A Serious Games System for the Analysis and the Development of Visual Skills in Children with CVI

A Pilot Study with Kindergarten Children

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Abstract. The development of visual skills is crucial in sustaining an adaptive cognitive and social development in children. The paper describes the result of a pilot study, involving a group of 4 years old children, with a set of serious games to improve the assessment and rehabilitation process in children with CVI. The system uses an eye tracker system to correctly measure the performances of the child and his/her capability to watch and touch a moving object at the same time and to perform ab cognitive visual decision making.

Keywords: Serious games based assessment · Rehabilitation

1 Introduction

The development of visual skills is crucial in sustaining an adaptive cognitive and social development in children. Cerebral Visual Impairment (CVI) is the leading cause of visual impairment in western countries. It is crucial then to develop procedures and activities effective in involving children in an early assessment and in the rehabilitation process. In this paper we will describe a set of serious games, with a particular emphasis on the *HelpMe!* game, created to improve the assessment and rehabilitation process in children with CVI.

Cerebral Visual Impairment (CVI), also known as Cortical Visual Impairment, is a disability that entails a visual deficit, due to a brain damage [13]. People affected by this disability need that an object is moving to be able to see it; they have a reduced ocular field and ocular delay, and find it difficult to understand complex images. Moreover, they are not able to see and touch an object at the same time: they usually watch the

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object first, and then they try to touch it, often losing eye contact. A child affected by CVI can experience all (or a set of) these difficulties, with different level of severity. Additionally, psychological literature has shown that the development of visual skills is crucial not only for the independent movement in the environment but also both for a positive social and cognitive development [8, 12, 15].

The use of a serious game with this kind of children allows to obtain as much attention as possible from them, since they have fun, but it is very important that the game interface is fluid to adapt itself to different situations: the child can then play the game using different devices, e.g., a tablet, a computer with or without a touch monitor, etc. Moreover, the game must work even in absence of the network connection and must be configurable to adapt itself to any child with different difficulties. Finally, the game must evolve together with the improvement of the child.

Given the particular target of users, there are two main issues which should be addressed in order to increase the effectiveness of the system. First of all, the choice of an interactive modality is very important. As shown by Forlines and colleagues, the touch interfaces are a more ecological paradigm for children; indeed, they interact with the screen as they would interact with a real object [6]. For this reason, the interaction method preferred for the children interface component is a touch interface, to better involve the children to the game and naturalize the interaction with it, through a tablet or a touch monitor.

Secondly, the system integrates an eye tracker system to correctly measure the performances of the child and his/her capability to watch and touch a moving object at the same time and to perform a cognitive visual decision making.

In this paper we will describe the system and a set of three serious games developed to train and assess children affected by CVI. An initial development of the system can be found in [2]. At that time, we developed a prototype which has not been tested with children. In this paper we begin the test phase of the system involving a group of normally developing children in the study in order test the feasibility of the games and the effort needed in the learning process. Additionally, different levels of difficulty and processes were taken into account together with the recording of different performance indices to be used as baseline in the rehabilitation program against which to measure the effectiveness of the system in the habilitation/rehabilitation process.

The aim of this study was then to test the system using several tasks with a group of normally developing children; to test the adaptability of the system to various children characteristics. This will help setting the level of difficulty and sensitivity to address different clinical issues before using it in the assessment of visual skills in children with CVI and in training their ability to watch, touch and move an object at the same time, their visual problem solving skills.

The paper is organized as follows: Sect. 2 discusses background with related works, Sect. 3 describes the three serious games and Sect. 4 provides some details about system development and architecture. In Sect. 5, a pilot study with kindergarten children is described. Finally, Sect. 6 presents conclusions and directions of research studies.

2 Background

Serious games, i.e., games or applications developed not only for fun, but to propose, under a game, exercises helpful in developing particular skills of the user, have been developed in several different contexts and applications are known for example in the military field, in the governmental field and also in the education field [11].

