low achievers, irrespective of their actual gaming ability and capacity to reach the solution.



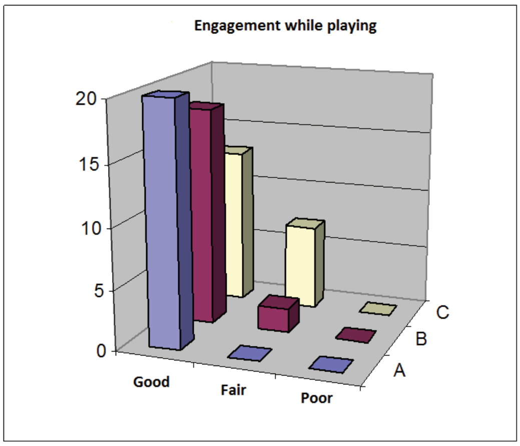


Figure 7: Level of attention and engagement shown by pupils in the three groups

These data are confirmed by a parallel investigation conducted, with the same modality and methodology, on a sample of 27 pupils identified by teachers for low academic achievement and learning difficulties. This study (Dagnino et al, 2013) revealed that the 70% of the group had a good level of attention while up to the 83% of the children showed a good level of engagement in the proposed tasks.

These data confirm that a considerable amount of children of the target age are attentive and engaged in the interaction with mind games, despite their level of achievement, even those that need adequate support by educators to reach the game solution.

5. Discussion

The final aim of the described experiment was to investigate whether digital mind games can be used successfully to elicit and support the development of those “transversal” reasoning abilities that affect global school achievement.

To this aim, evidence was found that:

- A substantial consistency exists between primary school students’ school achievement and the ability of playing digital mind games.
- The great majority of students, independently from their level of school performance, are basically very attentive and engaged in game-based learning tasks.

As a matter of fact, from the conducted experiment it emerged that:

- The performances at games are scaled and reflect the results of high, medium and low achievers.
- The ability itself of recalling games' rules is more present in high achievers and progressively at a lesser extent in the other groups of students.
- Inference tasks are well performed by high achievers but represent a sensible obstacle for low achievers (mainly when inferences need processing more numerous data).
- The ability of verifying the work done by also managing uncertainty and establishing whether the data available at a given moment of the game are sufficient to decide whether a certain guess is correct or not is peripheral for the group of low achievers.
- The ability to put into practice what learnt during exercises is almost a prerogative of high achievers
- The level of autonomy in playing games is good for both high and medium achievers while low achievers need some external help.
- Digital games attract all students' attention and stimulate their engagement and motivation.

Since the experiment was based on games that do not require knowledge/competences specific to curricular school subjects (e.g. arithmetic, linguistic), the obtained results suggests that playing with mind games entails transversal skills that are involved also in curricular tasks and activities (e.g. making inferences, verifying the work done, recalling rules, etc.).

Furthermore, digital games are suitable tools to exercise such skills in that they are well accepted by students and able to stimulate their positive attitude towards learning.
The actual effectiveness of game-based training programmes in the field of logical abilities is substantiated also by the findings of a previous research experience conducted by the authors (Bottino et al, 2007) that showed a positive impact of the gaming activity on both school performance and learning behaviour.

The experiment, in fact, had evidenced that a group of students who had undergone a game- based reasoning and logical training with games for a long period (three school years) performed better at a national math test with respect to a control group. The teachers involved in the experiment had also reported a positive impact of the gaming activities on the general learning behaviour of the students involved in the experiment.

Based on all these results, we could reasonably draw the conclusion that mind games could be adopted profitably in early educational programmes targeting the development and the enhancement of "transversal" reasoning skills and that they may have, in turn, a positive impact on the students' global school achievement.

6. Conclusions and future work

This paper is based on an in-field experiment conducted in primary schools and based on the use of digital mind games. The experiment has showed that a strong correlation exists between school achievement and the ability to play digital mind games even if these games do not require knowledge/competences specific to curricular school subjects. Moreover the experiment has showed that during gaming activities all children were attentive and engaged, irrespective of the difficulties they encountered.

These findings, in the light of results from related experiments, suggest that, at early school levels, mind games can be well accepted, suitable and effective tools to trigger and foster those reasoning abilities that are brought into play in curriculum-wide learning experiences. As a consequence it can be argued that early interventions in the field of reasoning abilities carried out by means of game-based activities can positively impact on students school performance (mainly in the areas of maths and logical reasoning).

The reported experiments were, nevertheless, exclusively targeted to primary schools; further in-depth investigations seem to be required in order to be allowed to generalize and extend the emerging considerations and assumptions.

In particular, the question whether the abilities and skills acquired at this stage can actually be transferred to other school levels and/or curricular areas, remains open and asks for further related long-term experiments.

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