

## Visuo-spatial attention and reading abilities: an action game prototype for dyslexic children

Giuseppina Rita Mangione<sup>a1</sup>, Luca Andrea Ludovico<sup>b2</sup>, Pio Alfredo Di Tore<sup>c3</sup>,  
Stefano Di Tore<sup>d4</sup>, Felice Corona<sup>e5</sup>

<sup>a</sup>INDIRE National Institute of Documentation, Innovation and Educational Research, Italy,  
g.mangione@indire.it

<sup>b</sup>University of Milan, Italy, ludovico@di.unimi.it

<sup>c</sup>IC San Valentino Torio, Italy, alfredo.ditore@gmail.com

<sup>d,e</sup>University of Salerno, Italy, stefano.ditore@gmail.com, fcorona@unisa.it

---

### Abstract

*The ability to play action videogames – not directly related to phonological or orthographic training – seems to be a teaching tool able to intervene specifically on spatial attention and drastically improve the reading skills of dyslexic children. The MADRIGALE project aims at the design and development of an action game, simultaneously involving both phonological and attention training in order to adapt educational game strategies for special needs.*

*Within the MADRIGALE project, the design of the prototype was presented at the International Conference on Intelligent Networking and Collaborative Systems, while an experimentation about educational effectiveness of the prototype, conducted using 'Prove MT2' as a benchmarking tool for measuring accuracy and speed of reading, was published in the International Journal of Emerging Technologies in Learning (iJET). This paper is an extension of the work presented in SIREM – SIEL 2014 Conference, and presents the results of a Game Evaluation Sheet administered to 50 primary school teachers with experience of dyslexic students*

**Keywords:** *dyslexia; adaptive education; visuo-spatial attention; phonological processing; action videogames*

---

### Introduction

Studies conducted over the years in relation to dyslexia and developmental dyslexia (DE) argue that the difficulties in learning, reading and writing skills have not a pathological nature but represent an individual variant in development that determines conditions that hinder the acquisition and improvement of some skills (Stella, 2003).

---

<sup>1</sup> Giuseppina Rita Mangione is responsible for the theoretical framework, the literature review, the organization of meetings with teachers for the game analysis.

<sup>2</sup> Luca Andrea Ludovico designed and developed the software application.

<sup>3</sup> Pio Alfredo Di Tore designed the questionnaire, collected and analyzed data.

<sup>4</sup> Stefano Di Tore is responsible for the design and development of DFONT and related research.

<sup>5</sup> Felice Corona is the scientific coordinator of research.

Among difficulties in reading, we find those related to the visual and visuo-spatial level (Pavlidis, 1985). The enhancement of reading skills (Strong, Torgerson, Torgerson, & Hulme, 2011) requires the student to take part in activities that stimulate the acquisition of a long chain of skills, including the management of attention. In particular, the visuo-spatial attention plays a key role in the acquisition of reading skills.

Attention can be nurtured by exercises that present the selection of a letter from a collection of other graphemes (Bouma, 1970), requiring a quick orientation of visual attention (Yeshurun & Rashal, 2010) before the application of the correct integration phoneme-grapheme (Vidyasagar & Pammer, 2010). The cognitive processes underlying the improvement of reading skills through visuo-spatial attention are not fully transparent to scientific inquiry yet (Dehaene et al., 2010), and are the subject of innovative and experimental studies.

Researchers from the General Psychology Department of the University of Padua studied visual attention in dyslexic children of primary school, investigating the brain's ability to isolate individual symbols on paper. Each of the 96 children involved in the research had a sheet with a few lines of doodles or non-alphabetic bullet markers and they had to look for the corresponding targets by sliding the rows from left to right, to locate and to delete them with a pencil. Both visual attention and language skills had been tested in children prior to the acquisition of reading. Surprisingly, the deficit in visual attention predicted subsequent reading skills much better in comparison to the language skills. Since recent studies have shown that specific rehabilitation programs can improve reading skills, children at risk of dyslexia could be treated with prevention programs based on visuo-spatial attention even before the acquisition of reading (Franceschini et al., 2013).

The skills called into question by this visual search task belong to two distinct classes. On the one hand, there is the so-called 'serial scan', which reproduces the mechanism of reading, symbol after symbol, and on the other hand, there is 'spatial attention' that takes into account the position of each symbol in context.