Serious games are becoming very important also in clinical setting both for professionals, to train or to simulate real-life experiences, and for patients, for instance, to hide rehabilitation and rehabilitation exercises under a game. Esteban et al. developed a system to combine 3D computer simulation to the learning process for new doctors, to teach them particular procedures [5].

Several studies show the goodness of the usage of serious games with children. De Bortoli and Gaggi showed how a visual acuity test can be hidden under a much more interesting game, with the consequence that children pay much more attention and the diagnosis is more accurate [3]. Other authors [4, 7] showed that non-expensive equipment and serious games can open opportunities for home rehabilitation, reducing the *drop-out-from-therapy* phenomenon, and improving the effectiveness of rehabilitation programs. This is the case for instance, of children with CVI.

An early assessment and intervention can increase the possibility for children with CVI to drastically reduce the effects of this deficit [10]. A good diagnosis can be achieved only with the total collaboration and attention of the patient, but test exercises (like Lea symbols) are extremely boring and children usually do not pay much attention the answers they give. So, the diagnosis may become inaccurate.

Serious game can support effectively the diagnostic as well as the rehabilitation process. Campana has shown that, in children with CVI, simple iPad games which did not address specific goals (i.e., *Bubbles Magic*), but presenting words or pictures and playing different sounds on the device, are effective in orienting attention to the tablet and to what happens on the screen [1].

Tap-n-see Zoo is a game specific for children with CVI where a teddy bear moves on the screen and a sound is heard by the child when he/she taps on it. In order to use this system to track the development or improvement in visual skills, there is the need to integrate the serious game with an eye-tracker system to record the child's eyes movement during the rehabilitation program and to better measure his/her improvements. We developed this improvement in our system and we also propose a game to train a specific skill: the *problem*-solving capabilities of the child.

3 The Serious Games Activities

Our system proposed three serious games which consisted in different interactive situations through which the typical development and assessment of visual abilities in children is conducted. During the execution indices related to eye movements, accuracy, response time and completion task time, are collected and later analyzed.

A. Where is Nemo going? This is the first situation proposed, which we use to calibrate the eye tracker. Participants are asked to look to the goldfish Nemo, which move though 5 points on the screen. This step allows also the participant to practice with the system. Eye movements across different quadrants of the visual field are stimulated in the child since Nemo is placed in the four corners and its midpoint.

B Where is Peppa/George going? With this game, we ask children to orient their attention. Children must follow a stimulus, a cartoon character chosen according to participant gender, which is moving on the screen. The situation stimulates eye movements and attention shift across different quadrants of the visual field.

C. Help me! The Santa Claus's assistant. Children are trained in more complex visual processing requiring cognitive decision making. The location of the game is the North Pole, in particular at Santa Claus' laboratory. Participants are asked to help Santa Klaus in a long lasting task, that is preparing in advance the bags of Christmas presents. Pictures of objects belonging to three different target semantic categories (animals, vehicles and clothing) are used together with objects belonging to other categories (intruders) taking into account the age of acquisition and the organization of the semantic lexicon at children's age. Each level of the game has a different set of target semantic objects, e.g., "musical instruments", "clothes for dolls", "cars" and so on, each of which is composed by a set of different images that show objects belonging to that particular semantic category.

Participants are then required to orient the attention and focus on an object; to discriminate between target images (i.e., images that belong to the target category) and intruders, and make a cognitive decision putting the firsts into Santa Claus' sack, and throwing out of the screen the other ones. Figure 1(a) depicts the game interface dedicated to the children. Eye and touch movements are recorded by the system and showed to the doctor (see Fig. 1(b)).

