Application of Eye Tracking to Support Children's Vision Enhancing Exercises

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Abstract The paper presents the results of an initial experiment aimed to check if it is possible to enhance a low vision stimulation intervention with interactive games. There were 35 children with normal vision and various vision deficits examined using three different interactive games. The interactivity was achieved with the usage of an eye tracker—a device that is able to register eye movements and recalculate it to a gaze point—a place on a screen where a child is looking at. The obtained results are encouraging as most of the children were able to fulfill all games' achievements and expressed their engagement.

Keywords Eye tracking · Low vision · Vision stimulation

1 Introduction

Vision plays a crucial role in human life. Vast majority of information that is acquired by human brain is registered by eyes. It is especially important to children when they learn how to handle in their environment and learn various skills like reading and writing. Lack of ability to see the surrounding world properly may cause some serious negative consequences for children not only for cognitive processes but also for psychosocial ones.

Previously, there was a common belief that people with low vision should save their sight and use it sparingly. However, it occurred that intensive use of eyes does not cause damage or decrease the degree of remaining vision [2]. Moreover, intensive eye related exercises may improve vision or at least enable children to use their eyes more efficiently and develop some new visual skills. Therefore, nowadays, it is the

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well-established practice to use various vision related exercises during low vision rehabilitation [8]. The main problem of such exercises is that they are boring and cumbersome for children. Many people recall such a treatment from their childhood as a nightmare. Therefore, our idea was to combine vision exercises with fun, by letting children to play games. This idea was possible due to the usage of a simple and affordable eye tracker that enabled to add some interaction during exercises.

1.1 Low Vision Stimulation Intervention

Low vision stimulation intervention should not be confused with vision therapy. Vision therapy is developed to cure specific eye related diseases—e.g. surgically or pharmaceutically—and it is provided by ophthalmologists. In contrast, vision stimulation intervention helps children to use their vision more effectively [8]. It has been proven that it may help to activate brain areas and maximize vision comprehension even without any other medical interventions. It is especially important for brain diseases for which there is no medication or surgery. Cortical Vision Impairment (CVI) is one of the examples of such a disease. CVI is a condition in which the visual pathway and visual processing centers of the brain are damaged and result in reduced vision [6]. There are reports that 95 % of children with CVI developed higher levels of vision within a period of 3.7 years after receiving a program of visual intervention [7].

As there is an evidence that playing computer games may enhance visual skills [1] there are attempts to use it directly during treatment of children with low vision. One of the examples is a virtual-reality (VR)-based display system that facilitates the treatment of amblyopia [4].

1.2 Eye Tracking

Eye tracking is meant as an ability to determine gaze position—the place where the user is looking at. Although there are multiple different eye tracking methods, the most convenient and popular one is a so called videooculography (VOG). Typically VOG utilizes an infrared camera and infrared light sources. Reasons to use infrared light are twofold. Firstly, a pupil (eye center) may be easily localized in infrared light, because it is the darkest region of an image. Secondly, infrared light sources are invisible for participants and therefore not disturbing their vision. A position of reflections of light sources from a cornea—called 1-st Purkinje reflections or glints—may be used as an additional input which makes eye position measurement less sensitive to head movements (Fig. 1).

The data that is taken into account while estimating eye position is a vector between an eye center (center of a pupil) and glints. Obviously, length and direction of such vector depends on a distance from a screen, camera and light sources position

Fig. 1 Eye image with visible glints (1-st Purkinje reflections)

and—last but no least—a corneal curvature, which is person specific. Therefore a calibration procedure must be performed prior to the vector's usage as a source for gaze position. Typically the calibration consists of presentation of some (5–9) points on a screen. The task for participants is to look at these points for some time. Based on the gathered data the system is later able to compute a function that recalculates an eye center and a glint vector to screen coordinates of a participant's gaze.

2 Method

All vision related exercises were conducted with the usage of a computer and an eye tracker device. Participants were seated at a computer display and worked with a specially designed application. Their eye movements were registered with an Eye Tribe eye tracker. The Eye Tribe is an example of VOG devices. It is able to record eye movements with frequency 30 or 60 Hz. The device should be located below a display and there is a prior calibration required before every usage. Based on an eye tracker output it is possible to calculate information about screen coordinates of a gaze point (e.g. a place where the participant is looking at).

