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Serious Games to Support Cognitive Development in Children with Cerebral Visual Impairment

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Abstract
Cerebral Visual Impairment (CVI) is a disability that entails a visual deficit, due to a brain damage. Children affected by this disability are not able to see an object if it is not moving. In this paper, we present a study on the use of serious games in the assessment and rehabilitation of children with CVI. Our serious games help them keeping focused on the exercise by using touch interface, game paradigm and cartoon characters. The paper reports lesson learned from data collected in a user study to highlight the high potential of using these games also in the rehabilitation process. For this reason, we develop the games also in the mobile platforms to allow children to train their skills at home, i.e., more intensively and in a familiar environment.

Keywords Serious games based assessment and rehabilitation · CVI · Mobile games

1 Introduction

Cerebral Visual Impairment (CVI) is a disability that entails a visual deficit, due to a brain damage [21]. People with CVI are not able to see an object if this is not moving, they experience a reduced ocular field and ocular delay, find difficult to understand complex images and they are not able to see and touch an object at the same time. Child affected by this disability can experience different levels of these difficulties and usually are not able to focus their attention, even for short interval of time. CVI is also known as Cortical Visual Impairment.

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Developmental trajectories of children with CVI can then differ, in particular qualitatively, from those of children with normal development [27]. Visual disorders can, in fact, impair development of direction and maintenance of *attention* to locations in space that contain relevant information [3, 25]. If visual information cannot be processed accurately and completely, stored information in *visual memory* is incomplete and inaccurate; similarly, the use of vision for action will be less successful [8]. Without an optimal eyes movements patterns and an accurate letters and words processing, the development of an efficient reading strategy will be impaired [16].

Furthermore, for what relates *language development*, assigning names and linguistic labels to visual stimuli, e.g. forms, figures, colors and objects, but also animals, flowers, toys, etc., may be difficult and inaccurate, if visual stimuli are not processed and identified correctly. And correct identification of *visual affective and social information*, which is essential to "read" emotions of other people, can be affected with impaired vision. As a result, social responses may be inadequate or even absent [26].

Stiers and Vandenbussche [24] have shown that children with visual impairment and still useful vision, can learn to engage attention and develop special strategies to enhance the capture of visual information by attention as well as they can learn strategies to develop some reading skills. Similarly, monitoring and controlling relevant information for a flexible adaptation to changes in the environment in the presence of visual impairment, can develop and operate properly when supplementary or compensatory skills are supported in their development and employment [23]. These results motivate to devote particular efforts to make rehabilitation activities more accepted and effective.

For these reasons, many studies have shown that *serious games* can help children affected by disabilities to avoid the *drop-out-from-therapy* phenomenon since they help to obtain their attention and to protract the training session since they have fun [6, 11–13, 18].

In [5] and [13] we described two serious games designed to train children affected by CVI. The system allows to track both eyes movements, thanks to an integrated eye-tracker module, and users' touch interaction.

Children are required to follow a cartoon character or recognize, among intruders, objects belonging to the target category announced by the speaker.

We initially tested the system with 28 children from kindergarten, aged from 3 to 6 years old, who did not experience disability. This initial testing confirmed the acceptability of the system, and the confidence of the children while playing with it. Information about performance in children with normal sight level were also obtained in [13] and were used as baseline when analyzing performance in children with CVI. A second test was conducted by asking to 19 children affected by CVI to play with our games. In this paper, we present two examples of specific patterns which emerged from two participants to highlight the use of the games under conditions of different severity and the high potential use of these games shown by the results obtained with a four years old child who presented with a higher visual cognitive functioning.

The paper is organized as follows: Section 2 presents related and previous works, Section 3 presents the system architecture, while in Section 4 we presents the results obtained during our tests. Section 5 describes the implementation of the mobile version of the games. Finally, Section 6 presents conclusions and directions for future research studies.

2 Related works

Serious games are games or applications which are developed not only for fun, but to engage users into an activity, which produces a common good or teaches something valuable to the player. The idea is to hide, under the games, some exercises to develop particular skills of the user: in this way the user does something useful, which she/he normally would not, because she/he enjoys doing it. If the user has fun, she/he will probably continue to play, achieving the serious goals of the game.

Actually there are a lot of different applications of serious games [18]. In the military field, serious games are used to train soldiers using virtual environments. The main scope is to prepare soldiers to situations and obstacles that may populate the real world, to make them able to make decisions faster and safer. Serious games can be used in the governmental field to simulate the population's reaction to political decisions [20] and in the educational field to increase learning abilities of children as well as to train employees [28].

Serious games are becoming very important, either for doctors, e.g., for their training or to simulate real-life experiences, and for patients, e.g., to hide rehabilitative 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 [9]. Patients can use rehabilitative exercises hidden by games, which encourage them, for instance, to perform specific upper limb movements as those proposed in [17]. Other authors offer telerehabilitation to post-stroke patients so that they can perform the long series of exercises at home [7] or show that not expensive equipment and serious games can open opportunities for rehabilitation programs that could last several months, reducing the *drop-out-from-therapy* phenomenon [12].