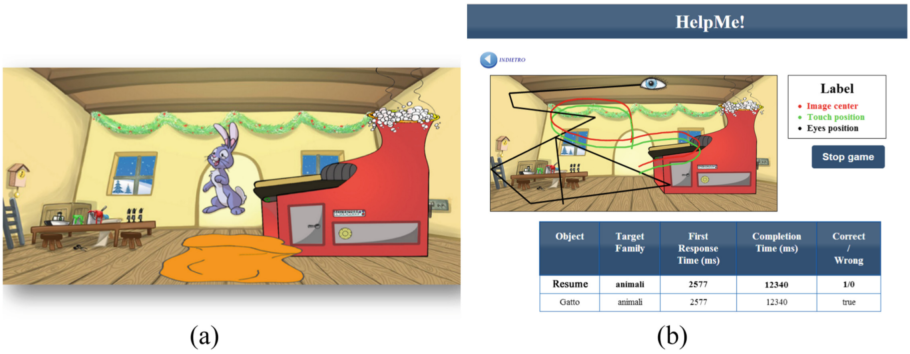

Fig. 1. (a) Screenshot of the child interface of the game '*Help me! The Santa Claus's assistant*'; (b) Screenshot of the doctor interface of the game '*Help me! The Santa Claus's assistant*'.

To avoid that the child becomes more interested on the background image instead of the objects presented on the screen, the background image was made as easier as possible, avoiding a large use of details.

Each level is described inside the system by a target category, the number of target images and intruders which compose that level and the maximum amount of time (in seconds) the child can use to give an answer. Every level is organized with a sequence of images, both target and intruders, organized according to a specific pattern previously established.

Orienting sounds and audio are also used to guide the child during the game, i.e., to give the first instructions, to tell the child which is the target family coming next, to provide live feedback about his behavior and choices, etc.

If the child fails to discriminate one of the images of a particular set of pictures, the child is asked to repeat the actions. After three failures in the same level, the game moves to the next sequence.

4 The System: Architecture and Implementation Issues

The system used here was initially presented in [2] and goes under a process of adjustments and improvements. We report here the main issue and we refer to [2] for detail information.

The design of the system architecture has been deeply influenced by the need of being used in very different scenarios, e.g., kindergarten, doctor's offices, children' house, and has to transform its user interfaces gracefully, in order to adapt itself to the different characteristics of each environment and to remain usable by all the children with any kind of devices. As an example, the system should work even in absence of Internet connectivity which is necessary only to send to the server the information stored during the rehabilitation made at home. The server receives this information, saves them and calculates an evaluation of each exercise. All the information are stored in the database to provide to the doctor the possibility to watch a simulation of the rehabilitation program performed by the user and his/her progress

However, the system does not need to provide all its features in all situations, but it must be robust in case some components are lacking e.g., even if the eye tracker is not available when a child is at home, the system must provide the possibility to play the game even with the child computer or tablet. In this case the system will record only the touch interactions of the child and not the movement of the eyes.

For this reason, the system has been structured in four different components, following a client-server architecture. In particular, our system includes:

1. a server, which manages, synchronizes and stores data produced from the other components;
2. an eye-tracker system that produces information relative to eyes position;
3. the user interface for the children, i.e., a component responsible to present the game and manage child interactions (see Fig. 1 (a));
4. the user interface for the doctor, i.e., a component which is able to present data collected on the child performances (see Fig. 1(b)). Moreover, it gives to the doctor the possibility to change the game behavior to better adapt it to a specific patient.

All the components have been developed as much independent as possible, so that they can be removed, or replaced in the future. This is particular important both to adapt the system to particular situations, e.g., the absence of the eye tracker system or if the child uses a tablet instead of a computer to perform his/her rehabilitation exercises, and to allow an easy reconfiguration of the system. As an example, we substitute the original open source eye tracker system used in [2] with the professional Eye Tribe Tracker Pro[1] without the need to change the anything in the other components. Moreover, all components can reside, all together, in the same computer: as an example we used a Microsoft Surface 4, 4 GB RAM, Inter Core i5, with an additional external monitor, during our pilot study. We need the external monitor since we need to interface, one for the doctor and one for the child.

Two specific components, one for the child to play the game, and one for the doctor to manage the game settings and to provide online information about children behavior, manage the user interface. To better involve the children to the game and naturalize the interaction with it, we use a touch interface. However, it is possible to interact with a mouse if a touch device is not available.