The ability to play action videogames – not directly related to phonological or orthographic training – seems to be a teaching tool able to intervene specifically on spatial attention and to drastically improve the reading skills of dyslexic children (Franceschini et al., 2013). However, even if there are many scientific papers that highlight the benefits of phonological training in the field of language acquisition, an effective modelling of how the sound experience can be integrated with language recovery programs does not emerge with equal force and clarity. Based on this theoretical framework, this project aims at the design and development of an action game, simultaneously involving both phonological training and attention training in order to adapt educational game strategies for special needs (Wang, 1992) by supporting *teaching adaptively* (Mangione, 2013).

## **1. Training of visuo-spatial attention in recent scientific research**

The characteristics that define an action videogame are:

- High game speed;
- High degree of perceptual, cognitive and motor load (need to track the movement of items, need to plan different strategies, actions to put into practice quickly, etc.);
- Temporal and spatial unpredictability;
- High importance of the events that take place away from the centre of the screen (Green, Li & Bavelier, 2009a; Dye, Green & Bavelier, 2009b).

Researchers tested the attentional, phonological and reading skills in two groups of dyslexic children, matched for age and for disorder severity, before and after the use of two types of game, action and non-action, for 9 daily meetings of 80 minutes. Children who used action videogames were able to read faster without losing accuracy and also showed progress in other attention tests. In particular, the group who used action videogames increased reading skills more than they did in 8760 hours of spontaneous development, and achieved a final degree greater than or equivalent to the one obtained with traditional treatments (Franceschini et al., 2012).

The attentional abilities are increased by action videogames, too. Hitting a moving target implies an ability of environmental perception and therefore a prompt attention to details that helps dyslexic children much more than a reading exercise. Thanks to videogames, dyslexic children have learned to steer and focus their attention. Consequently, they are able to extract the relevant information from a written word in a more efficient way, thus reducing the excessive side interference due to their disability (Franceschini et al., 2013).

The individual variations detected in visuo-spatial and cross-modal attention functions explain about 50% of the variance relative to the improvements in reading, even after controlling for age, IQ (Intelligence Quotient) and changes in phonological skills.

Another recent study (Harrar et al., 2014) confirms that action games can help people who suffer from dyslexia to improve their ability to read and write. Such games – according to scholars – are able to stimulate individuals affected by dyslexia to better integrate multi-sensory impulses.

Let us imagine the following scenario: during a conversation with an interlocutor, someone calls the speaker from behind. The focus will move from the person he is watching at and talking with to the back sound. This is a clear example of moving cross-sensory attention. Authors have discovered that shifting the focus from watching to hearing is particularly difficult for people with dyslexia (Harrar et al., 2014). This research involved participants with dyslexia and not in a video game that required players to press a few buttons in response to different inputs, namely audio and visual stimuli. The dyslexics were less responsive in pressing the button when switching from one visual stimulus to an aural one, thus demonstrating a greater difficulty in shifting attention from one sensory channel to another, particularly when moving from an image to a sound.

According to researchers, such a phenomenon could be at the root of the problems that dyslexics encounter in reading and, if confirmed, the findings could lead the way to new strategies to improve how to learn the written language.

Traditional approaches require that the letters of the alphabet are first presented visually and then phonologically. This discovery reveals that people with dyslexia may learn associations between letters and sounds faster than listening to the sound and then observing the corresponding word. Traditional approaches to reading act exactly in the opposite way. Research results demonstrate that action videogames involving the training of many sensory abilities at the same time could be an effective exercise for patients with dyslexia.

In addition, through suitable training, dyslexics may enhance their ability to integrate multisensory stimuli and to understand written words as well. Training dyslexics to quickly move the focus from visual to auditory stimuli, as it happens during game experience, may help their ability to read and write.

The possible use of video games to increase the attentional abilities would be undoubtedly functional for populations of children and adolescents with developmental dyslexia. This is the most difficult form to treat with traditional methodologies to improve reading skills, which are repetitive and very costly for the child and therefore more likely to be subject to drop-out (Franceschini et al., 2013).