Furthermore, games can be tailored for particular disease groups in order to improve patients' recovery and motivation. For instance, *Re-Mission* is a game that helps young patients to understand and deal with cancer by employing game avatars representing the drug that destroys cells with cancer and providing a forum where patients can discuss and support each other [14].

Other approaches show the goodness of the usage of serious games with children. In [6], the authors showed how a visual acuity test can be hidden under a much more interesting game, with the consequence that children pay much more attention to the exercise, and so to the answer for the doctor, with the result that the diagnosis will be more accurate. The game is named *PlayWithEyes* and it is used for the diagnosis of amblyopia: the authors ask the children to perform an orthoptic test to evaluate their visual acuity [6]. DYSL-X [1] integrates Dyslexia predictors in a tablet game to capture the children's attention and obtain a more accurate measurement. The authors evaluated several existing games for preschoolers to derive a set of guidelines to design an optimal tablet game for 5-year-old children; then, these guidelines were used to develop Diesel-X, a game about a dog robot, Diesel, who has to fight against a gang of criminal cats.

It is easy to see that serious games are extremely useful for children because the game can lure players into performing with accuracy an assessment of a particular disease as well as offering rehabilitation and telerehabilitation programs that could last a long period of time. Particular attention should be paid to the interface and to how the game can be effective in engaging children. One interesting possibility is to use the so-called tangible interfaces, which use physical artifacts for accessing and manipulating information [19]. To this aim, Forlines et al. [10] investigated the differences between mouse and direct touch input, both in terms of quantitative performance and subjective preference. The work demonstrated that touch interfaces, even if they may not lead to greater performance, especially for speed and accuracy, are preferable for other considerations like fatigue, spatial memory and simplicity. This is particularly true for children, even those called digital native speakers, who find touch interaction very natural, thus avoiding the need for long training sessions to learn how to interact with touch applications.

To the best of our knowledge, the first attempt to use a game for rehabilitation of children affected by CVI was carried out by Laura Campaña of the Junior Blind of America. She has shown, that if traditional rehabilitation tools are replaced by iPads with some simple games, even without any specific goal and which are not created for this particular kind of children (i. e., Bubbles Magic) that present some words or pictures and play different sounds, the result is that the child is attracted by the pictures and the sounds on the device, he/she pays lot of attention to the tablet and to what happens on the screen [2]. *Tap-n-see Zoo* is an application specific for children with CVI which moves a teddy bear on the screen and plays a sound when the child taps on it [15].

Our solution improves this first approach, since it integrates 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. Moreover, it proposes a game to train a specific skill: the problem-solving capabilities of the child.

3 System

As already introduced in the previous sections, the main purpose of the project is to create a system that is able to perform the assessment and rehabilitation of children affected by Cerebral Visual Impairment. In particular, the system provides to the child three different tasks, each of which has a specific target behavior and purpose.

In particular the proposed tasks were:

1. *Catch me! Where is Peppa / George going?* (Fig. 1). The task goal is on the ability to orient attention, using a cartoon character that moves on the screen. The different movements, chosen according to participant gender, are defined by the doctor depending on child's need.

Fig. 1 Example of the *CatchMe!* game. The cartoon moves on the screen according to game setting and child characteristics

2. *Help me! The Santa Claus's assistant* (Fig. 2). The idea of this serious game is to help Santa Claus in a long-lasting task, i.e., to prepare in advance the sack 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). All pictures take into account the age of acquisition and the organization of the children semantic lexicon at their age. Each child is required first of all to orient the attention and focus on the object, secondly to discriminate between semantically related target images (i.e., images that belong to the target semantic category) and intruders, and third to make a cognitive decision putting the target object into Santa Claus' sack, throwing out of the screen the other ones. It is then a complex set of actions tapping in particular dynamic visual attention, cognitive processing and visuo-motor coordination. If the child fails to discriminate one of the images of a particular set of pictures, he/she is asked to repeat the actions. After three failures in the same level, the game moves to the next sequence.

In addition to these two particular tasks, which are the main ones that collect data and can provide an evaluation of the visual-cognitive condition of the child, there is another task performed before the other two, called *Where is Nemo going?*. In this case, the purpose of the task, which is proposed first to the child, is to let the child practice with movements in the visual field. In particular, the child is asked to look to the goldfish Nemo, which appears on the screen and moves into different directions. The hidden purpose of this task is to calibrate the system, and in particular to calibrate the eye-tracker that will follow the eye movements of the child during the following tasks.

3.1 System architecture

The main potential users of our system are two: the *doctor*, that is responsible of defining the exercises settings of the two tasks, and can check the collected data of the tasks, and

Fig. 2 Example of the *HelpMe!* game. The order of the objects on the screen is changed according to the game definition from the doctor

the *child*, that uses the games and plays with the system, while the system collects the data.

The main parts of the system are the following (see Fig. 3):

1. A server, that stores the data about each game and child and manages the game;
2. A client for the child, used to show the game and to collect the data about the interaction of the child with the system;
3. A client for the doctor, that is mainly used when the exercises is performed at doctor's office to show data in real-time;
4. The eye tracker, an optional component used to collect data about eye gaze of the child.

