

Proceedings

**2014 International Conference
on Intelligent Networking
and Collaborative Systems**

IEEE INCoS 2014

10–12 September 2014
University of Salerno, Salerno, Italy

Editors

Fatos Xhafa, *Technical University of Catalonia, Spain*
Leonard Barolli, *Fukuoka Institute of Technology, Japan*
Francesco Palmieri, *Second University of Naples, Italy*
Mario Koeppen, *Kyushu Institute of Technology, Japan*
Vincenzo Loia, *University of Salerno, Italy*



Los Alamitos, California
Washington • Tokyo



All rights reserved.

Copyright and Reprint Permissions: Abstracting is permitted with credit to the source. Libraries may photocopy beyond the limits of US copyright law, for private use of patrons, those articles in this volume that carry a code at the bottom of the first page, provided that the per-copy fee indicated in the code is paid through the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923.

Other copying, reprint, or republication requests should be addressed to: IEEE Copyrights Manager, IEEE Service Center, 445 Hoes Lane, P.O. Box 133, Piscataway, NJ 08855-1331.

The papers in this book comprise the proceedings of the meeting mentioned on the cover and title page. They reflect the authors' opinions and, in the interests of timely dissemination, are published as presented and without change. Their inclusion in this publication does not necessarily constitute endorsement by the editors, the IEEE Computer Society, or the Institute of Electrical and Electronics Engineers, Inc.

IEEE Computer Society Order Number E5339
BMS Part Number CFP1416I-CDR
ISBN 978-1-4799-6386-7

Additional copies may be ordered from:

IEEE Computer Society
Customer Service Center
10662 Los Vaqueros Circle
P.O. Box 3014
Los Alamitos, CA 90720-1314
Tel: + 1 800 272 6657
Fax: + 1 714 821 4641
<http://computer.org/cspress>
csbooks@computer.org

IEEE Service Center
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
Tel: + 1 732 981 0060
Fax: + 1 732 981 9667
[http://shop.ieee.org/store/
customer-service@ieee.org](http://shop.ieee.org/store/customer-service@ieee.org)

IEEE Computer Society
Asia/Pacific Office
Watanabe Bldg., 1-4-2
Minami-Aoyama
Minato-ku, Tokyo 107-0062
JAPAN
Tel: + 81 3 3408 3118
Fax: + 81 3 3408 3553
tokyo.ofc@computer.org

Individual paper REPRINTS may be ordered at: <reprints@computer.org>

Editorial production by Lisa O'Conner
Cover art production by Mark Bartosik



**IEEE Computer Society
Conference Publishing Services (CPS)**

<http://www.computer.org/cps>

Author Index

Agussalim.....	400	Capuano, Nicola.....	498, 492
Albano, Giovannina.....	689	Caragnano, Giuseppe.....	604
Almanea, Mohammed Ibrahim M.	628	Caralt, Jordi Conesa.....	710
Alriyami, Qasim M.....	427	Carboni, Massimo.....	152
Altun, Oguz.....	320	Carlino, Gianpaolo.....	152
Alves, Rui.....	653	Carpentieri, Bruno.....	65
Amato, Alba.....	592, 598	Carpinteri, Santino.....	18
Amato, Flora.....	551	Carraciuolo, Luisa.....	545
Angelopoulou, Olga.....	445	Carullo, Giuliana.....	42
Anna, Pierri.....	475	Caruso, Mario.....	563
Apostolidis, Ippokratis.....	683	Castiglione, Aniello.....	42, 350
Arnedo-Moreno, Joan.....	328	Castiglione, Arcangelo.....	189, 65
Asimakopoulou, E.	433	Celotto, Antonio.....	125
Asimakopoulou, Eleana.....	406, 411, 439, 427	Cerocchi, Adriano.....	563
Askalani, M.	433	Chen, Huajun.....	85
Aurino, Francesco.....	145	Chen, Jesse Xi.....	731
Aversa, Rocco.....	586	Chen, Kefei.....	91
Avolio, Giovanni.....	616	Chen, Shih-Han.....	356
Baldoni, Roberto.....	563	Chen, Ying-ping.....	242
Balzano, Walter.....	362	Coca, J. M. León.....	433
Baneres, David.....	480, 328	Colella, Antonio.....	350
Barillari, M.R.	112	Comas, Jorge.....	653
Barillari, U.E.S.	112	Conesa, Jordi.....	457, 480
Baró, Xavier.....	328	Consolo, Stefano.....	34
Barolli, Admir.....	138	Contreras, Andres Velasquez.....	304, 504
Barolli, Leonard....	469, 197, 369, 451, 342, 457, 463, 282, 157, 138, 268	Corona, F.	710
Baron, Holman Bolivar.....	504	Cretella, Giuseppina.....	647
Baron, Holman Bolívar.....	304	Cui, Baojiang.....	79
Barone, Giovanni Battista.....	545	D'Alessio, Bonaventura.....	119
Barrero, F.	433	D'Ambrosio, Ciriaco.....	189
Bassi, Roxana.....	184	D'Aniello, Giuseppe.....	169, 249, 104
Battaglia, Luigi.....	616	D'Apice, Ciro.....	96
Benincasa, Gianpio.....	96	Dai, Wei.....	527
Benkner, Siegfried.....	610	Daradoumis, Thanasis.....	469, 184, 463
Bessis, N.	433	de Donato, Antonio.....	104
Bessis, Nik.....	406, 411, 439, 427	De Francesco, Alberto.....	659
Bocchi, Yann.....	581	De Maio, Carmen.....	498
Boccia, Vania.....	545, 557	De Meo, Pasquale.....	57
Bolletta, Paolo.....	152	De Rosa, Anna Chiara.....	104
Bologna, Ciro.....	104	De Salvo, Alessandro.....	152
Borckholder, Chris.....	610	De Santis, Alfredo.....	42, 189, 350
Bottalico, Davide.....	545	De Vivo, Alfonso.....	104
Brenga, Carmine.....	125	Del Prete, Domenico.....	557
Bruneo, Dario.....	641	Del Sorbo, Maria Rosaria.....	362
Bulfon, Cristina.....	152	Demetriadis, Stavros.....	176
Caballe, Santi.....	157, 138	Demetriadis, Stavros N.	665
Caballé, Santi.....	469, 197, 369, 184, 451, 342, 457, 463, 328	Di Martino, Beniamino.....	592, 598, 647
Canonico, Roberto.....	539	di Martino, F.	112
Capone, Alessandro.....	119	Di Napoli, Claudia.....	659
Capone, Vincenzo.....	152	Di Santo, Giuseppe.....	104