The usage of the eye tracker made a gaze contingent interaction between a participant and a computer possible. There were overall seven different visual games prepared for the purpose of the experiment. The aim of each game was to force participant's eye movements to accomplish some tasks (Fig. 2).

Finally, only three of that games were used during experiments. During the first game (named "object game"—OG) child's task was to find objects with a specified color. A child had to look at such an object and click a trigger button. There were always four objects with the specified color on the screen. Figure 3 shows a sample screen from this game.

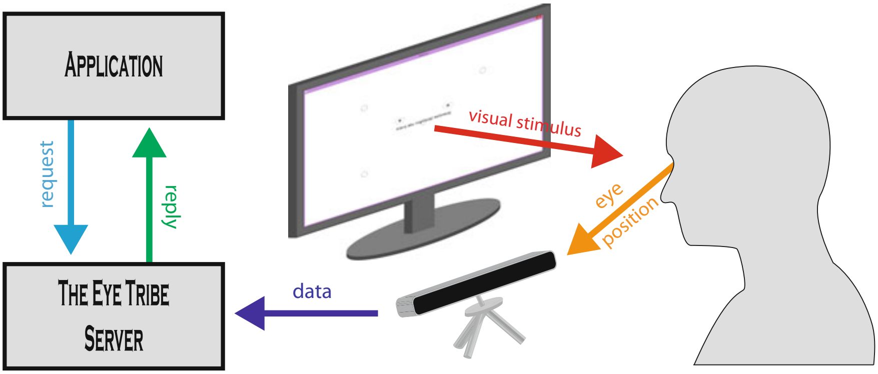

Fig. 2 System architecture

Fig. 3 A sample screen from the first game (OG). There is an initial screen visible on the *left*. The task for a child is to find all *yellow* objects, look at it and click a trigger button. A chosen object disappears. The game screen after pointing all four objects is visible on the right panel. Additionally, *red circles* with lines visualize fixations (places where gaze was focused for some time) and scan paths of the gaze

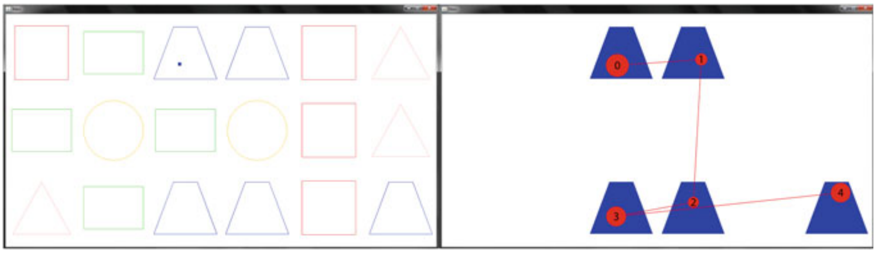

Fig. 4 A sample screen from the second game (FG). There is an initial screen visible on the *left*. The task for a child is to find all trapezoids, look at it and click a trigger button. A chosen object disappears. A sample of recorded fixations (*red circles*) and a scan path are visible on the *right panel*. Additionally, trapezoids have been highlighted, which was not possible during the game

The second game (named "figure game"—FG) was very similar but this time a task was to find geometrical figures. Contrary to the first game, objects were painted in low contrast with white background (Fig. 4).