The server is based on a Java component that, during the exercises performed by the child at doctor's office, manages all the data and packets sent by the client for the child and the eye tracker, to put together all these data and to send a report in real-time to the doctor about the current performances of the child. In this way, the doctor can see the child's performances and have an immediate feedback about how the child is going. If necessary, he/she can adjust exercises difficulties and settings to make the games more suitable for the child.

On the other side, the client for the child is responsible to show the different games to the child and to collect information about his/her interaction with the screen. In particular, while the child plays, the client collects information about where he/she is touching on the screen, how much time it takes to him/her to start interacting with the screen after the initial stimuli, etc. In this way, all these information can provide an easy to read and understand report about the child performance.

All these information are sent from the child client to the server, where even the eye tracker system sends the data. This component is based on the eye tracker system "The Eye Tribe"[1]. In particular, the eye tracker is responsible of gaining information about the eye gaze of the child during the exercises, to give an understanding of where the child is watching during his/her exercises. Therefore, it is possible to see if there is an improvement during the exercises about the ability of the child in watching on the screen, and in particular in watching correctly at the showed image. This component is optional, meaning that the system can run even without the data provided by the eye tracker. This feature is extremely important because the eye tracker can sometimes provide no data, if it is not able to understand where the child is watching. Thus, supporting even no data coming from the eye tracker component, makes the system extremely scalable, as we will see in Section 5, were we will explain how only the client for the child can be detached from the system and used to create a mobile application that can be used by the children at home to exercise and make home rehabilitation. Figure 4 provides an example of the

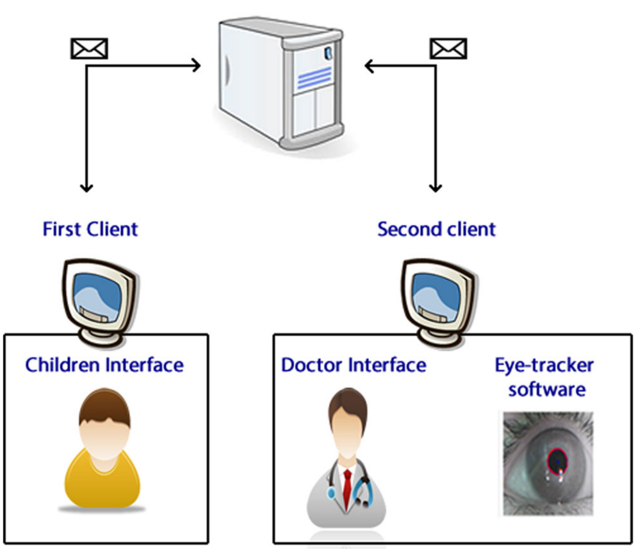

Fig. 3 The system architecture

[1] http://aws-website-theeyetribe-lbmoo.s3-website-us-east-1.amazonaws.com/theeyetribe.com/about/index.html

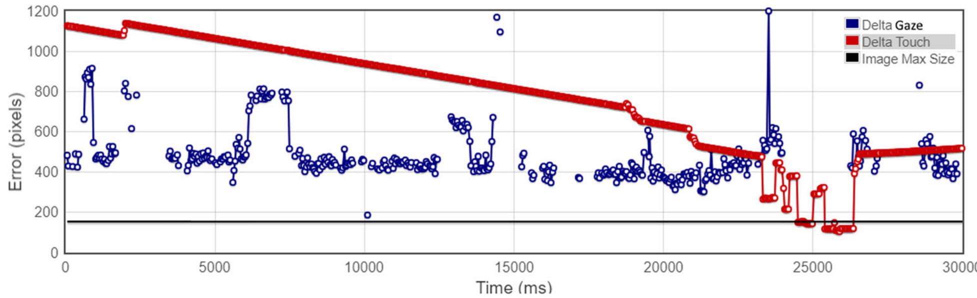

Fig. 4 Example of a the report for the doctor during the *CatchMe!* game

report for the *CatchMe!* game: the graph reported in real-time the position of the gaze and the touch of the child. Figure 5 provides an example of the report of the *HelpMe!* game: in this case the lines on the picture represents the gaze and the touch of the child and the position of the proposed image. The table instead reported the time needed to begin and complete the answer, and the number of correct and wrong answers.

4 Results and discussion

As already mentioned in Section 1, the test phase involved 19 children affected by CVI. Children involved were aged between 4 and 9 years old, 13 of them were females, 5 were males. Unfortunately, not all the data collected during the training sessions are significant to present for several different reasons:

– first, some children with CVI are unable to move their hands in a coordinated way, so they were not able to keep the finger touching the screen along the activity proposed;
– second, sometimes the eyetracker was not able to collect data due to the child difficulty in maintaining the head in the correct position, or because of too many head's movements;
– finally, the variability of children's age with respect to data available from children without CVI limit the comparison with peers without CVI.

For these reasons, in order to highlight the potential of this type of assessment in a variety of conditions associated with CVI, we decided to provide the analysis of two single profiles as examples, presenting changes in their performance in the activities which could be proposed to them and, in one of the two cases, comparing responses with data currently available from age-matched peers.