The analysis of empirical evidence confirms the importance of the strategies used to reveal the actual improvements in reading and writing skills, in praxis and space-time integration of the mentioned subjects. This seems to suggest the transferability of the proposed approach to special educational courses.

## 2. Pedagogical design elements

For the game play, we gave particular importance to the design of some specific aspects.

The first item is related to the use of a specific font that facilitates the process of reading in dyslexics. For this purpose, we chose *DFONT 2.0*, standing for Dyslexic Font. DFONT has been specifically designed to facilitate the process of reading in dyslexics, since it has graphical properties which have been designed to facilitate the recognition of letters and words. Figure 1 shows the set of uppercase and lowercase letters of the DFONT.

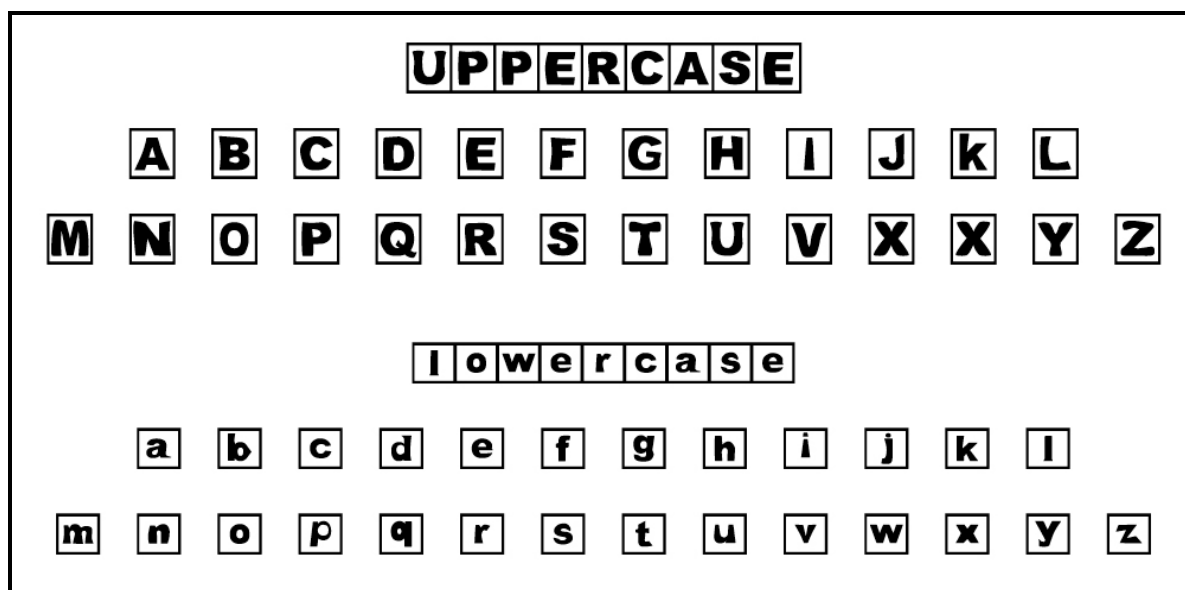


Fig. 1 Lowercase and uppercase letters of DFONT.

DFONT is a variant of the Arial font, which seems to be one of the most easily readable for people with dyslexia (Chung, 2002; Reid, 2004; Rello, 2008). Each letter of DFONT has been inserted in a 'cage' (i.e. a square box) in order to facilitate the recognition of the individual characters. In DFONT, the width of the blank

character is about three times greater than its equivalent in Arial. This change is intended to facilitate the recognition of single words (Perea, 2012, Reid, 2004). Moreover, in DFONT, kerning is absent and each letter is centred with respect to its own cage. This modification has been introduced to allow an easier identification of the position of individual characters (see Figure 2).

Another modification of DFONT is related to the shape of those letters that are more easily mistaken by the dyslexic subjects: < b , d >, < q , p >, < n , u > (Fischer, 1978; Lachmann, 2003; Reid, 2004). In many fonts, the coupled letters differ only in their orientation. In order to make them easily recognizable, their shape has been further characterised, as shown in Figure 3.

DFONT is currently being tested at the University of Salerno (Sibilio, 2014).

