A Mobile Web Game Approach for Improving Dysgraphia

Daniela Giordano and Francesco Maiorana
Department of Electrical, Electronic and Computer Engineering, University of Catania, Viale A. Doria, 6, Catania, Italy

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Abstract: Dysgraphia is a learning disability that affects the performance of children's handwriting, which can seriously impact their school performance and their willingness to write their thoughts, and can also adversely affect their social life and can lead to low self-esteem. In this work a mobile web-based serious game for improving children's handwriting is presented. The design principles of the game are presented as well as the software tools and frameworks used for its implementation, including the results of an initial informal testing with children which are presented and discussed.

1 INTRODUCTION

According to the National Center for Learning Disabilities (National Center for Learning Disabilities) dysgraphia is "a learning disability that affects writing, which requires a complex set of motor and information processing skills. Dysgraphia makes the act of writing difficult. It can lead to problems with spelling, poor handwriting and putting thoughts on paper." For example, professional teachers, trained and with an extensive experience teaching how to write and in reading children writing, call the parents of a disgraphic student to say, "I am sorry but I really cannot read your child's handwriting any longer". For students with dysgraphia, writing can be a difficult and slow process. Being pressured to write may add to their anxiety. Nevertheless these children deserve special attention in order to fulfill their potential.

It is estimated (Rosenblum, 2003) that nearly one-third of students fail to acquire efficient handwriting skills. The effects of poor handwriting easily go beyond the handwriting process and may impact the social aspect of life. According to the National Center for Learning Disabilities (National Center for Learning Disabilities) the most common social challenges that may be faced by dysgraphic people are:

1) The child is easily frustrated by writing assignments—to the point of temper tantrums.
2) Children with dysgraphia may have language processing issues which can make it difficult to express ideas and speak about specific topics. Language processing difficulties can make it difficult for children to understand humor or language nuances such as sarcasm.
3) The child lacks confidence and frequently says, "I'm not good at school". Children with dysgraphia may sense they're different from other kids and worry they're not smart. That can lead to low self-esteem.
4) Having social issues on top of writing challenges can take a toll on the child.

Research suggests that 75% of children with a learning disability have other social skill problems (Kavale, 1995). A high risk of dropping out of school in students with a learning disability has also been demonstrated (Reschly, 2006). The difficulties can involve other areas and can be used to detect early symptoms. Among these we recall the following areas: visual-spatial, fine motor, language processing, spelling/handwriting, grammar and organization of language.

It is well recognized that students should not lose their handwriting abilities and handwriting should not be replaced by an extensive use of the keyboard. Free hand handwriting, as reported in (James, 2012), activates the left fusiform gyrus, the inferior frontal gyrus and the posterior parietal cortex since children have to plan and execute the action. Practicing handwriting may facilitate reading acquisition in young children, have a beneficial effect on children with dyslexia and is also useful in training fine motor skills. According to the British Dyslexia Association, the most widely recommended handwriting style is called continuous cursive, especially for dyslexic children. "Its most important

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feature is that each letter is formed without taking the pencil off the paper – and consequently, each word is formed in one, flowing movement" (http://www.bdadyslexia.org.uk/parent/help-with-handwriting).

To improve handwriting, extensive practice is necessary. However, dysgraphic children may not be keen to face an activity that is difficult, unrewarding and seemingly boring. Technological tools such as word processing, word cueing, word prediction and speech recognition do not replace the necessity of teaching and improving students' abilities in the handwriting process. In literature there are many examples of very good programs that guide children in a series of exercises to improve their handwriting. Among these we recall: Write-on handwriting (Ford-Hebert, 2004) which is based on the assumption that handwriting must be taught at the automatic kinesthetic level using implicit memory and allowing working memory to focus on the thought to be expressed or on the word to be spelled; Handwriting Without Tears (Olsen, 2001), whose beneficial effects have been evaluated in many researches such as (Hape, 2014), Callirobics (Laufer, 1990) which uses music to relax the participant and adds rhythm to the writing pattern exercise. These types of resources can be framed among curriculum resources since they provide complete curricula suitable for different age ranges and levels.

Many software tools such as ComPET (Rosenblum, 2006), Ductus (Guinet, 2010), HandSpy (Monteiro, 2012), Eye and Pen (Alamargot, 2006), Telemaque (Hennion. 2005), and the recently developed mobile web platform (Giordano, 2014) have been used to study writing graphism and in assisting the specialist with an early diagnosis.

The use of a game-based approach has not been explored much. Attempts have been made for a game-based rehabilitation approach such as (Curtis, 2009) where the authors present four platform-independent games with adjustable levels of difficulty to assist patients in their rehabilitation of handwriting skills after a stroke. In (Tan, 2013) the authors present a prototype of a tablet-based game for handwriting practice and its initial evaluation by adults (mean age 24 years) in a pilot study reporting a perception of usefulness and an appreciation of the gameplay, except for the flow. In (Maxim, 2008) the authors present an immersive gaming environment for improving children's handwriting using a tablet PC. Among other games it is possible to recall the work of other researchers, such as (He, 2012) aiming at increasing motivation and engagement.