Our analysis highlights a series of information emerging from the performance of Faith and Hope, two 4 years old girls, both with a marked CVI but characterized by a different severity. In particular, because of the limited

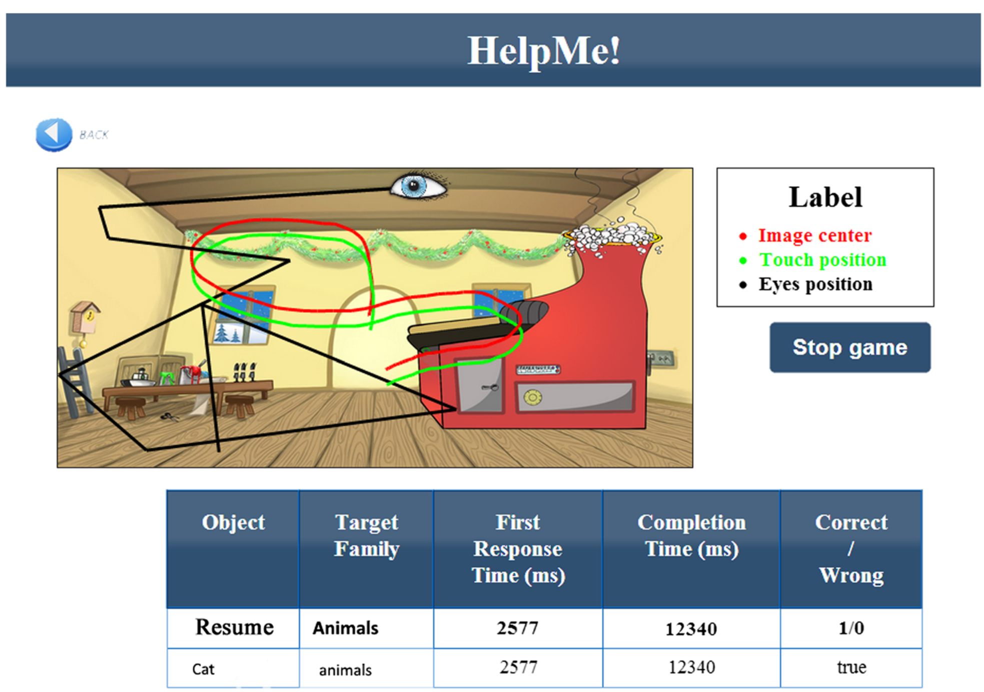

Fig. 5 Example of the report for the doctor during the *HelpMe!* game

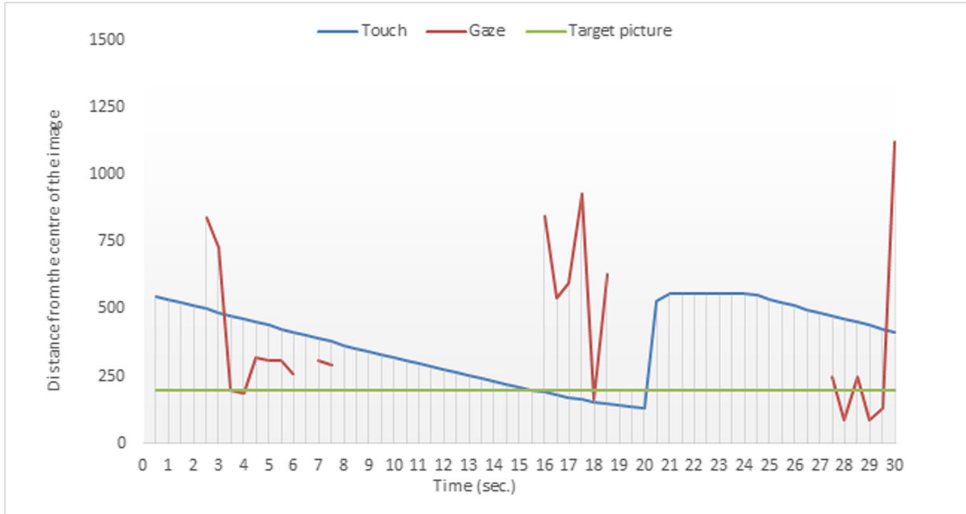

Fig. 6 Delta for Touch and Gaze with respect to the target picture in a portion of Faith's task execution

language development, i. e., in the ability to correctly identify pictures and name them, only the calibration phase and one game could be proposed to Faith while Hope was able to play for the full session.

The goal of the proposed activities was two-fold, i.e., to assess the level of processing of the visual information available to them, and to analyze the learning potential and retention of visual information.

While game *Were is Nemo going?* was used to develop familiarity with the situation and calibrate the system, eye movements, accuracy of the answer and reaction times were collected and analyzed respectively for game *CatchMe!* and *HelpMe!*.