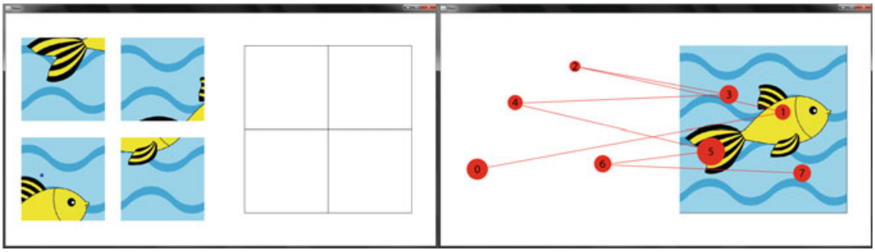

Fig. 5 A sample screen from the third game (PG). There is an initial screen visible on the *left*. The task for a child is to look at one piece and click a trigger button. After that the child should look at the correct place for this piece and once again click the trigger. A sample of recorded fixations (*red circles*) and scan paths after completing the task are visible on the *right panel*

Fig. 6 The four difficulty levels for the puzzle game

The third game was a classic puzzle game (PG). The task for participants was to point with eyes a piece of image on the left side and then point with eyes the correct place on the right side of the screen (Fig. 5).

All games were prepared with four different difficulty levels. A sample of these levels for puzzle game (PG) was presented in Fig. 6.

3 Participants

35 participants aged 5–12 took part in the experiment based on games presented in the previous section. 25 of them were patients of Department of Ophthalmology, Medical University of Silesia, Katowice, Poland. All participants have been divided into four groups:

- HL—children without any diagnosed problems with sight (10 participants),
- GA—children with good visual acuity but with some other dysfunctions (10 participants),
- LD—children with low disorder of sight (10 participants),
- SD—children with significant disorder of sight (5 participants).

All experiments were provided after parent's consent. The purpose of the experiment was to answer the four research questions:

1. Is it difficult for children to work with eye tracker and the application?
2. Do sight disorders influence the game results?
3. Is it more difficult to play games with only one eye?
4. Is such kind of therapy interesting for children?

4 Results

Every experiment started with a calibration of the eye tracker and then a participant played all three games. It is important to mention that there were seven children that did not accomplish at least one of the games. The reason of it could be problems with calibration or just the lack of interest in the game, which resulted in the lack of concentration.

4.1 Timing Analysis

There were three different parameters taken into account when analysing data recorded for OG and FG games:

- Time to find the first element (T1),
- Time to find the next element (TN),
- Total time of the game from the start to the end (TT).

It is visible that the best results are obtained for healthy children (HL). The results for other groups are similar with no significant differences. The total time for group with significant disorder (SD) is higher than for the other groups. What is interesting, the time to find the first element is about 50 % of the total time for the first three groups while it is only 30 % of the total time for the fourth group (Tables 1, 2 and 3).

Although the task was similar to the object game (OG), all groups but the second one (GA) needed more time to accomplish it. The reason was obviously the lower contrast of the image. It was especially problematic for participants from the SD group—they needed three times more time to accomplish the task comparing to the healthy children (HL). Interestingly, children from the GA group finished the second game faster than the first one.

Table 1 Results for the object game (OG) divided into groups

Group (size)	T1 (s)	TN (s)	TT (s)
HL (9)	9.8	3.5	19.5
GA (9)	22.7	9.6	42.7
LD (9)	20.9	8.4	46.2
SD (3)	17.4	12.6	54.5

Table 2 Results for the figure game (FG) divided into groups

Group (size)	T1 (s)	TN (s)	TT (s)
HL (10)	7.5	6.3	26.3
GA (9)	9.3	6.7	27.6
LD (9)	17.6	12.6	55.2
SD (4)	27.8	16.1	79.5

Table 3 Results for the third game divided into groups

Group (size)	T1 (s)	TN (s)	TT (s)
HL (9)	9.8	4.2	40.4
GA (9)	5.8	5.4	65.7
LD (8)	25.6	9.7	93.1
SD (3)	32.9	10.9	210.2

For the third game (puzzle game) there were also three parameters taken into account:

- Time to get the first element (TG),
- Time to put the first element (TP),
- Total time of the game from the start to the end (TT).

Similarly to the previous games, healthy children (HL) were the fastest and children with significant disorders (SD) the slowest ones. The between groups differences are higher, what shows that this game was more challenging for children with low vision.

4.2 *Results for both Eyes and One Eye*

Eye patching (disclosure) is one of the most popular treatments of children with amblyopia [3]. That is why it was decided to check if it is more difficult to play games with one eye covered. Only the children from HL (healthy children) group took part in the experiment. The children played the same game with two eyes and with one eye covered. The same time related parameters were used to compare both results. It showed no significant difference as it is visible in Figs. 7 and 8 for the first and second games.