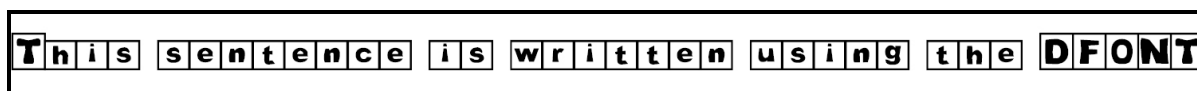


Fig. 2 Sentence written using DFONT.

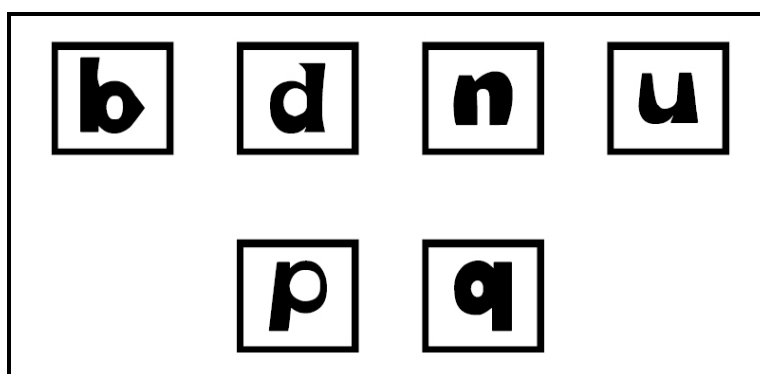


Fig. 3 Letters of DFONT.

The second item refers to skill levels and specific difficulties to insert in the game. The idea is finding a balance in order to improve both users' involvement and self-esteem.

Finally, reinforcement techniques have also been designed and implemented in the game. Reinforcement refers to those devices adopted to improve performance and motivation.

Now let us describe the key aspects of the game play.

The basic goal of the game is reconstructing the right sequence of letters for the words proposed by the system. Each round is made of two distinct phases: in the first one, the system draws a word and highlights its letters on a board while pronouncing them; during the second phase, the user has to select the sequence of letters in the right order and as fast as possible. Similarly to most games, in our proposal, the player has to face increasing difficulties in order to get involved in the game play. According to in-use terminology of video gaming field, we define the concept of *level* or *stage* as a difficulty phase or given section of the game.

As regard the identification of difficulty-related axes, we considered five specific dimensions:

- *Number of letters on the board* – when letters are few, the game is easier for a number of reasons, for example, because the player can better identify the spatial position of symbols, symbols are bigger and more clearly distinguishable and such.
- *Type of letters on the board* – a key problem for a dyslexic child is being able to focus on a graphical symbol and to recognise it against others. Some letters are clearly different in their graphical aspect, whereas others may be perceived as similar.
- *Word length* – since the game play requires recreating a sequence of symbols, the longer the sequence, the harder the player's task.
- *Symbol layout inside words* – for a dyslexic child, some configurations, for example, spelling words with double consonants, are harder to be recognised.
- *Symbol layout on the board* – the way symbols are located in the interface may influence the perceived difficulty, above all for children who are affected by concentration problems.



Fig. 4 Screenshot of the beginning of a match.

Another pedagogical aspect refers to *feedback* and *reinforcement techniques*. The feedback in education is called 'formative' and aims at changing the way of thinking and behaving of the students in order to enhance their learning process and their results in terms of performance. The feedback used in educational context is generally indicated as a crucial element for the improvement of knowledge (Azevedo & Bernard, 1995; Bangert-Drowns et al., 1991; Sales, 1993; Shute, 2008) and the acquisition of skills (Narciss, 2007). In addition to its influence on achievement, feedback is seen as a *reinforcement factor* that acts on motivation to learn (Hattie & Gan, 2011; Narciss & Huth, 2004).

As the final goal is providing a game environment to bind phonemes and graphemes, the occurrence of user errors cannot merely lead to the end of the game session. Rather, a number of reinforcements is incrementally provided to players, so that they can improve their performances. Specifically:

- *Colours*. Any letter can be further distinguished through the use of coloured boxes and high-contrast colour combinations;
- *Intonation*. Any letter can be associated to a different pitch, so that the spoken word is in a certain sense sung letter by letter.