Author Index

Di Tore, P.A.	710	Junyent, Montse.....	480
Di Tore, Pio Alfredo.....	486	Kandeil, Dalia AbdelRazek.....	221
Di Tore, S.	710	Karakostas, Anastasios.....	176, 683
Di Tore, Stefano.....	486	Khan, Amin M.	1
Diaz, Johann Trujillo.....	504	Ko, Chia-Yin.....	356, 336
Diaz, Johanna Trujillo.....	304	Köeppen, Mario.....	296
Dimitriou, Tatiana.....	683	Kolici, Vladi.....	282, 268
Distefano, Salvatore.....	274	Kollar, Ingo.....	677
Donadio, Pasquale.....	539	Kotera, Kohei.....	396
Donatiello, Antonio.....	104	Krishna, K.P. Sai.....	421
Doria, Alessandra.....	152	Kudelka, Milos.....	509
Esposito, Antonio.....	647	Kulla, Elis.....	157
Fedeli, Laura.....	699	Lala, Argenti.....	268
Feidakis, Michalis.....	469	Laura, Luigi.....	119
Ficco, Massimo.....	616, 586	Lee, Ming-Chang.....	242
Fioccola, Giovanni Battista.....	539	Leu, Fang-Yie.....	242, 356, 336
Fischer, Frank.....	677	Li, Jin.....	85, 79
Folla, Mariano.....	145	Li, Xuan.....	85
Forte, Vincenzo.....	563	Liu, Jung-Chun.....	356, 336
FrancaVilla, Matteo Alessandro.....	604	Liu, Zheli.....	79
Franco, Carlos Franco.....	504	Ljubuncic, Igor.....	622
Franken, Sebastian.....	49	Lobo, Tomas Pariente.....	610
Freitag, Felix.....	1	Loia, Vincenzo.....	249
Fujihara, Akihiro.....	213	Long, Yu.....	91
Gaeta, Angelo.....	720, 492	Longo, Francesco.....	641
Gaeta, Matteo.....	720, 492, 249, 96	Ludovico, Luca Andrea.....	486
Gañán, David.....	457, 463	Luksys, Evaldas.....	406
Gargiulo, Francesco.....	145	Luo, Jinman.....	85
Genoud, Dominique.....	581	Maggio, Valerio.....	96
Gholami, Reza.....	311	Magnisalis, Ioannis D.	665
Giordano, Maurizio.....	659	Mandorf, Susanna.....	237
Giri, Ravi.....	622	Manetti, Vittorio.....	616
Goldis, Andrew.....	622	Mangione, G.R.	710
Gou, Juanqiong.....	533	Mangione, Giuseppina Rita.....	486, 492
Graziosi, Carlo.....	152	Mao, Xianping.....	91
Greco, Daniela.....	104	Marzano, Antonio.....	695
Greguš, Michal.....	515, 229, 237	Mas, Xavier.....	328
Guan, Zhongliang.....	527	Mateo, Jordi.....	653
Guarino, Giuseppe.....	720	Matsui, Tomomi.....	378
Guerrero, Ana-Elena.....	328	Matsuo, Keita.....	469
Herrero, Albert.....	282	Matsuo, Ryota.....	163
Hori, Yoshiaki.....	396	Me, Gianluigi.....	119
Huang, Yi-Li.....	356, 336	Mecella, Massimo.....	563
Ikeda, Makoto.....	157	Meda, Nao.....	384
Inaba, Takaaki.....	157	Mele, R.	112
Ivanochko, Irena.....	515	Meng, Jiaxiao.....	85
Jara, Antonio J.	581	Merlo, Alessio.....	575
Jeners, Nils.....	49	Merola, Leonardo.....	557, 152
Jia, Chunfu.....	79	Messina, Fabrizio.....	26, 57
Johny, Olayinka.....	439	Migliardi, Mauro.....	575