This paper presents a mobile web-based serious game for teaching handwriting to children from 4 years old, hence without reading abilities, to 12 years old. The software user interface is presented in section 2, design principles of the game are presented in section 3, the software architecture as well as the tools and frameworks used for its implementation are presented in section 4, the results of an initial informal testing with children are presented and discussed in section 5 and finally, section 6 draws conclusions and highlights future work.

2 SOFTWARE USER INTERFACE

The game was implemented as a client – server web-based game. The game is a "runner" game where the player has to collect various types of fruit with different points associated with each fruit. The scenery of the game is shown in Figure 1. Along the way, obstacles appear that have to be avoided by the player by drawing simple shapes like lines or circles, which allows the player to train in drawing pre-graphism. An interactive introductory animation guide shows the player the different types of gestures that have to be performed in order to avoid the different obstacles.

Figure 1: Scenery of the game.

The objects are generated at run time in a pseudorandom location inside the canvas where the game takes place; the objects are removed when they are no longer visible. During play several letters or words fall down simultaneously and must be caught by the player. The letters have to be rewritten in order to form a word that is shown at the top of the screen. A cloud appears containing the reference lines where the user has to trace the letter or the word, as shown in Figure 2. This type of interface was designed according to the user security design principles.

When the player writes the letter or the word, the pixel coordinates of all the points drawn by the user with the associated time are sent to the server.

The children playing the game can use either their finger, according to the Montessori methods (Montessori, 1914), or a digital pen such as the Jot Pro by Adonit (http://www.adonit.net/jot/pro/).

Moreover, both the $1 and $n shape recognizer algorithms are performed and the percentage of matching with the reference trace is computed. The best grade of matching is given as feedback to the user along with the percentage of pixels above and below the reference line. Figure 3 shows an example of textual feedback that can be shown if required by the user.

Figure 2: The word tracing interface.

Exercise : Tsperimentazione1TestNumero1ok
Result : Very good
Matching score 0.62
You did wrong with 1 dots
1 are over the top line
0 are below the bottom line
Total mistake percentage 0.31%

Figure 3: An example of textual feedback.

The reference trace can also be shown if required by the user in the initial game settings. The children playing the game can use either their finger, according to the Montessori methods (Montessori, 1914), or a digital pen such as the Jot Pro by Adonit (http://www.adonit.net/jot/pro/).

3 GAME DESIGN PRINCIPLES

The user interface should be designed in such a way as to facilitate its use by a non-reading child and should be engaging. The design principles followed, also in accordance with game design guidelines such as (Moreno-Ger, 2008), are:

1) provide immediate and informative feedback. The feedback should be visual via a comparison with a reference trace and by means of objective parameters related to the quality of written text.
2) reduce the short memory load. This is obtained, for example, by clearly visible score and record. The presence of the record is an incentive for playing the game.
3) offer a feedforward mechanism to improve user security. As an example, we used bright colors for positive objects, such as the fruit to collect, and the dark colours for obstacles, such as the moon with the presence of spines. User security is also enforced during the writing process. The presence of a cloud, which is typical in comics where the words are written, is an indication for the user to trace the letter.
4) the game should be accessible from a browser and available anytime, anywhere from any type of device.
5) The game should allow for the tracking of student performance by storing the entire set of pixels drawn during the writing process.

Along the way, obstacles appear that have to be avoided by the player by drawing simple shapes like lines or circles, which allows the player to train in drawing pre-graphism. The type of fruit could also be associated with a different shape to draw: e.g. an apple indicates horizontal lines, a banana indicates vertical lines and a cherry indicates circles.

Hidden within the dynamics of the game should be a set of writing exercises which are presented to the young player in such a way as to avoid boredom. Instead, it promotes a good writing process by offering a reward which is necessary in order to proceed in the game. The game should propose the retracing of letters, words and symbols both in print and cursive. All the data collected during the writing process should be securely saved on a server for further processing and analysis, and an immediate encouraging feedback about the writing performance should be given to the players. The feedback is related to several items: the quality of the writing in comparison with a reference trace done by a proficient writer, the percentage of pixels above and below the reference line, and the time required for the trace. The game should be web-based and run on different mobile platforms and an initial set of strategies for a responsive design should be implemented.

4 SOFTWARE ARCHITECTURE

A web service provides the client with the set of exercises, in a JSON format, which is proposed throughout the game. The client side of the game was entirely developed in HTML5 and Javascript with a set of frameworks. In particular, the following libraries and frameworks were used:

1) Phaser (http://phaser.io/), a graphics engine with physics systems that allow for an easy handling of collisions, to provide objects with mass and other physical properties for more realistic simulation.
2) $1, a 2D gesture recognizer (http://depts.washington.edu/aimgroup/proj/dollar/).
3) $n, a multistroke recognizer (http://depts.washington.edu/aimgroup/proj/dollar/ndollar.html).
4) Hammer (http://hammerjs.github.io/), an open-source library that can recognize gestures made by touch, mouse and pointer events.