4.1 CatchMe! Visuo-motor coordination game following a visual stimulus moving on the screen

The goals set with this game were twofold. First of all it aimed at describing the basic level of the target skill, that is visuo-motor coordination; secondly at providing information on the learning potential of the participant in order to make more effective subsequent rehabilitation decisions. To accomplish the second goal the game was proposed a second time and some manipulations were introduced [22], dealing mainly with cues and feedback provided during the execution.

4.1.1 Describing visuo-motor coordination

Figures 6 and 7 represent the Euclidean distance between the center of the image presented on the screen and, respectively, the position of the partecipant's eye (Gaze) and the position of the finger on the screen (Touch). The green solid line represents the position of the Target picture on the screen. The pictures provide a temporal description of the performance occurring across the activity and highlights the direction of changes occurring for an interval of time of 30 seconds.

As far as Faith's performance is concerned, along the time interval described in Fig. 6, the Touch index results in an almost unstable line showing a fluctuating performance along the considered time interval. The picture, however, shows a decrease in the distance between the point of the actual touch and the position of the picture on the screen, with Faith finger being able to get closer and closer in the central portion of the time interval described[2], thus suggesting the ability to move toward a more accurate performance.

As far as Hope's performance is concerned, as shown in Fig. 7, along the time interval described in the graph, the Touch index results in an almost stable line with a more marked reduction in the last portion of the considered time interval. At the same time, the picture shows a decrease in the distance between the point of the actual touch and the position of the picture on the screen, with the gap passing from more than 1000 pixels to an interval comprised between 500 and 250 pixels. Hope's finger is then closer and closer to the picture and sometimes on the picture, thus suggesting a systematic trend toward a more accurate performance and a learning process activated in a visuo-motor task.

4.1.2 Sustaining learning with repeated task execution and a higher complexity

Both Faith and Hope were then required to execute the task for a second time. In this case, starting from a

[2]Consider that the distance is computed from the center of the picture, but the picture itself has a dimension, which depends on the user's setting, and in this case is 200x400 pixels.

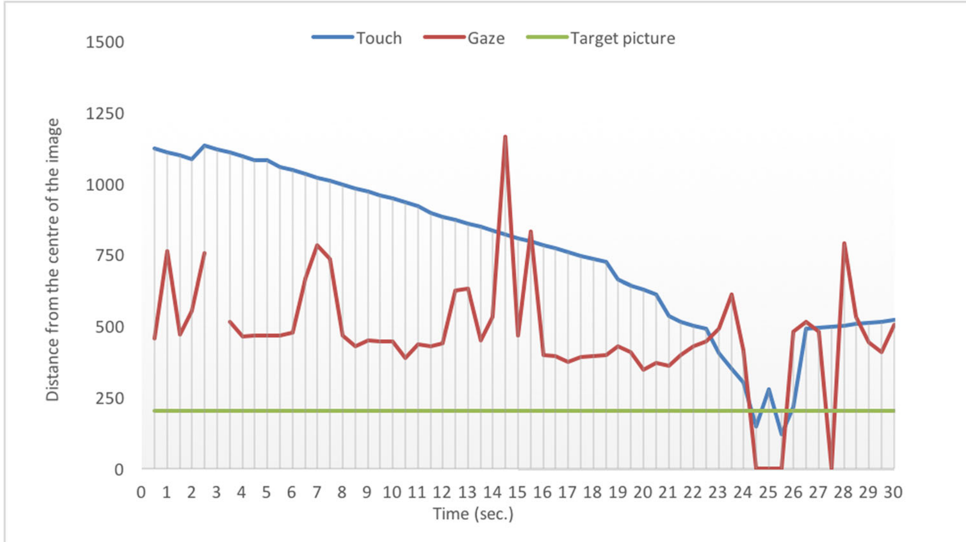

Fig. 7 Delta for Touch and Gaze with respect to the target picture in a portion of Hope's task execution

higher performance gained in the first execution, they were presented the target item in different portion of the screen, hence requiring to orient their visual attention to different portions of the visual field. Figures 8 and 9 describe their performance.

In Fig. 8 Faith performance is presented showing that the distance between the touch and the solid line representing the Target image was mostly correct along the described time interval. The finger pointing was consistently on the actual position of the object moving on the screen. Therefore, in the second trial, except for a short time interval, Faith was accurate and capable of persisting at a very accurate level along the task thus suggesting a high potential of her ability to maintain a visual attention along time.

In Fig. 9, Hope performance is presented showing that the distance between the Gaze line and the solid line representing the Target image was rapidly and markedly decreasing along the time interval described. Here the finger pointing was consistently close to the actual position of the object moving on the screen. In a second trial, once she refreshed the task, her performance improved in accuracy and persisted at very accurate level thus suggesting that continuing with the training the performance could be more accurate and stable displaying her learning potential in focusing attention and in coordinating the hand movements in order to accomplish the task.