Author Index

Mignone, Mara.....	119	Reina, D.G.	433
Miguel, Jorge.....	451, 342	Ritrovato, Pierluigi.....	704
Miranda, Sergio.....	689, 704	Rohith, Kayathi.....	421
Miwa, Hiroyoshi.....	213, 415, 163, 378, 289, 384	Rojas, Mario Martinez.....	304
Mohseni, Sina.....	311	Romano, Emanuela.....	475
Moore, Philip.....	205	Roomizade, Arash.....	311
Mora, Néstor.....	463	Rosaci, Domenico.....	57
Morana, Giovanni.....	18	Rossi, Pier Giuseppe.....	699
Moré, Joaquim.....	480	Rozenfeld, Avikam.....	622
Moscato, Francesco.....	551, 635	Ruiu, Pietro.....	604
Moscato, Vincenzo.....	145	Russo, Guido.....	557, 152
Mossucca, Lorenzo.....	604	S., Sudarshan.....	421
Nace, Dritan.....	377	Saad, Amani Anwar.....	221
Naddeo, Salvatore.....	557	Saglimbeni, Yuriy Kaniovskiy Alfredo.....	610
Nagata, Akira.....	396	Sakamoto, Shinji.....	157
Nakamura, Katsuichi.....	396	Salant, Eliot.....	641
Notti, Achille M.	695	Salerno, Saverio.....	498
Nowakova, Jana.....	133	Sansone, Carlo.....	145
Nowakowski, Piotr.....	610	Santoro, Corrado.....	26
Oda, Tetsuya.....	469, 457, 138	Sarné, Giuseppe M.L.	57
Ogiela, Lidia.....	73, 257	Scarfò, Antonio.....	569
Ogiela, Marek R.	73, 257	Scialdone, Marco.....	592
Ogiela, Urszula.....	73	Scotti, Giuseppe.....	557
Ohnishi, Kei.....	296	Selimi, Mennan.....	1
Ohtsubo, Masakazu.....	316	Senatore, Sabrina.....	125
Orciuoli, Francesco.....	169, 726, 249, 96	Sessa, S.	112
Ottaviano, Giuseppe.....	659	Shang, Xiaopu.....	527
Pappalardo, Giuseppe.....	26	Silde, Alice.....	445
Pardi, Silvio.....	557, 152	Slotta, Jim.....	671
Parente, Mimmo.....	169	Smørdal, Ole.....	671
Perego, Raffaele.....	659	Snasel, Vaclav.....	133
Perner, Petra.....	262	Solsona, Francesc.....	653
Petrillo, Umberto Ferraro.....	34	Sotiriadis, S.	433
Pettinati, Francesca.....	104	Sotiriadis, Stelios.....	439
Picariello, Antonio.....	145	Sperandeo, Raffaele Giulio.....	647
Pierr, Anna.....	492, 689	Stefano, Antonella Di.....	18
Pino, Luigi.....	10	Stoshikj, Marina.....	229
Pizzolante, Raffaele.....	189, 65	Sula, Ardiana.....	184
Platos, Jan.....	133, 509	Takayama, Yuki.....	415
Porta, Laura.....	328	Takizawa, Makoto.....	138
Prieto, Josep.....	451, 342, 328	Tasquier, Luca.....	586
Prinz, Wolfgang.....	49	Tegos, Stergios.....	176
Puccio, Lorenzo.....	152	Teixidó, Ivan.....	653
Puliafito, Antonio.....	641	Terzo, Olivier.....	604
Qassem, Tarik.....	205	Tettamanti, Marco.....	575
Querzoni, Leonardo.....	563	Tomasiello, Stefania.....	249
Rak, Massimiliano.....	10	Tonellotto, Nicola.....	659
Rao, M.V. Panduranga.....	421	Topal, Ali Osman.....	320
Raya, Jordi.....	197, 369	Toral, S.L.	433
Reformat, Marek Z.	731	Torres, Nestor.....	653

Author Index

Toti, Daniele.....	716	Wang, Liangliang.....	91
Trovati, Marcello.....	411	Wang, Sheng-Mao.....	336
Tsiatsos, Thrasylvoulos.....	683	Wecker, Christof.....	677
Tsolaki, Magda.....	683	Wen, Zhaocong.....	85
Tsuru, Masato.....	400	Wolfsthal, Yaron.....	641
Turtur, Mauro.....	10	Wood, Steven.....	610
Uchida, Kazunori.....	197, 369	Wu, Yongjie.....	521
Uchida, Masato.....	390	Xhafa, Fatos.....	469, 197, 369, 184, 451, 342, 282, 138, 268, 205
Urikova, Oksana.....	515	Yamamura, Taiki.....	289
Usié, Anabel.....	653	Yang, Jun.....	79
Venticinque, Salvatore.....	592, 598	Yoshida, Kaori.....	316, 296
Ventre, Giorgio.....	539	Youssef, Sherin Moustafa.....	221
Vilaplana, Jordi.....	653	Yu, Liming.....	533
Villano, Umberto.....	10	Zarei, Niloofar.....	311
Villari, Massimo.....	641	Zehnalova, Sarka.....	509
Viserta, Valeria.....	104	Zhang, Meiqing.....	521
Vitiello, Autilia.....	169	Zhang, Runtong.....	527
Vogel, Freydis.....	677	Zito, Daniele.....	18

MADRIGALE: A MULTIMEDIA APPLICATION FOR DYSLEXIA AND READING IMPROVEMENT GAMIFYING LEARNING EXPERIENCE

P.A. Di Tore, S. Di Tore, G.R. Mangione

Università degli Studi di Salerno
Via Giovanni Paolo II, 132
84084 Fisciano (SA), Italy
gmangione@unisa.it

L.A. Ludovico

Università degli Studi di Milano
Via Comelico, 39/41
20135 Milan, Italy
luca.ludovico@unimi.it

ABSTRACT

In modern society about 10% of children experience difficulty in learning to read. They suffer from a neuro-developmental disorder called dyslexia. Scientific research has shown that the ability to play action video games improves reading skills of dyslexic children. MADRIGALE research aims at designing and implementing an educational action game oriented to promote, through forms of engaging and motivating interaction, phonological training and visuo-spatial attention in dyslexic subjects aged between 7 and 9.