To address portability, the game and the child interface must be usable on any device. For this reason, the application has been developed as a Rich Internet Application (RIA), a web application that works with lots of data elaborated both by the client and the server, exchanged in an asynchronous way, with a look and feel similar to desktop application.

We developed our application using the new HTML5 standard, which is nowadays widely supported and that does not require to download a specific plugin and offers two important features which improve portability of the system: local storage and cache manifest. When a cache manifest file is associated to an HTML page, the browser reads this files and downloads all the files listed in its cache, that are all the files necessary to provide the requested page. In this way, we have a performance improvement (the browser does not need to download all the file every time) and the browser can provide the application even without Internet connectivity.

The client-server communication is based on a simple protocol of packets exchanging encoded into the JSON format. The protocol has been developed using Web Socket API, a new feature of HTML5 which allows to defines a new communication protocol that creates a full-duplex single socket connection between server and client [9].

The WebSocket protocol is implemented, at client side, by the browser. At the server side we implemented the server component using Java 7, using a Java implementation of the server which supported the last specification of the WebSocket protocol and handshake.

The usage of the WebSocket protocol provides several improvements in real-time application performances. Firstly, it reduces the amount of overhead introduced in each information packet, reducing the throughput necessary to send all the packets. Secondly, it reduces latency, because after the initial handshake between the client and the server, every time the server has new data for the client it can send it immediately, without waiting for a new request from the client (like the polling technique). Moreover, WebSocket allows to provide to the doctor a real-time feedback about the behavior of the child, with information packets sent every 40 ms (limited by

[1] https://theeyetribe.com/.

eye-tracker performances). Figure 1 (b) shows the doctor interface: the server receives, records and sends to the doctor client the movements of the image (the red line), of the user touch (the light green line) and of the gaze (the black line) along the time. In this way, the doctor is able to watch what is happening on the child side, viewing where the child is touching, how he/she is moving the image on the screen, and where he/she is watching. Furthermore, we provide several summary information about child choices and interaction with the game.

Our system is also able to store data about patients' exercise for further consultation by doctors. The doctor can consult data during the child exercises or offline, for further analysis. For each session game an XML file stores information about the used device, the screen size, etc. Information about the image position on the screen, the touch interaction of the child and where the eyes are watching on the screen are stored into three different text files, in which each entry, i.e., a packet, follows the pattern <*ΔT; left; top*> where ΔT is the timestamp, and *left* and *top* contains the left position and the top position of the recorded element (the touch position, the center of the image or where the eyes are watching) on the screen. Even the exercises settings used by the doctor for each child are stored in the server with an XML file (every child has his own settings associated), providing the possibility to the doctor to use several times the same exercise with the same child, avoiding him to insert every time the same settings (this is particular important for performances analysis for the doctor).

The application has been successfully tested with Chrome from version 14.0, Firefox from version 11.0, Safari from version 5.0 and Opera from version 12.0.

An important issue that our system has to deal with is the synchronization of the components. As we will see in the next section, data about children exercises are measured in milliseconds. Therefore, if system components are distributed in different computers, it is very important to synchronize information coming from eye-tracker and child interface.

Therefore, the main task of the server is to synchronize and store this information during the session game, in order to avoid loss of data, so to define a common initial time zero shared by all the components.

Due to the natural difference between clocks in different autonomous computers, the starting time for the game and the eye-tracking software will be different. But this different times have to represent the same UCT time, in order to start their operation at the same moment. In this way, if two packets have the same ΔT, i.e. the offset from the beginning of the game, the information provided are relative to the same moment. The algorithm used to synchronize the starting times for all the components is based on the work by Sichitiu and Veerarittiphan [14]. This synchronization step usually requires less than a minute and must be performed only once for each component, the first time it is connected to the system.