4.2 *HelpMe!* A controlled access to complex visual information in a visual decision making task

Given the relevance of the processes investigated in the cognitive development of children and the relevance for school inclusion, cognitive decision making relying on more

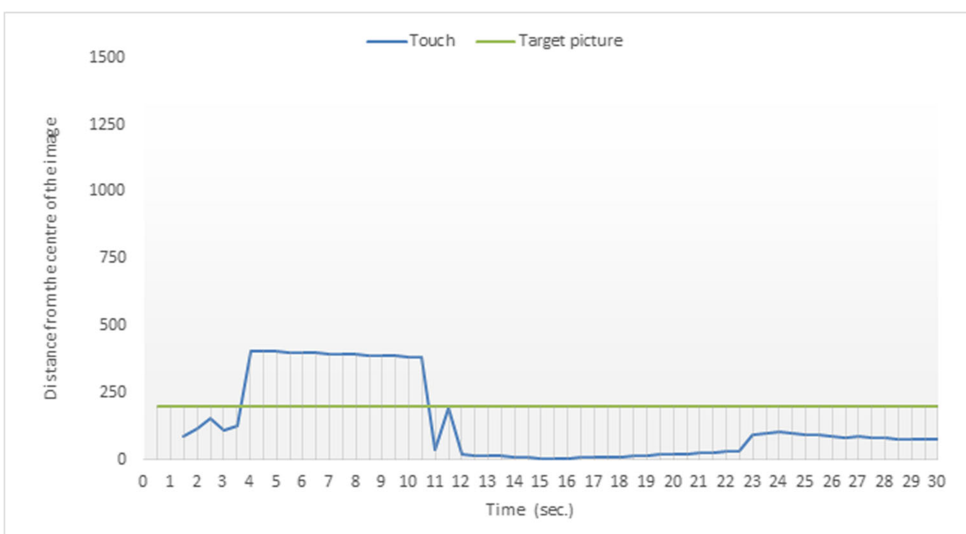

Fig. 8 Delta for touch with respect to the target picture in a portion of the repeated task execution in Faith performance

Fig. 9 Delta for Gaze with respect to the target picture in a portion of the repeated task execution for Hope performance

complex visual information was introduced. Both accuracy of visual attention performance and decisions made were then analyzed.

The task was proposed to both Faith and Hope. Given that Faith was unable to fully understand the instructions and properly carry out the task during the practice session, different activities were proposed to the two children. Only Hope performance in the *Help Me!* game will be described here.

4.2.1 Accuracy in visual semantic decision making

In this game Hope was required to decide on the semantic category to which the object represented on the screen belonged to. Her performance was 77% of correct answers in the first presentation of the items. However, she was capable of reaching full correct performance in the second execution of the task.

Figure 10 shows the details about her performance as compared to age matched peers and described in terms of standard deviation from mean level obtained with 28 children in a previous study [13]. The decision time refers to the time needed to take a Yes/No decision about the semantic category of the object appearing on the screen; the completion time refers instead to the time needed to move the object from the position where it has appeared to the Santa's sack, or to put it in a corner.

The game highlights Hope ability in selecting the appropriate object, maintaining the gaze to an attention level adequate to keep track of the movement until she reaches the appropriate destination. The time required either to decide and to complete the task is within the normal age range insofar it falls within ±1.5 standard deviation.

We analyzed the performance of Hope with respect to the performance of age matched peers to understand if

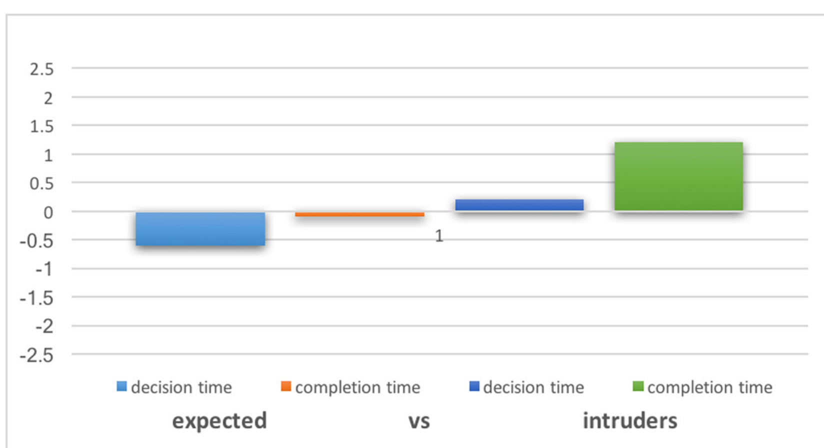

Fig. 10 Hope reaction times expressed as standard deviation from age matched peers in the decision and completion tasks for both expected items and semantic intruders

the performance can be comparable or if children affected by CVI have always worse performances. This result underlines that we cannot take for granted that children with CVI cannot deal with these tasks; we might expect, instead, that some children might exhibit, on these tasks, information processing skills falling within the range of a normal development. This applies both when the picture appearing belongs to the category announced by the speaker and when it is an intruder. Finally, as commonly expected with this type of task, the time required to process the intruder is longer and, strengthening our view, this holds for both the group of peers and for Hope.

4.2.2 Category specific decision making

Objects proposed to Hope belonged to different semantic categories. Her specific skill in making decision about objects from different categories, also characterized by different levels of internal visual structure (e.g., an animal or a car) was then analyzed. Additionally her answers to both expected items and intruders, requiring a specific decisional ability, were separately analyzed.

