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Reasoning abilities in primary school: A pilot study on poor achievers vs. normal achievers in computer game tasks

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ABSTRACT

This paper presents the results of preliminary research on the assessment of reasoning abilities in primary school poor achievers vs. normal achievers using computer game tasks. Subjects were evaluated by means of cognitive assessment on logical abilities and academic skills. The aim of this study is to better understand the relationship between school performance and logical reasoning and to analyze the major cognitive abilities underpinning digital games. The study also considers emotional and behavioral aspects through individual observation of poor achievers. The results point out higher logical difficulties in the target group compared with controls, supposedly related to working memory capacity and attention control.

1. Introduction

Thinking skills are considered as cross-skills because deeply involved in basic learning processes, such as reading, spelling, and math (Cotton, 1991; Zahor & Dori, 2003) and are usually examined referring to specific domains, such as critical and reflective thinking (Van Gelder, 2005; Wolcott, Baril, Cunningham, Fordham, & St Pierre, 2003), problem solving (Karmiloff-Smith, 1979; Schoenfeld, 1992) and metacognition (Brown, 1987). Nunes et al. (2007) stress the key role of logical skills in school learning: logical competence at the beginning of the school career predicted children's math learning 16 months later. Armour-Thomas and Allen (1990) proved that high achievers performed better than low achievers on all types of analogical-reasoning processes. In addition, performance was better when the task required two rather than three or five analogical-reasoning processes. More recent studies propose working memory capacity and attention control as the determinant cognitive abilities that underlie thinking skills performance (Cornoldi, 2007; Engle & Unsworth, 2005; Heitz, Unsworth, & Engle, 2005).

Literature on digital games focuses on reasoning abilities in mind games and on how they can be fostered (Bottino, Ferlino, Ott, & Tavella, 2007; Bottino & Ott, 2005; Mc Farlane, Sparrowhawk, & Heald, 2002). Paivio (1971) proposes the imagen and logogen double encoding theory and states that computer games facilitate both verbal and iconic bimodal learning, and highlights the importance of the iconic aspect in supporting working memory.

In a literature review, Aguilera and Mendiz (2003) point out that most studies agree on the utility of computer games to develop specific abilities, such as selective attention, problem solving abilities, decision making, and of course Information and Communications Technologies skills.

Other authors, instead, point out the potential of computer games as assessment tools. Robertson and Howells (2008) state that digital games can be effectively used to detect cognitive abilities and to identify difficulties. In this perspective, Benigno, Bottino, Ott, and Tavella (2010) standardized Logivali test, a multimodal logical abilities evaluation battery used in the present study.

1.1. The research project

In our research work we referred particularly to the constructs of logical reasoning and the role of working memory as a theoretical frame. The main objective was to go deeper into the relationship between school learning and these constructs, by means of computer games. We examined the performance of poor and normal school achievers in logical tasks and focused on the difference in their patterns of solution. Despite the availability of studies on the relationship between logical reasoning and school achievement, none of them was carried out by means of a test combining computer mind games and paper & pencil evaluation tools. In the past, computer games have

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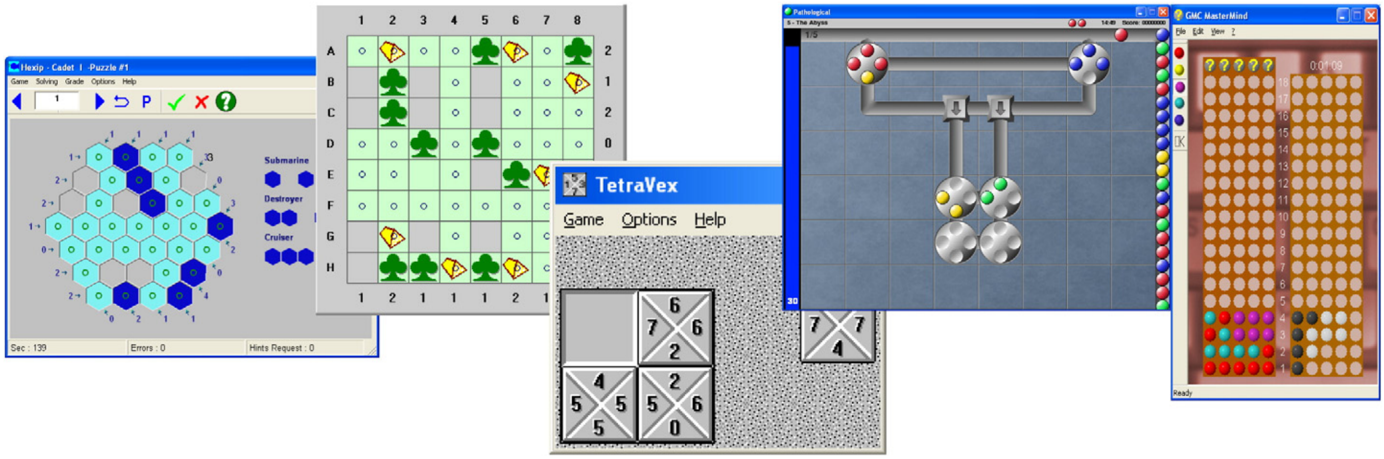