Index Terms— dyslexia; visuo-spatial attention; phonological processing; music action games

I. INTRODUCTION

In Italy, the Law no.170 - 8 October 2010 recognizes dyslexia, dysgraphia, dyscalculia and the dysorthography as learning disabilities, referred to as *DSA (Specific Learning Disorders - Specific Learning Disabilities)*. For the purposes of this act, the term *dyslexia* indicates a “specific disorder that is manifested by a difficulty in learning to read, especially in the decipherment of linguistic signs, or in the correctness and speed of reading”. Thanks to this law, methodologies, tools and teaching aids for dyslexia become a topic of great interest in educational research.

Studies conducted over the years demonstrate that the difficulties in learning to read and write do not have pathological character, but they represent an individual variant that hinders the acquisition and development of certain skills [1]. These obstacles can be related to *visual and visuo-spatial processing* [2], *hearing level processing* [3], *phonological processing* [4], and *meta-phonological processing* [5].

The identification of instructional strategies that involve this particular aspect is an arduous task and the outcome is uncertain. In fact advances in phonological processing do not automatically imply an improvement of reading skills [6]. Reading requires the mastery of a long chain of skills, including the management of attention. Letters must be selected from a set of other graphemes [7] through a quick

orientation of visual attention [8] before the application of the correct phoneme-grapheme integration [9].

Although the cognitive processes underlying the enhancement of reading skills are not completely clear to scientific investigation yet [10] it is still possible to “mitigate and restrict the functional consequences of the disorder through specific educational interventions” [11]. Scientific literature suggests to foster the automation of psycholinguistic processes of conversion among oral strings and orthographic strings through: i) exercises structured to facilitate the reading of isolated words as well as words embedded in a given context, ii) kinaesthetic and rhythmic activities, iii) activities to enhance visuo-spatial attention skills, iv) exercises to learn the conversion rules among graphemes and phonemes, and v) repeated readings with adaptations and subsidies (text-to-speech, tutors, audio recordings) [12]–[21].

Our research aims at designing and implementing an educational action game oriented to encourage, through forms of engaging and motivating interaction, the acquisition and development of reading skills in dyslexic subjects aged between 7 and 9.

II. ACTION GAMES AND READING SKILLS

The visuo-spatial attention plays a key role in the acquisition of reading skills. Scientific research has shown that the ability to play action video games - not directly related to reading or to phonological training - dramatically improves reading skills of dyslexic children [20]. The characteristics that define an action video game are: a high degree of game speed, a high degree of perceptual, cognitive and motor load, temporal and spatial unpredictability, and the occurrence of specific events away from the center of the screen [22], [23].

Researchers tested the attentional, phonological and reading skills in two groups of dyslexic children, matched for age and severity of the disorder, before and after the use of two types of game, action and non-action, in 9 daily meetings of 80 minutes. In particular, the group who used the action video game improved reading skills more than they did in 8760 hours of spontaneous development and with a higher or

equivalent degree to that obtained with traditional treatments [24].

Also the attention skills are increased by a treatment with action video games. Having to hit a moving peripheral target involves: i) an ability of perception of the context, and then ii) a rapid attention to detail that helps dyslexic children much more than a reading exercise. Thanks to video games, dyslexic children have learned to steer and focus in a more efficient way their attention in order to extract the relevant information of a written word, reducing the excessive side interference they seem to suffer from [20].

The individual variations detected in visuo-spatial attention and cross-modal functions explain about 50% of the variance relative to improvements in reading, after clustering by age, IQ and changes in phonological skills. Another recently published study [25] confirmed that action games can help people who suffer from dyslexia to improve their ability to read and write. Action games are able to stimulate dyslexic individuals to better integrate multi-sensory impulses.

The survey involved a group of dyslexic and non-dyslexic participants in a series of video games requiring players to press a few buttons in response to different inputs, sounds and visual effects. Dyslexics, however, has been slower than non-dyslexics in pressing the button when switching from a visual stimulus to an auditory one. This demonstrates a greater difficulty in shifting attention from one sensory channel to another, particularly when the task prompted to move from an image to a sound. According to this experiment, the phenomenon could be at the root of the problems that dyslexics encounter in reading. If confirmed, the findings could now lead the way to new strategies to improve their ability to learn the written language.

In traditional approaches the alphabetic letters are presented first visually and then aurally. Current research reveals that dyslexic people can learn associations among letters and sounds faster than listening to the sound alone and then observing the corresponding word. Traditional approaches to reading do exactly the opposite. These results demonstrate that action video games involving the training of more sensory abilities at the same time could be a great gym for patients with dyslexia.

With the right practice, in addition, dyslexics may enhance their ability to integrate multisensory stimuli, improving simultaneously also the easiness of understanding written words. Training dyslexics to quickly move the focus from visual stimuli to hearing, as happens when you play a video game, could help their ability to read and write. The possible use of video games to increase attentional skills could be useful for populations of children and adolescents with dyslexia, more difficult to treat with methods focused on increasing the reading skills through repetition. Since the latter method is very exhausting for the child, its adoption frequently caused drop-out [20].

Referring to the multisensory learning experience, “a combination of music and linguistic theory can produce a program that successfully re-mediate students with dyslexia”. Besides, it is scientifically proven that “training in music is an effective additional strategy for helping children with reading difficulties” [26]. “Rhythm-based training fosters children’s reading comprehension, reading accuracy and reading rate” [27].