5 A Pilot Study with Kindergarten Children

A pilot study was carried out involving 20 children whose age ranged from 4 years to 4 years and 10 months, who attended a Nursery School in the city of Padova. None of the participants presented developmental issues.

Table 1. Analysis of Pearson's correlations between indices recorded in the game

MEANS	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1.Animals Target Response Time	-	.893**	.485*	.625**	.304	.212	.566**	.252	.304	.645**	.455*	.540*
2. Animals Intruder Target Response Time		-	.619**	.880**	.652**	.258	.765**	.289	.134	.321	.648**	.235
3. Animals Target Completion Time			-	.680**	.534*	.562**	.541*	.635**	.504*	0.041	.866**	.471*
4. Animals Intruder Completion Time				-	.714**	.548*	.738**	.644**	.167	.149	.840**	.169
5. Vehicles Target Response Time					1	.537*	.591**	.637**	.444*	.213	.672**	.281
6.Vehicles Intruder Response Time						-	.514*	.746**	.501*	0.37	.583**	.550*
7. Vehicles Target Completion Time							-	.567**	.175	.222	.649**	.284
8. Vehicles Intruder Completion Time								-	.568**	.227	.748**	.498*
9. Clothing Target Response Time									-	.715**	.467*	.813**
10. Clothing Intruder Response Time										-	.530*	.938**
11. Clothing Target Completion Time											-	.283
12. Clothing Intruder Completion Time												-

Procedure The activity was proposed to children individually and articulated in a session lasting about 45–50 min. It was carried out in the reading room of the kindergarten. The activity required the presence of two operators dedicated respectively to the equipment and children characteristics (e.g., tallness and distance from the screen), task instruction and analysis of the recorded responses.

Results The correct answers, response and completion times recorded in the '*Help me! Santa Claus's assistant*' game have been analyzed insofar they are relevant for the issues addressed here: response time refers to the time needed to touch the picture appeared on the screen (either target or intruder), while the completion time refers to the time needed to put the object in Santa's sack or to take it out of the screen.

The performance recorded evidence that the majority of participants is capable of correctly executing the game on the first run, with a percentage of correct answers equal to or higher than 90%. The remaining 10% of participants correctly complete the game within the third presentation.

Analysis of Pearson's correlations between indices recorded in the game (see Table 1) highlights significant positive correlations between the response time and the completion time of the task for each category. More specifically a positive relationship was found between the time required to direct the attention and initiate the response and the time needed to take and carry out the semantic decision.

Response times recorded for each semantic category suggest specific decision-making patterns for the different categories in response activation and completion times (see Table 2).

Table 2. Means and standard deviations of response and completion time respectively for target items and intruders, in the semantic categorization task (*Santa Claus' assistant* task).

	RESPONSE TIMES		COMPLETION TIMES	
	M	DS	M	DS
ANIMALS – target	6006,42	4733,921	9759,02	5815,76
ANIMALS – intruder	6109,80	3386,81	9548,83	10203,97
VEHICLES – target	3148,90	2229,05	5752,00	5446,14
VEHICLES – intruder	6750,00	9318,25	9780,00	9725,55
CLOTHING – target	2481,97	2037,00	4210,17	2469,62
CLOTHING – intruder	1684,00	897,40	5493,67	1385,16

In particular, results from t-tests show that to decide that a stimulus does not belong to the semantic category (intruder) requires a longer time than deciding that a stimulus (target) belongs to a specific category, namely animals ($t = -5.85$, df 19, $p = .001$), vehicles ($t = 2.831$, df 19, $p = .01$) or clothing ($t = -3.257$, df 19, $p = .004$).

6 Conclusions and Future Directions

The aim of the study was twofold, i.e., to test the system with a group of normally developing children and the adaptability of the system to the variability of children characteristics before using in the clinical setting. Moreover, we want to test the adequacy and sensitivity of a set of games with increasing difficulty in the assessment of the ability to watch, touch and move an object at the same time, to test their visual problem solving skills.

As regards the content and the information gathered from the games, there are some relevant conclusions which are preliminarily suggested by the study.