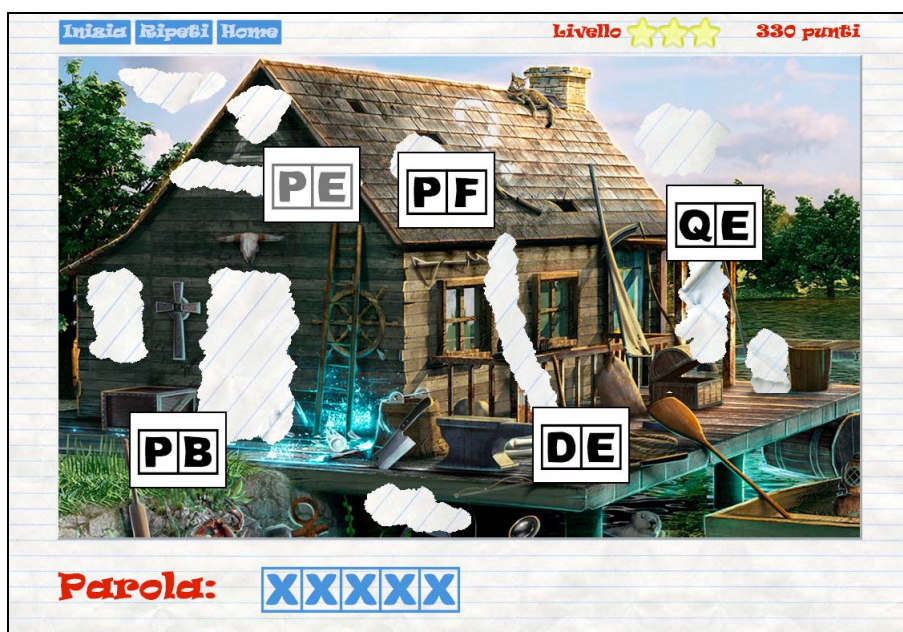


Fig. 5 Reinforcement type: symbol visibility and colour contrast.

### 3. Method

The initial phase of experimentation involved the administration of a questionnaire relating to different aspects of the game in order to allow a detailed analysis. The questionnaire was administered to 50 teachers from Italian primary schools, who were asked to play at the prototype and evaluate, using the questionnaire, the different aspects. All teachers involved said they had gained, during their professional activities, experiences about teaching in the presence of people with dyslexia. In particular, the questionnaire consisted of 19 questions relating to: adequacy of game times, effectiveness of educational content, educational effectiveness of the interaction, educational effectiveness of the game, educational effectiveness of design choices, possible improvements.

### 4. Results

Shown below are the most relevant findings. The game is, in the evaluation of teachers, suitable for age between 6 and 7 years. In particular, the mean of the answers to the question 'What do you believe is the most appropriate age for the enjoyment of this game?' was found to be 6.8 years. Considering that the game is aimed at dyslexic students attending primary school, the average age indicated by the teachers seem to be in sync with the purpose of the prototype. Regarding the timing of the game, 98% of teachers took less than 10 min to complete one of the tests in the game and were satisfied with the timing and the duration of individual sessions; 96% of teachers thought that the contents of the game were adequate and the interaction effective (Figure 6). With regard to the overall evaluation of the prototype, the questions 'how much did you like this game? (0–10)' and 'how much do you believe is game useful from an educational point of view? (0–10)', teachers responded denoting a reasonable interest in the game and its possible educational application (Figure 7). Particularly interesting were the responses to questions about possible improvements that can be implemented within the game.

When asked, 'Do you think that the introduction of a level editor – a tool that gives the teacher the opportunity to design custom scenarios and define his own lists of words – would increase significantly the educational effectiveness of the game?' 100% of users responded positively, while, at the question 'Do you have suggestions that can help us improve the game experience?', 100% of the subjects gave suggestions that contained, among others, references to the possibility of implementing mechanisms that allow the teacher to customise the game.

Particularly interesting are also the answers given to questions about the complexity of the game. Considering the complexity of the activities proposed by the game in reference to a group of users made up of students aged between 6 and 8 years old, the average response was 3.38 on a scale of 0 to 10. The rating obtained seems to indicate that the game may appear too simple or elementary for the intended audience.