Figure 11 shows Hope performance as compared to age matched peers. As shown in the figure, items from different categories, with different internal structure, showed a similar level of difficulty for Hope, with the performance in decision making falling within normal age range, either for expected and intruders, that is with unexpected items.

4.2.3 Completion time for specific semantic categories

The time needed to complete the task, for different semantic categories was then analyzed. As shown in Fig. 12, Hope's performance was within normal age range with expected items, i. e., objects congruent with the category announced by the speaker. With intruders of different categories, the time required to complete the task was significantly longer thus suggesting a longer execution time but only when it deals with a structurally more complex category such as means of transportation, although items were characterized by the same familiarity level and age of acquisition as a semantic category.

4.2.4 Summary of results

Data collected with these games highlighted visual attention and visuo-coordination skills in both Faith and Hope, i. e., in two children with severe CVI but different involvement of cognitive functioning. These games have been useful in describing their ability to follow a moving object keeping her gaze coordinated with the finger till the object reached the final appropriate destination. By describing the improvement in the performance during the task, they have been successful in highlighting their learning potential. Additionally, as far as Hope is concerned, data collected with these games also highlighted her visual object recognition and visuo-semantic decision making skills. Indexes used were then useful in tracking learning development in terms of both accuracy and speed of processing, which are relevant in terms of rehabilitation choices and for future perspectives.

From a methodological level of analysis, the described assessments suggest that the tools are adequate, at least when working with 4 to 6 years old children with CVI and residual vision, either in the assessment of visual basic skills and in supporting the development of decision making skills which play an important role in cognitive development.

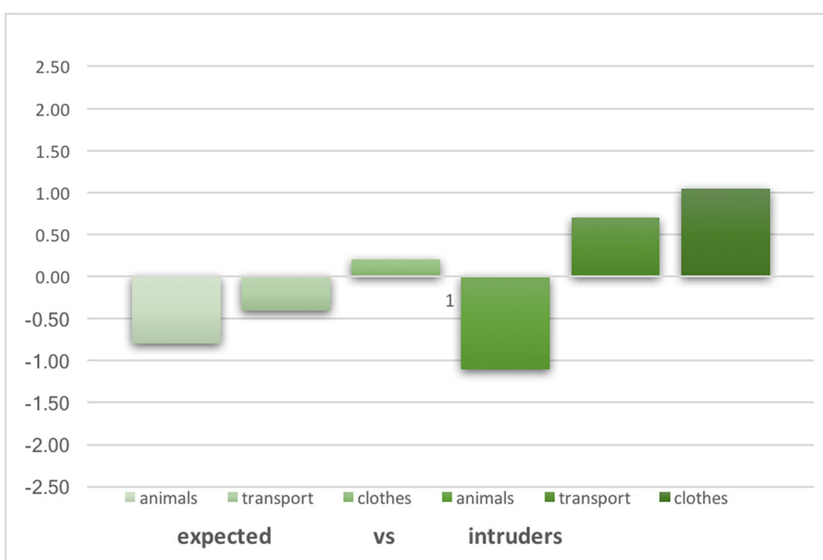

Fig. 11 Hope reaction times expressed as standard deviation from age matched peers in the decision making task for both expected items and semantic intruders

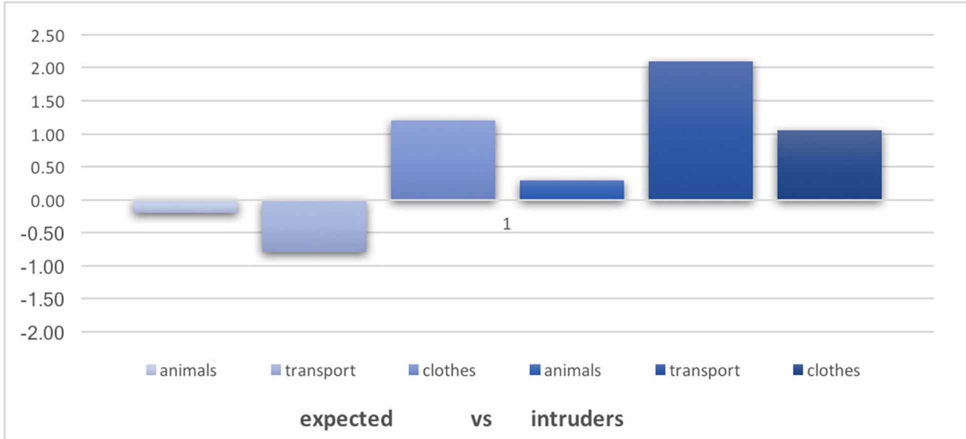

Fig. 12 Hope reaction times expressed as standard deviation from age matched peers in the completion task for both expected items and semantic intruders

Additionally, results provide some general guidelines for subsequent applications of the tools:

- proposing repeated execution of the tasks,
- looking at both accuracy and reaction times and
- manipulating complexity either in visual scanning of the screen and in complexity of the visual structure of pictures used is important in order to foster the potential of the system.