Even if there are many scientific contributions that emphasize the benefits of sound even within the language, an effective modeling of how the sound and game experience can be integrated with linguistic training programs does not emerge with equal strength and clarity. In order to overcome this lack, our research aims at designing and developing an action game able to promote phonological training and to nurture the visuo-spatial attention in dislexic children.

III. INTERACTION DESIGN: EDUCATIONAL AND METHODOLOGICAL GUIDELINES

In the awareness that “effectiveness of game based-training is thoroughly dependent on the processing demands inherent to the exact game experience” [28], we have to itemize some functional considerations that guided the choice and design of game tasks, described in the next section.

III-A. Phonological Training

With regard to the phonological training, we need to specify that currently the game is designed for the Italian language. Needless to say, “the reading process is different for different orthographies” [29].

Katz has synthetically described the relationship between morphology and phonology as follows: “The attempt to make an efficient match between the written form, on the one hand, and morphology and phonology, on the other, typically determines whether the orthography chosen is a syllabary, a syllabary-cum-logography, or an alphabet. Further, within the group of alphabetic orthographies itself, there are varying degrees of dependence on the strict alphabetic principle: the range of correspondence between grapheme and phoneme varies both in consistency and completeness. The degree of this dependence is to some extent a function of a language’s characteristic phonology and morphology, just as was the choice of the kind of orthography itself” [29].

According to Katz, the Italian writing system is *shallow* [29]: “It has highly consistent spellingsound correspondences” [28]. The *shallowness* causes that naming latencies are linearly related to length in letters [30]. “Latencies decrease as children gain skill in computing pronunciations over larger groups of letters. Italian dyslexics have not made this shift; like younger normal readers, they read aloud slowly but relatively accurately” [29]. In other words, the shallowness implies that an insufficient phonological word analysis does not automatically translate, in the dyslexic subjects, into a high number of errors, but rather in an

increase of the slowness of reading at the expense of text comprehension. “In languages with *loose* relationships between graphemes and phonemes (e.g., English), when the phonological analysis of words is insufficient, a variety of errors is produced. In languages with considerably more regular grapheme-phoneme correspondence (e.g., Italian), the number of errors may be small since phonological reading is generally correct, and the most conspicuous symptom is slowness in reading” [30]. Bavelier and colleagues summarize effectively: “Performance in reading aloud is only weakly related to comprehension in shallow orthographies, for which it is possible to read aloud quickly and accurately with little or no comprehension” [28].

The implementation proposed below starts from these concepts. For instance, the game tasks require a higher and higher promptness in user’s reactions to sound stimuli.

III-B. Visuo-spatial Attention Training

With regard to visuo-spatial attention training, scientific research has confirmed that deficits related to visuo-spatial attention are among the main expressions of dyslexia [9], [24], [31]. “Attentional dysfunction is an important core deficit in dyslexic individuals. Letters must be precisely selected from among other cluttering graphemes by rapid orientation of visual attention before the correct letter-to-speech sound integration applies”.

In this regard, “the cognitive processes involved in reading a written text may differ in reference to structures of different complexity, starting from the design characteristics of which consists of a letter (lines, angles, etc.)” [18]. This concept has led to a series of studies that aim at improving the process of reading in dyslexic individuals - in terms of accuracy and speed - by acting on specific parameters such as letter spacing, size and shape [17], [32], [33].

Consequently, the game uses a font that facilitates the process of reading in dyslexics, called DFONT and developed at the Department of Human, Philosophical and Educational Sciences of the University of Salerno. Currently such a font is made of 102 glyphs, including letters (uppercase and lowercase), numbers, accents, symbols, and punctuation.

DFONT has been released both in TTF (True Type Font) and OpenType format, consequently it is usable under Windows, Linux, Android and IOS operating systems. The key graphical feature of DFONT is related to letter shaping. A particular attention has been paid to differentiate the shape of the letters *b*, *d*, *q*, *p*, *n*, *u*, namely those letters that, in most fonts, differ as regards their form but not their spatial orientation, being often confused by dyslexics [34]–[36].

Each letter of DFONT is also surrounded by (and centered in) a squared “cage”. This particular change has been made to stem the phenomenon of crowding [37], [38] through the attempt to create a kind of visual order. This should help dyslexics to distinguish both the individual characters and the extent of each word more easily. Another parameter which

has been customized is word spacing: the size of the blank character in DFONT is equal to about 3 times its equivalent in Arial. In fact scientific literature suggests that a greater spacing between words increases the readability of the text for dyslexics [39].

The effectiveness of DFONT was tested through a pilot study, using the tests of speed and accuracy of reading in the MT battery [18].

IV. GAME DESIGN AND DEVELOPMENT

In accordance with the educational principles explained above, we have designed a software prototype conceived to involve children affected by dyslexia.

The idea is providing a game interface for young users, aged 7-9 approximatively, where the association among graphical signs and their pronunciation is made explicit.

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.

The main area of the interface, shown in Figure1, presents a number of letters that the user has to choose in order to compose words. Each letter can be used many times. The sequence to reproduce is created letter by letter during the first phase of each round, and it may remain visible during the second phase to help the player. Images in the background are conceived to enrich the graphical interface without providing too much “noise”. In fact it is known that one of the aspects to improve in dyslexics is the ability to focus attention on specific spots [24]. Finally, basic text information is provided in the upper corners to trace the current score and level.