Fig. 1. Screenshots from all games.

been frequently used in research to develop cognitive abilities while the use of digital games to evaluate differences in logical reasoning abilities is the innovative object of this study.

2. Materials and methods

2.1. The tool we used: the LOGIVALI TEST

For the evaluation of logical skills we used the Logivali test (Benigno, Bottino, Ott, & Tavella, 2010; Benigno, Chiorri, & Tavella, 2010) based on digital mind games[1] in association with evaluation and observation paper and pencil tools.

The Logivali Test is based on five digital mind games: Hexip, Treetent, Tetravex, Pathological and Master Mind. They do not involve school subject skills beyond basic literacy and, most importantly, do not imply arithmetical skills, as this may not allow to highlight logical abilities (Levine, Jordan, & Huttenlocher, 1992); on the contrary, they imply arrangement and inference tasks, according to Greeno and Simon (1988) (Fig. 1).

The Logivali Test comprises five paper and pencil sub-tests based on screen shots of the problems to be solved, conceived to assess the abilities identified a priori as transversal to all games[2]:

- Ability 1 — “*Knowing the rules of the game*”.
- 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 pieces of information or game constraints).
- Ability 4 — “*Third level reasoning*” (to be able to make an inference taking into consideration more than two given pieces of 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 or a given configuration is correct or not).
- Ability 6 — “*Operatively apply reasoning abilities*” (to be able to solve a given game step by step. This last ability is related to the ability to proceed autonomously until the solution is reached).

There is a difficulty progression in Abilities 2, 3 and 4 due to the increased number of items to remember and process, so that working memory capacity and control activity are strongly implied.

The test validity and internal consistency reliability have been measured for each ability scale.

As to the construct validity (Table 1), scores obtained on Logivali test are related to scores on Raven's matrices (cognitive abilities evaluation test) and on a mathematic achievement test (Amoretti, Bazzini, Pesci, & Reggiani, 2007).

Criterion-related validity has been performed relating Logivali test scores with final school tests results in Italian and Math (Table 2). Correlations show a good level of agreement between the Logivali test results and the children's academic performances.

Finally, all ability scales show a satisfactory degree of internal consistency reliability (Table 3).

The Logivali Test also includes observation forms for the individual monitoring of cognitive abilities and behavior of target children. Cognitive abilities are evaluated by means of a four-level rating scale (yes, quite, little, no), in relation to the degree children master the six abilities mentioned above. As to behavior observation, subjects are evaluated by means of a rating scale concerning autonomy in gaming, attention and motivation.

2.2. Participants

The participants are 118 fourth graders, 61 females and 57 males, comprising a target group of 27 pupils referred by teachers for their poor academic achievement. Children with diagnosis of cognitive delay, specific learning disabilities and foreign students in Italy for less than one year were excluded from the research sample.

The teachers' judgment about students' performance comprised the mean results in school tests of Mathematics and Language for two terms. Moreover, to substantiate teachers' evaluation, a cognitive

Table 1
Logivali test correlations (Spearman's *rho*) with Raven's matrices and a mathematic achievement test for the construct validity evaluation.

Test	Ability 1	Ability 2	Ability 3	Ability 4	Ability 5	Ability 6
Mathematic test	.36	.57	.44	.56	.45	.47
Raven's matrices	.52	.46	.34	.56	.49	.49

[1] The player is dealing with computer games based on a mechanism of action-feedback which asks him to adopt strategies, to think about the optimal “moves” to make and to evaluate the best decisions to be taken.

[2] The sum of the individual scores for each skill assessed, in the five sub-tests, makes up the total score of that skill (e.g. the total score of Ability 1 is the sum of the results that the subject scored in the five sub-tests for that ability).