The sequence of points drawn by the user with the associated time are sent to the server in the JavaScript Object Notation (JSON) (Crockford, 2013), a lightweight data-interchange format used to facilitate the exchange of structured data between client and server. On the server side, the MySQL (http://www.mysql.com/) database was chosen as the relational Database Management System and the PHP (http://php.net/) scripting language was used to develop the application. The XAMP (http://www.apachefriends.org/en/xampp.html) suite was used.

The architectural diagram is shown in figure 4.

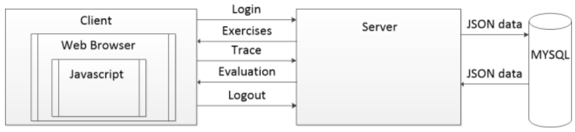

Figure 4: Architectural diagram.

The game was implemented as a finite state machine as shown in Figure 5. The initial state is the “Boot” state. In this state the JSON file containing the set of exercises is requested to the server by means of a XMLHttpRequest and loaded in the game and the size of the assets of the game is adapted in a responsive manner to the device where it is running.

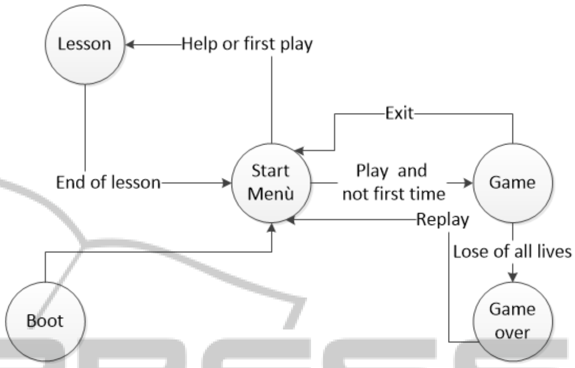

Figure 5: The game finite state machine.

Once these operations are completed, the game moves to the “Start Menù” state where the game waits for a user command: the player can choose the play button to start the game or the help button to start the interactive tutorial which explains the different tracing mechanisms as well as the rules of the game. If the user chooses the help button, the game moves to the “Lesson” state where the interactive tutorial is presented to the player. At the end of the tutorial the game returns to the “Start Menu” state. If the user chooses the play button, the game moves to the “Lesson” state if it is the first time that the game is started, otherwise the game moves to the “Game” state.

In the “Game” state, the player has the option to play a session game, to pause it or to stop it in order to return to the “Start Menu” state. This is the central part of the game where all its dynamics are implemented: the random generation of the game settings, the management of the writing exercise visualization, the game interaction and so on. If the player losses all his/her lives, the game moves to the “Game over state” where the scores are presented. If the user chooses to replay the game, the “Menu” state is reached once again.

Each state, according to the Phaser program structure, is divided into three phases: a pre-loading phase where all the assets are loaded; a create phase executed only once where all the initial objects are created; and an upload phase, repeated at regular intervals, where the game state is updated.

5 PRELIMINARY TESTING

The game was tested informally by three children supervised by the developer who gave a test run and suggestions on the gameplay. The objectives of the case study were to understand the children's motivation in playing the game and if the writing exercises were sufficiently hidden in the game and not seem as an exercise. Their feedback was positive, reporting a good and fun gameplay and were not bothered by the writing exercises which, instead of being considered a hindrance, were seen as an opportunity to advance in the game. The evaluation of the game session suggested the following improvements:

1) increase the velocity of the game both at the beginning and as an increasing factor based on the level of the game.
2) the initial position of the player should be adjusted with the user's age: a central position

for the older players and a more distant one for the younger users, thus allowing more time to decide on the move and to interact with the game.

3) the interaction during the writing process was intuitive for all the users but some of them required an explicit message assuring them of the success of the writing process.

An extensive field study will provide more indications and improvements.

6 CONCLUSIONS

In this work the design of a mobile web-based serious game for addressing dysgraphia was discussed. The game allows the user to practice in pre-graphism delete simple forms such as straight lines and circles, which are used to move the player, and in writing letters or words in order to obtain a better score, more lives and other rewards to advance in the game. The game provides immediate feedback both visually and by means of objective parameters such as the percentage of matching against a reference trace and the percentage of pixels above and below the reference line. All the data during the writing process, such as all the pixel coordinates and the time of tracing, are permanently stored on a server.

As a further work we plan to design other games aimed at facilitating writing training by young players and to correlate different types of games with different learning styles in accordance with the Visual, Aural, Read/write, Kinesthetic (VARK) theory. We will also perform a field study aimed at collecting writing data and assessing players' improvements in the writing process. In particular by collecting and analyzing the data while the children play the game it will be possible to study the progress on the learner.

We also plan to see how a group training version of the game would impact on writing and how the children influence each other while playing the game.

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