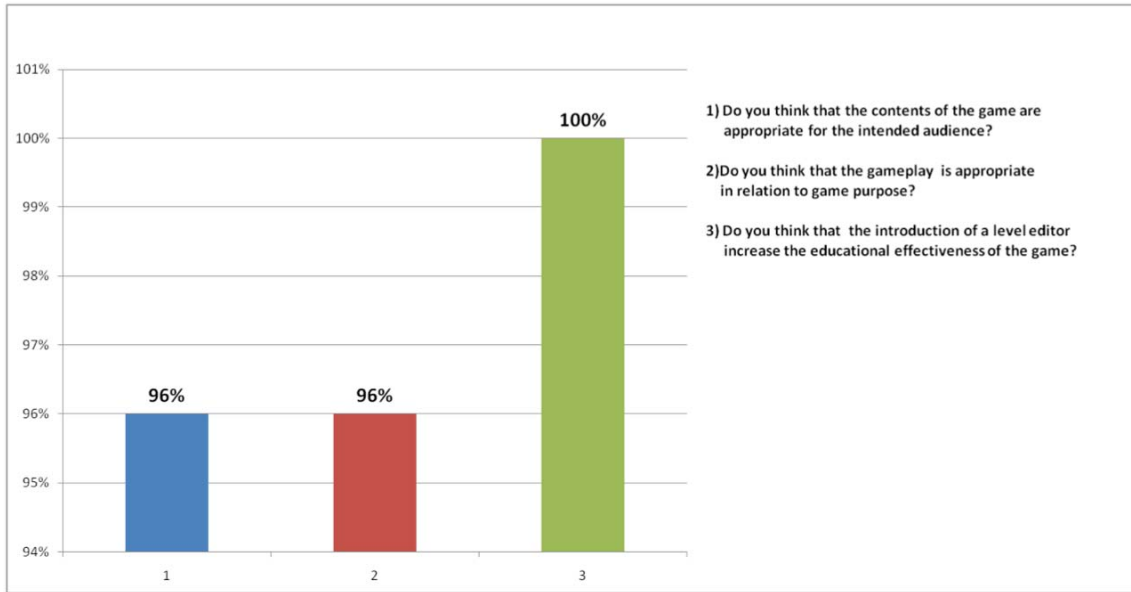


Fig. 6 Adequateness of game contents and interaction effectiveness.

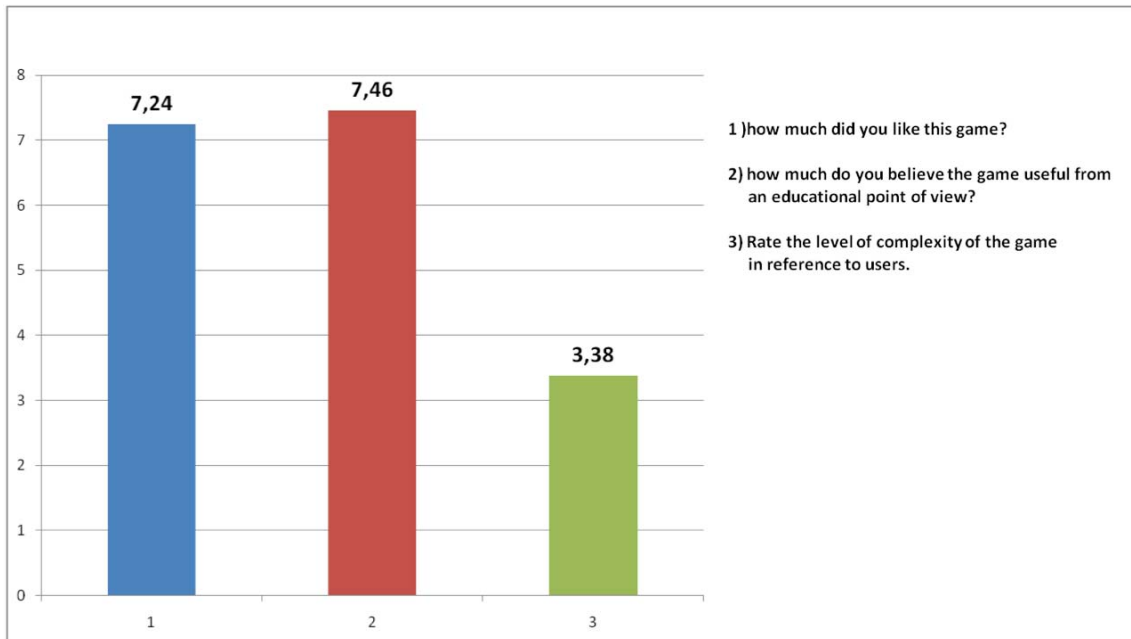


Fig. 7 Usefulness and complexity of game from an educational point of view.