Finally, data collected in situations characterized by different limitations in cognitive skills supports the usefulness of at least some of these games also when marked cognitive development is associated with CVI. Moreover, since the system proposes different tasks, characterized by different contents and degree of complexity and it is easy to personalize, it is useful for a quite wide range of visual impairment conditions, i. e., children with different degrees of impairment and patterns of skills, thus overcoming barriers both in the assessment and in the rehabilitation process.

5 Going mobile for ecological intensive rehabilitation/practice

As we already presented in Section 4, results from the assessment of specific visual skills in a child with CVI, when tested with our system, were useful both in assessing basic skills and in analyzing learning potential and persistence of learned tasks related to the ability of recognizing and following object moving on the screen and, more demanding, on taking cognitive decisions on the incoming materials.

Considering that the described results are observed in a test that lasted for a very short interval of time, about 15 minutes, the possibility of using the game for longer time intervals becomes very interesting and more appealing. A further step is then implementing a solution, which might allow children and their parents to have the opportunity of practicing these activities in a more extended, and, at the same time, intensive, way: to give the child the possibility of using the game at home, thus giving the possibility of practicing the more they can, whenever they want, with the support of their parents, and in a more comfortable and familiar environment.

Since the games are proved to be engaging, either the duration of the training session and the complexity can be set and modified when needed to a more complex and demanding level of analysis, thus providing a personalized learning.

For this reason, we implemented a mobile version of our games *CatchMe!* and *HelpMe!*, to make them available to children to play at home, maybe following a program provided by their doctor.

One of the problem it is necessary to address, when developing applications for mobile users, is related to market fragmentation. Despite the low number of children affected by CVI, supporting only a particular device/operating system could strongly reduce the number of potential users, hence reducing the possible benefits of our application. For this reason, the best approach for developing is a cross-platform framework [4], that let developers build only one application using the framework specific language, and after deploy this application to multiple mobile operating systems, e.g., iOS, Android, Windows Phone, etc. Since the system has already been developed and tested, we decided to use the Apache Phonegap framework[3]. The advantages of this framework is that it uses a webkit engine to incubate a web application, developed using HTML5, CSS3 and Javascript, into a mobile application that can be installed on mobile platforms.

Due to technology limitations, i.e., we can assume that all children have a smartphone or a tablet, but they surely do not have an eye-tracker at home, differently from the complete platform able to collect data from eyes and

[3] https://phonegap.com/

touch interactions, the smartphone/tablet version of our games only implements the data collection of the touch interactions, as it is extremely complicated to implement a kind of eye-tracker using only the front camera integrated in each smartphone/tablet device.

The mobile application, after requesting for username and password defined with the doctor when the child was added to the system, let the child decide with which game he/she wants to play, i.e., *CatchMe!* or *HelpMe!*. Then, the application downloads the game settings for the child, that could be personalized by the doctor after having analyzed the performances of the child, to make the exercises more suited for the current state of the child.

Once downloaded the settings, the application records information about the touches and the interaction of the child with the game during the whole session, and stores this data locally in the memory of the device. Only at the end of the game session, and if an Internet connection is available, the application will ask to upload the data on the server. The uploaded data contain information about the game settings used during the game played by the child, e.g., screen resolution, images size, etc.; the interactions of the child with the screen and the game and, in case of the *HelpMe!* game, the number of correct and incorrect answers. For the *CatchMe!* game, once all the data upload has been completed, the server analyze interactions and image's movements to provide an objective evaluation of the touch performances of the child.

Once the data is uploaded, the doctor is able to analyze data and performance of each child for the specific exercises carried out; he/she can also modify settings and tasks to make them more suitable for further progresses of the child and/or taking into account the difficulties encountered by the child while exercising at home.

6 Conclusions

In this paper, we have analyzed the results obtained using our serious games for the assessment and rehabilitation of children affected by CVI. Combining both basic visual search task with more complex tasks requiring attention and cognitive processes, such as decision making, allows a "whole child" evaluation and helps identifying all areas of strengths and difficulties, a direction advocated by neuropediatrics as crucial for fostering the development of children with CVI.

By supporting the assessment of preserved skills, the system supports also a personalized learning for children with CVI, that is providing a condition in which the pace of learning, the level of difficulty and the instructional approach are optimized for the needs of each learner. In addition, the activities implemented in the system are meaningful and familiar to learners thus driving their attention. Identifying ocular, oculomotor, perceptual and/or visuo-cognitive preserved skills is, in fact, essential for CVI children in order to apply specific habilitation programs and increase their potentials for inclusion and participation.

Despite the difficulty in collecting data that can be compared with normally developing children, the analysis of data collected with a four year old child has shown an improvement in the performance even with a very short training session (only 15 minutes), so the system is promising for implementing a personalize learning. For this reason, the mobile version of our serious game which we implemented can be effective in allowing children to train themselves at home, for longer interval of time. Moreover, the system implemented provides a mechanism for recording learning achievements and communication between the family and the professionals. The pace and learning development curve can provide the basic information for identifying strategies for everyday life both at home with family members and for teachers in the educational settings.

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