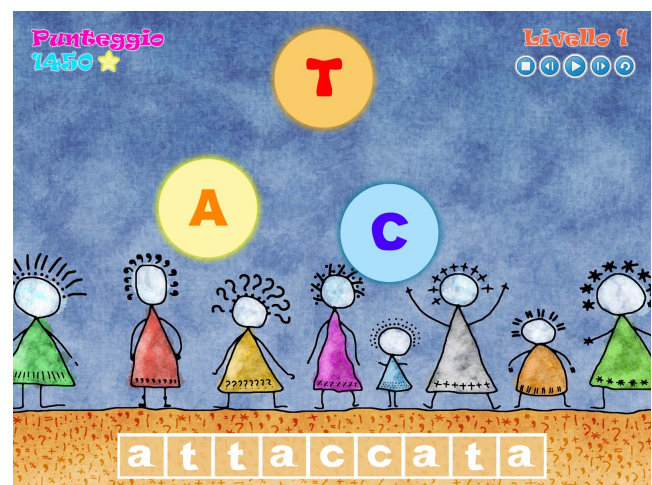


Fig. 1. The game interface.

DFONT, namely the special font described above, has been employed. From tests conducted on a number of dyslexics, this font has proved to be effective, allowing a better and easier recognition of letters.

For the game play, two aspects are fundamental. The first item is related to *skill levels*. 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 regards this peculiar activity, we have identified the following axes (see Figure 2):

- *Number of letters on the board*. When letters are few, the game is easier for a number of reasons, e.g. because the player can better identify the spatial position of symbols, as well as symbols are bigger and more clearly distinguishable. Please note that letters can be reused to compose words, consequently having n symbols does not imply that the system will draw only n -letter words;
- *Type of letters on the board*. A key problem for a dyslexic child is being able to focus on a graphical symbol and to recognize it against others. In this sense, some letters are clearly different (e.g. *W* against *L*) whereas other are perceived as similar (e.g. *K* against *R*);
- *Word length*. Since the game play requires to recreate a sequence of symbols, the longer the sequence the harder the player's task. Besides, repetitions in the use of letters are more likely to appear in long words.
- *Symbol layout inside words*. For a dyslexic child, some configurations - e.g. spelling words with double consonants - are harder to be recognized.
- *Symbol layout on the board*. In the graphic interface design, we tried to avoid misleading layouts, such as linear sequences. Needless to say, the way symbols are presented in the interface influences the difficulty in reconstructing sequences, above all for children who are affected by concentration problems;
- *Semantics*. For a child it is easier to associate a mental image to words such as "dog" than "asphyxia". In this sense, the mental image can be considered as a form of reinforcement in addition to other aspects of the board.

Moreover, even if the game has been originally conceived to present symbols composed by single letters, other kinds of aggregations - such as phonemes or syllables - could be introduced.

The second key aspect refers to *reinforcement* techniques. In fact, since the goal is providing a game environment to bind phonemes and graphemes, one error - or n errors - cannot merely be a failure that leads to the end of the game session. Rather, a number of reinforcements is incrementally provided to players, so that they can improve their performances. In particular:

- *Colors*. Any letter can be further distinguished through

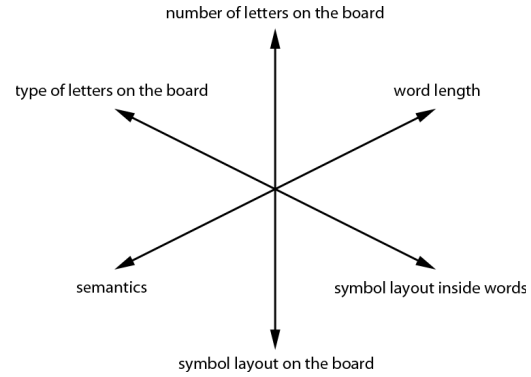


Fig. 2. Axes for increasing difficulty levels.

the use of colored boxes and high-contrast color 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.

Even if the main requirement is reconstructing the right letter sequence, the game is designed to reward promptness as well. As regards this aspect, being quick influences both score and game progress. When the user promptly provides the right answer, he/she is considered ready to face more difficult levels.

V. CONCLUSIONS

Our research aims at defining and consolidating a theoretical and applicative framework capable of guiding the development of educational tools intended for Learning Disabilities, by using those educational approaches arising from the principles and contexts of music and game education. Here the focus is on visuo-spatial attention and phonological training.

As a result of these activities, a prototype of educational action game for dyslexics has been developed, and it is currently undergoing an *alpha testing* phase (i.e. software performance verification). A validation stage is needed to ensure that such an educational tool matches the user's needs, and that the initial specifications were right [40].

In particular, validation, from the educational standpoint, will be based on the evaluation of effectiveness and efficiency. The reading skills will be measured (ex-ante, ex-post) by referring to the most widely used and trusted test battery in Italy [18]. Tests to measure accuracy and speed in reading will be performed by using *Prove MT2*, a specific set of tests available on the marketplace.

According to Cornoldi, "the evaluation of the speed and accuracy of reading is considered to be the measure that best describes the reading skills required in various contexts of school and extra-school life" [41].

Efficacy will be assessed by comparing the changes in the parameters of reading speed and accuracy to the esti-

mated extent of natural change (i.e. without treatment) of the dyslexics. In order to be considered effective, the proposed methodology will produce “a change greater than that expected without the implementation of specific recovery procedures” [42]. For the measurement of such a natural change, the reference is the one provided by [43].

The parameter related to the efficiency will instead be calculated by relating the results of the effectiveness with the intensity and duration of treatment, once again making reference to the comparative study conducted by [42]. According to this study, the minimum duration to produce an appreciable change varies from 3 to 5 months, with an intensity of at least 5-6 hours per month.