## 5. Future works

The data emerging from the analysis provide interesting insights about possible future developments of the software.

In particular, the results show that it is desirable to improve the game by giving users the ability to customise several aspects. The development and implementation of mechanisms of customisation within the game could similarly be useful in relation to the problems expressed by the teachers about the excessive simplicity of the gameplay of the prototype. The ability to customise parameters such as time, backgrounds, images, words, scores and such could allow the teacher to adjust the complexity and difficulty of the game in reference to the situation.

## References

- Azevedo, R. & Bernard, R. M. (1995). A meta-analysis of the effects of feedback in computer-based instruction. *Journal of Educational Computing Research*, 13(2), 111-127.
- Bangert-Drowns, R. L., Kulik, C. L. C., Kulik, J. A. & Morgan, M. (1991). The instructional effect of feedback in test-like events. *Review of educational research*, 61(2), 213-238.
- Bouma, H. (1970). Interaction effects in parafoveal letter recognition. *Nature*, 226, 177-178.
- Chung, S.T. (2002). The effect of letter spacing on reading speed in central and peripheral vision. *Investigative Ophthalmology & Visual Science*, 43(4), 1270-1276.
- Cogo-Moreira, H., de Avila, C. R. B., Ploubidis, G. B. & de Jesus Mari, J. (2013). Effectiveness of Music Education for the Improvement of Reading Skills and Academic Achievement in Young Poor Readers: A Pragmatic Cluster-Randomized, Controlled Clinical Trial. *PloS one*, 8(3), e59984.
- Cornoldi, C., Colpo, G. & Gruppo, M. (2011). Prove di lettura MT-2 per la Scuola Primaria. Giunti OS.
- Cottini, L. (2008). Per una didattica speciale di qualità: dalla conoscenza del deficit all'intervento inclusivo: Morlacchi.
- Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Nunes Filho, G., Jobert, A. & Cohen, L. (2010). How learning to read changes the cortical networks for vision and language. *Science*, 330(6009), 1359-1364.
- Douglas, S. & Willatts, P. (1994). The relationship between musical ability and literacy skills. *Journal of Research in Reading*, 17(2), 99-107.
- Fischer, F.W., Liberman, I.Y. & Shankweiler, D. (1978). Reading Reversals and Developmental Dyslexia a Further Study, *Cortex*, 14(4), 496-510.
- Fonte, V. (2014). Una metodologia d'intervento olistico per il recupero delle dislessie in età evolutiva: esperienza sonoro-musicale e linguistica creativa quale approccio educativo-didattico integrato in <http://hdl.handle.net/10579/4607>
- Franceschini, S., Gori, S., Ruffino, M., Viola, S., Molteni, M. & Facoetti, A. (2013). Action video games make dyslexic children read better. *Current Biology*, 23(6), 462-466.
- Franceschini, S., Gori, S., Ruffino, M., Pedrolli, K. & Facoetti, A. (2012). A causal link between visual spatial attention and reading acquisition. *Current Biology*, 22(9), 814-819.
- Gaab, N., Tallal, P., Kim, H., Lakshminarayanan, K., Archie, J., Glover, G. & Gabrieli, J. (2005). Neural correlates of rapid spectrotemporal processing in musicians and nonmusicians. *Annals of the New York Academy of Sciences*, 1060(1), 82-88.
- Gabrieli, J.D. (2009). Dyslexia: a new synergy between education and cognitive neuroscience. *Science*, 325(5938), 280-283.
- Harrar, V., Tammam, J., Pérez-Bellido, A., Pitt, A., Stein, J. & Spence, C. (2014). Multisensory Integration and Attention in Developmental Dyslexia. *Current Biology*, 24(5), 531-535.
- Hattie, J. & Gan, M. (2011). Instruction based on feedback. *Handbook of research on learning and instruction*, 249-271.
- Hinostroza, J.E. & Mellar, H. (2001). Pedagogy embedded in educational software design: report of a case study. *Computers & Education*, 37(1), 27-40.