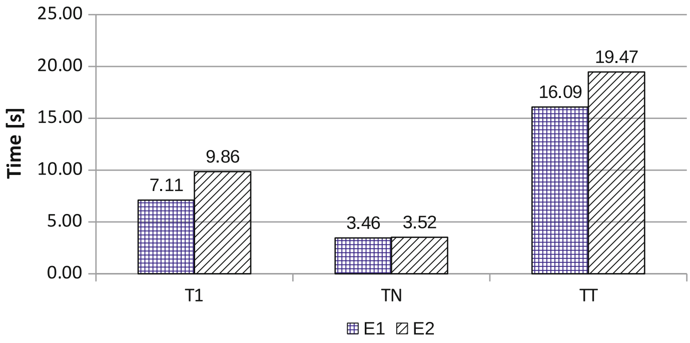

Fig. 7 Results for the HL group playing the first game with one eye covered (E1—*left*) and two eyes (E2—*right*)

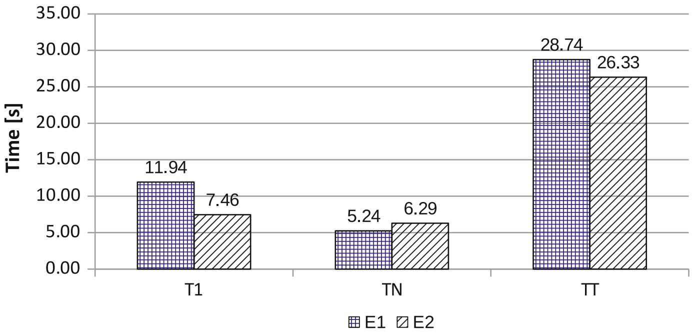

Fig. 8 Results for the HL group playing the second game with one eye covered (E1—*left*) and two eyes (E2—*right*)

4.3 Comparison of Results According to Age

The next step of the analysis concerned the age of children. As the range was quite broad the question was if the results are correlated with age. To have comparable results only children from groups HL and GA were taken into account as these children had the correct vision acuity (visus 5/5). It occurred that the correlation between age and total time is not significant (0.17) what means that age does not have important influence on ability to finish the game.

5 Discussion

Concerning the research question formulated at the beginning of the experiment, if it is difficult for children to work with the eye tracker and application, it occurred that about 87 % of attempts to finish the game were successful. It must be noticed that in most eye tracking experiments there is some group (approximately 5–10 % of population) that is not able to finish an experiment for different reasons [5]. Children (especially those with low vision) may be regarded as one of the most challenging groups, so, in our opinion, the results are quite encouraging.

There was at least one child in every group which did not accomplish at least one of the games. But it is worth noticing that out of 7 children that had problems, 5 had a diagnosed squint. Overall, only one of six patients with the squint was able to finish all three games. It suggests that the squint may be a serious obstacle while working with gaze contingent interfaces.

Sight disorders influenced the game results. The experiments showed—unsurprisingly—that children with normal vision were faster in accomplishing visual tasks. However, what may be more important, it also proved that even children with significant vision deficits may be successful in playing gaze contingent games. Noticeable, some of such children achieved results comparable to the healthy group.

Our experiments with healthy children showed that eye disclosure (pathing) does not significantly influence the results of the experiment. So it may be concluded that game based therapy may be successfully combined with the traditional patching.

It occurred that such therapy was far more interesting for children than typical vision enhancement exercises. Although some of them had problems with calibration and focusing on the task, most expressed their amusement and asked when they would have an opportunity to improve their results.

6 Summary

The paper presents a preliminary experiment aimed at checking if eye tracker enhanced visual games may be used during low vision stimulation intervention. It showed that such exercises are possible and even children with serious vision deficits are able to take part in them. The next step will be analysis of possibilities to incorporate it into the real low vision developing programs. We hope that this initial idea will be in future extended and it will be possible to evaluate its benefits for children with low vision care.

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