Amplitude and stratification of the sample group are currently being finalized, in order to establish future agreements with Italian *Territorial Centers for School Inclusion* (CTI), *Territorial Support Centers* (CTS) and the National Institute of Documentation, Innovation and Educational Research (INDIRE).

VI. REFERENCES

- [1] Giacomo Stella, *La dislessia: aspetti clinici, psicologici e riabilitativi*, vol. 133, Franco Angeli, 1996.
- [2] George T. Pavlidis, “Eye movements in dyslexia: their diagnostic significance,” *Journal of Learning Disabilities*, vol. 18, no. 1, pp. 42–50, 1985.
- [3] Paula Tallal, “Hormonal influences in developmental learning disabilities,” *Psychoneuroendocrinology*, vol. 16, no. 1, pp. 203–211, 1991.
- [4] Christine M. Temple and John C. Marshall, “A case study of developmental phonological dyslexia,” *British Journal of Psychology*, vol. 74, no. 4, pp. 517–533, 1983.
- [5] Maureen W. Lovett, “Developmental dyslexia,” *Handbook of neuropsychology*, vol. 7, pp. 163–185, 1992.
- [6] Gemma K. Strong, Carole J. Torgerson, David Torgerson, and Charles Hulme, “A systematic meta-analytic review of evidence for the effectiveness of the fast forward language intervention program,” *Journal of Child Psychology and Psychiatry*, vol. 52, no. 3, pp. 224–235, 2011.
- [7] Herman Bouma, “Interaction effects in parafoveal letter recognition,” *Nature*, vol. 226, pp. 177–178, 1970.
- [8] Yaffa Yeshurun and Einat Rashal, “Precueing attention to the target location diminishes crowding and reduces the critical distance,” *Journal of Vision*, vol. 10, no. 10, pp. 16, 2010.
- [9] Trichur R. Vidyasagar and Kristen Pammer, “Dyslexia: a deficit in visuo-spatial attention, not in phonological processing,” *Trends in cognitive sciences*, vol. 14, no. 2, pp. 57–63, 2010.
- [10] Stanislas Dehaene, Felipe Pegado, Lucia W. Braga, Paulo Ventura, Gilberto Nunes Filho, Antoinette Jobert, Ghislaine Dehaene-Lambertz, Régine Kolinsky, José Morais, and Laurent Cohen, “How learning to read changes the cortical networks for vision and language,” *Science*, vol. 330, no. 6009, pp. 1359–1364, 2010.
- [11] Lucio Cottini and Lanfranco Rosati, *Per una didattica speciale di qualità: dalla conoscenza del deficit all'intervento inclusivo*, Morlacchi Editore, 2008.
- [12] Jeanne Wanzek, Jade Wexler, Sharon Vaughn, and Stephen Ciullo, “Reading interventions for struggling readers in the upper elementary grades: A synthesis of 20 years of research,” *Reading and writing*, vol. 23, no. 8, pp. 889–912, 2010.
- [13] Barbara K. Given, John D. Wasserman, Sharmila A. Chari, Karen Beattie, and Guinevere F. Eden, “A randomized, controlled study of computer-based intervention in middle school struggling readers,” *Brain and language*, vol. 106, no. 2, pp. 83–97, 2008.
- [14] Maureen W. Lovett, Maria De Palma, Jan Frijters, Karen Steinbach, Meredith Temple, Nancy Benson, and Léa Lacerenza, “Interventions for reading difficulties a comparison of response to intervention by ell and efl struggling readers,” *Journal of Learning Disabilities*, vol. 41, no. 4, pp. 333–352, 2008.
- [15] Nancy Scammacca, Greg Roberts, Sharon Vaughn, Meaghan Edmonds, Jade Wexler, Colleen Klein Reutebuch, and Joseph K. Torgesen, “Interventions for adolescent struggling readers: A meta-analysis with implications for practice,” *Center on Instruction*, 2007.
- [16] H. Lee Swanson, “Reading research for students with ld a meta-analysis of intervention outcomes,” *Journal of learning disabilities*, vol. 32, no. 6, pp. 504–532, 1999.
- [17] Maurizio Sibilio and Stefano Di Tore, “Body, movement and space for a simplex didactics: a pilot study on the realization of a font for specific learning disabilities,” *Education Sciences & Society*, vol. 4, no. 2, 2014.
- [18] C Cornoldi, G Colpo, and MT Gruppo, *Prove di lettura MT-2 per la Scuola Primaria*, Giunti OS, 2011.
- [19] Katie Overy, “Dyslexia and music,” *Annals of the New York Academy of Sciences*, vol. 999, no. 1, pp. 497–505, 2003.
- [20] Sandro Franceschini, Simone Gori, Milena Ruffino, Simona Viola, Massimo Molteni, and Andrea Facchetti, “Action video games make dyslexic children read better,” *Current Biology*, vol. 23, no. 6, pp. 462–466, 2013.
- [21] Giuseppina Rita Mangione, Tiziana Discepolo, Pio Alfredo Di Tore, Stefano Di Tore, Carla Cozzarelli, and Felice Corona, “Measuring empathy to support learning design and narrative game: A phenomenological approach,” in *Complex, Intelligent, and Software Intensive Systems (CISIS), 2013 Seventh International Conference on*. IEEE, 2013, pp. 401–406.
- [22] C. Shawn Green, Renjie Li, and Daphne Bavelier, “Per-