- Johnson, D., Cox, M. & Watson, D. (1994). Evaluating the impact of IT on pupils' achievements. *Journal of Computer Assisted Learning*, 10(3), 138-156.
- Lachmann, T. & Geyer, T. (2003). Letter reversals in dyslexia: Is the case really closed? A critical review and conclusions, *Psychology Science*, 45, 50-70.
- Long, M. (2014). "I can read further and there's more meaning while I read": An exploratory study investigating the impact of a rhythm-based music intervention on children's reading. *Research Studies in Music Education*, 1321103X14528453.
- Lovett, M.W. (1992). Developmental dyslexia.
- Mangione, G.R. (2013). *Istruzione adattiva. Approcci, tecniche e tecnologie*. Lecce: Pensa editore.
- Narciss, S. (2007). Feedback strategies for interactive learning tasks. *Handbook of research on educational communications and technology*, 125-144.
- Narciss, S., & Huth, K. (2004). How to design informative tutoring feedback for multimedia learning. *Instructional design for multimedia learning*, 181-195.
- Overy, K. (2003). Dyslexia and music. *Annals of the New York Academy of Sciences*, 999(1), 497-505.
- Pavlidis, G.T. (1985). Eye Movements in Dyslexia Their Diagnostic Significance. *Journal of learning disabilities*, 18(1), 42-50.
- Perea, M., Panadero, V., Moret-Tatay, C. & Gómez, P. (2012). The effects of inter-letter spacing in visual-word recognition: Evidence with young normal readers and developmental dyslexics. *Learning and Instruction*, 22(6), 420-430.
- Reid, L.D. & Reid, M. (2004). Towards A Reader-Friendly Font: Rationale for Developing a Typeface that is Friendly for Beginning Readers, Particularly those Labeled Dyslexic. *Visible Language*, 38(3), 246-259.
- Rello, L. & Baeza-Yates, R. (2013) "Good Fonts for Dyslexia", in Proc. ASSETS, Vol. 13.
- Richards, T.L. & Berninger, V.W. (2008). Abnormal fMRI connectivity in children with dyslexia during a phoneme task: Before but not after treatment. *Journal of neurolinguistics*, 21(4), 294-304.
- Sales, G.C. (1993). Adapted and adaptive feedback in technology-based instruction. *Interactive instruction and feedback*, 159-175.
- Shute, V.J. (2008). Focus on formative feedback. *Review of educational research*, 78(1), 153-189.
- Sibilio, M. & Di Tore, S. (2014). Body, movement and space for a simplex didactics: a pilot study on the realization of a font for Specific Learning Disabilities. *Education Sciences & Society*, 4(2).
- Stella, G. (2003). *La dislessia: aspetti clinici, psicologici e riabilitativi* (Vol. 133). Milano: Franco Angeli.
- Strong, G.K., Torgerson, C.J., Torgerson, D. & Hulme, C. (2011). A systematic meta-analytic review of evidence for the effectiveness of the 'Fast ForWord' language intervention program. *Journal of Child Psychology and Psychiatry*, 52(3), 224-235.
- Tallal, P. (1991). Hormonal influences in developmental learning disabilities. *Psychoneuroendocrinology*, 16(1), 203-211.
- Temple, C.M. & Marshall, J.C. (1983). A case study of developmental phonological dyslexia. *British Journal of Psychology*, 74(4), 517-533.

***Visuo-spatial attention and reading abilities: an action game prototype for dyslexic children***

*Mangione, Ludovico, P. A. Di Tore, S. Di Tore, Corona*

Vidyasagar, T.R. & Pammer, K. (2010). Dyslexia: a deficit in visuo-spatial attention, not in phonological processing. *Trends in cognitive sciences*, 14(2), 57-63.

Wang, M.C. (1992). *Adaptive education strategies: Building on diversity*. Paul H. Brookes Publishing Company.

Yeshurun, Y. & Rashal, E. (2010). Precueing attention to the target location diminishes crowding and reduces the critical distance. *Journal of Vision*, 10(10), 16.