First of all, the proposed tasks are well accepted and agreeable to participants. As highlighted by the accuracy level, the games are very easy to understand in 4 years old children, who can deal with them flawlessly. When a difficulty occurs, children easily learn how to correctly execute them. As regards the information gathered from the serious game '*Help me!*' data collected underlines its usefulness in analyzing two distinct, but related, levels of visual processing; analyzing a more complex cognitive processing of visual information and decision making in children.

This test suggested us some procedural and methodological issue for the use with CVI children. In order to maximize the effectiveness, it is important to properly prepare the setting for an effective performance: child sitting and instrumentation, position of the chair, audio adequacy, and it is important to provide repeated feedback throughout the games.

Moreover, initial tests with children affected by CVI have provided good results in terms of acceptability of the system, so, given that, these games are intended for a long period of rehabilitation, we are currently developing the system to be accessible from the Internet, providing a specific user-dedicated interface, so that the user can be trained at home, thus reducing the *drop-out-from-therapy* phenomenon.

References

1. Campana, L.: iPad apps for children with visual impairments. In: Proceedings of CTEVH (2012)
2. Ciman, M., Gaggi, O., Nota, L., Pinello, L., Riparelli, N., Sgaramella, T.M.: HelpMe!: a serious game for rehabilitation of children affected by CVI. In: WEBIST, pp. 257–262 (2013)
3. De Bortoli, A., Gaggi, O.: PlayWithEyes: a new way to test children eyes. In: Proceedings of SeGAH 2011, pp. 1–4 (2011)
4. Di Loreto, I., Gouaich, A.: Mixed reality serious games: the therapist perspective. In: Proceedings of SeGAH 2011, pp. 1–10 (2011)
5. Esteban, G., Fernandez, C., Matellan, V., Gonzalo, J.: Computer surgery 3D simulations for a new teaching-learning model. In: Proceedings of 1st SeGAH 2011, pp. 1–4 (2011)
6. Forlines, C., Wigdor, D., Shen, C., Balakrishnan, R.: Direct-touch vs. mouse input for tabletop displays. In: Proceedings of ACM CHI 2007, pp. 647–656 (2007)

7. Gaggi, O., Galiazzo, G., Palazzi, C., Facoetti, A., Franceschini, S.: A serious game for predicting the risk of developmental dyslexia in pre-readers children. In: Proceedings of ICCCN 2012, pp. 1–5 (2012)
8. Galway, T.M., Metsala, J.L.: Social cognition and its relation to psychosocial adjustment in children with nonverbal learning disabilities. J. Learn. Disabil. **44**(1), 33–49 (2011)
9. IETF, Internet Engineering Task Force. The websocket protocol, RFC 6455 (2012)
10. Malkowicz, D., Myers, G., Leisman, G.: Rehabilitation of cortical visual impairment in children. Int. J. Neurosci. **116**(9), 1015–1033 (2006)
11. Michael, D.R., Chen, S.: Serious games: games that educate, train and inform. Thomson Course Technology, 1st edition (2006)
12. Odom, S.L., Chandler, L.K., Ostrosky, M., McConnell, S.R., Reaney, S.: Fading teacher prompts and peer initiation interventions for young children with disabilities. J. Appl. Behav. Anal. **25**(2), 307–317 (1992)
13. Roman-Lantzy, C.: Cortical Visual Impairment: An Approach to Assessment and Intervention, 1st edn. American Foundation for the Blind, New York (2007)
14. Sichitiu, M., Veerarittiphan, C.: Simple, accurate time synchronization for wireless sensor networks. In: Proceedings of IEEE WCNC 2003, pp. 1266–1273 (2003)
15. van Nieuwenhuijzen, M., Vriens, A., Scheepmaker, M., Smit, M., Porton, E.: The development of a diagnostic instrument to measure social information processing in children with mild to borderline intellectual disabilities. Res. Dev. Disab. **32**(1), 358–370 (2011)