- ceptual learning during action video game playing,” *Topics in cognitive science*, vol. 2, no. 2, pp. 202–216, 2010.
- [23] Matthew W.G. Dye, C. Shawn Green, and Daphne Bavelier, “Increasing speed of processing with action video games,” *Current Directions in Psychological Science*, vol. 18, no. 6, pp. 321–326, 2009.
- [24] Sandro Franceschini, Simone Gori, Milena Ruffino, Katia Pedrolli, and Andrea Facoetti, “A causal link between visual spatial attention and reading acquisition,” *Current Biology*, vol. 22, no. 9, pp. 814–819, 2012.
- [25] Vanessa Harrar, Jonathan Tammam, Alexis Pérez-Bellido, Anna Pitt, John Stein, and Charles Spence, “Multisensory integration and attention in developmental dyslexia,” *Current Biology*, vol. 24, no. 5, pp. 531–535, 2014.
- [26] Sheila Douglas and Peter Willatts, “The relationship between musical ability and literacy skills,” *Journal of Research in Reading*, vol. 17, no. 2, pp. 99–107, 1994.
- [27] Marion Long, “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*, 2014.
- [28] Daphne Bavelier, C. Shawn Green, and Mark. S Seidenberg, “Cognitive development: gaming your way out of dyslexia?,” *Current Biology*, vol. 23, no. 7, pp. R282–R283, 2013.
- [29] Leonard Katz and Ram Frost, “The reading process is different for different orthographies: The orthographic depth hypothesis,” *Advances in Psychology*, vol. 94, pp. 67–67, 1992.
- [30] Pierluigi Zoccolotti, Maria De Luca, Enrico Di Pace, Anna Judica, Marco Orlandi, and Donatella Spinelli, “Markers of developmental surface dyslexia in a language (italian) with high grapheme–phoneme,” *Applied Psycholinguistics*, vol. 20, no. 2, pp. 191–216, 1999.
- [31] Andrea Facoetti, Anna Noemi Trussardi, Milena Ruffino, Maria Luisa Lorusso, Carmen Cattaneo, Raffaella Galli, Massimo Molteni, and Marco Zorzi, “Multisensory spatial attention deficits are predictive of phonological decoding skills in developmental dyslexia,” *Journal of cognitive neuroscience*, vol. 22, no. 5, pp. 1011–1025, 2010.
- [32] Patrycja Rusiak, Thomas Lachmann, Piotr Jaskowski, and Cees van Leeuwen, “Mental rotation of letters and shapes in developmental dyslexia,” *Perception*, vol. 36, no. 4, pp. 617, 2007.
- [33] Larry D. Reid, Meta L. Reid, and Audrey Bennett, “Towards a reader-friendly font: Rationale for developing a typeface that is friendly for beginning readers, particularly those labelled dyslexic,” *Visible Language*, vol. 38, no. 3, pp. 246–259, 2004.
- [34] Allison D. Brooks, Virginia W. Berninger, and Robert D. Abbott, “Letter naming and letter writing reversals in children with dyslexia: momentary inefficiency in the phonological and orthographic loops of working memory,” *Developmental neuropsychology*, vol. 36, no. 7, pp. 847–868, 2011.
- [35] Katja Brendler and Thomas Lachmann, “Letter reversals in the context of the functional coordination deficit model,” *Proceedings of the International Society for Psychophysics*, vol. 17, 2001.
- [36] Isabelle Y. Liberman, Donald Shankweiler, Charles Orlando, Katherine S. Harris, and Fredericka Bell Berti, “Letter confusions and reversals of sequence in the beginning reader: Implications for ortons theory of developmental dyslexia,” *Cortex*, vol. 7, no. 2, pp. 127–142, 1971.
- [37] Manuel Perea, Victoria Panadero, Carmen Moret-Tatay, and Pablo Gómez, “The effects of inter-letter spacing in visual-word recognition: Evidence with young normal readers and developmental dyslexics,” *Learning and Instruction*, vol. 22, no. 6, pp. 420–430, 2012.
- [38] Donatella Spinelli, Maria De Luca, Anna Judica, and Pierluigi Zoccolotti, “Crowding effects on word identification in developmental dyslexia,” *Cortex*, vol. 38, no. 2, pp. 179–200, 2002.
- [39] Marco Zorzi, Chiara Barbiero, Andrea Facoetti, Isabella Lonciari, Marco Carrozzini, Marcella Montico, Laura Bravar, Florence George, Catherine Pech-Georgel, and Johannes C. Ziegler, “Extra-large letter spacing improves reading in dyslexia,” *Proceedings of the National Academy of Sciences*, vol. 109, no. 28, pp. 11455–11459, 2012.
- [40] J. Enrique Hinostroza and Harvey Mellor, “Pedagogy embedded in educational software design: report of a case study,” *Computers & Education*, vol. 37, no. 1, pp. 27–40, 2001.
- [41] Cesare Cornoldi, Patrizio E. Tressoldi, and Nicoletta Perini, “Valutare la rapidità e la correttezza della lettura di brani. nuove norme e alcune chiarificazioni per luso delle prove mt,” *Dislessia*, vol. 7, pp. 89–100, 2010.
- [42] Patrizio E. Tressoldi, Claudio Vio, Maria Luisa Lorusso, Andrea Facoetti, and Roberto Iozzino, “Confronto di efficacia ed efficienza tra trattamenti per il miglioramento della lettura in soggetti dislessici,” *Psicologia clinica dello sviluppo*, vol. 7, no. 3, pp. 481–494, 2003.
- [43] Patrizio E. Tressoldi, Giacomo Stella, and Marzia Faggella, “The development of reading speed in italians with dyslexia: A longitudinal study,” *Journal of learning disabilities*, vol. 34, no. 5, pp. 414–417, 2001.