Assistive tools for People with Cerebral Palsy: An Eye Tracker Calibration for Vision and Focus Training

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***Abstract*—Eye Tracking technologies opened countless opportunities thanks to their non-intrusive way to interact with people, not only defining new levels of entertainment, but also providing significant important data in healthcare, offering treatment through training for people with vision disorders. In this paper we present an approach for helping children with cerebral palsy to adapt to the world and increase their capacity of concentration by enabling them to use Eye Tracking devices without requiring the classic time consuming calibration tests.**

Keywords — Cerebral Palsy; Human-Computer Interaction; Eye Tracking;

I. Introduction

Eye tracking became a great provider of data for multiple domains, enabling the development of valid and reliable methods in Human Computer interaction and image processing [10] domains. Medical approaches have also great benefit out of this because of its non-intrusive way of providing relevant information for modern surgical training [6] . Having access to data such as gaze locations of people suffering of mental illness, attention and focus disorientations such as cerebral palsy, is an amazing opportunity for helping these people adapt to the world they live in and improve their life conditions in personal and work environments..

According to Cerebral Palsy Alliance [2] the "cerebral palsy" term refers to a group of disorders affecting a person's ability to move. The cause of the disorder is the damage to the developing brain either during pregnancy or shortly after birth. From a physical point of view symptoms of CP can be recognised as disturbances in body movement, muscle control, muscle coordination, muscle tone, reflex, posture and balance. People who have CP may also have visual, learning, hearing, speech, epilepsy and intellectual impairments. Although cerebral palsy is a permanent life-long condition, some of these signs of cerebral palsy can improve or worsen over time, depending if the proper treatment is applied as soon as the first symptoms are detected.

There is a classification of the types of CP [3] even though it is not made on a specific set of criteria. This information provides just some information, but it is used, even by doctors because it offers a simple method to communicate the scope of the impairment.

- *Mild CP* - a child can move without assistance; his / her daily activities are not limited.
- *Moderate CP* - a child will need braces, medications, and adaptive technology to accomplish daily activities.
- *Severe CP* - a child will require a wheelchair and will have significant challenges in accomplishing daily activities.
- *No CP* - the child has Cerebral Palsy signs, but the impairment was acquired after completion of brain development and is therefore classified under the incident that caused the CP, such as traumatic brain injury or encephalopathy.

Although approximately 2 in 1000 liveborn suffer from CP [8][9], recent studies showed us that the CP are decreasing [7]. Statistics show that at least 42% children having CP have also vision problems, 58% have difficulty with communication and 23%-56% have learning disabilities. Predominantly people with CP have abnormal muscle tone, leading to issues in reflexes, motor development and coordination. Because of these vision problems, these children most likely will struggle with essential tasks like reading, becoming very easily frustrated and distracted.

The problem seeked to solve is not the lack of vision, but rather the lack of the capacity to focus on the important targets. The solution developed resembles an attractive virtual environment in which the children are asked to find diverse objects or complete certain tasks which will help them to sharpen their visual skills and improve their attention on the elements that matter.

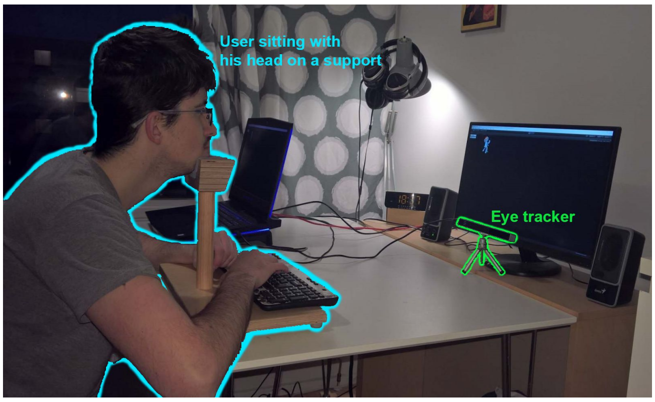

Figure 1. System setup

The system contains an eye tracker (TheEyeTribe [5]) set up under a 24" monitor and at 60cm away from the user (see Figure 1). The user is asked to sit in front of the system standing with his head on a support, so that the position of his eyes remains still and the distance between his head and the eye tracker is always the same.

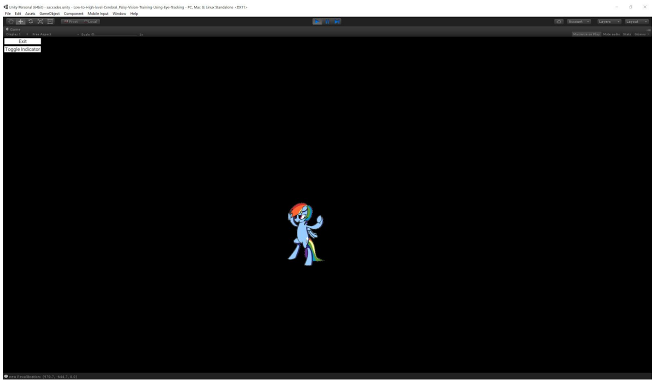

Figure 2. Training scenario

Figure 3: Interactable object dataset sample

II. The Environment

Since CP needs to be treated from an early age we focused on selecting our target users from a very young age range, but because the ability to communicate with them was also crucial in this procedure, we decided to work with children of age between 4 and 8 years old. Since CP is caused by a brain-disorder, it is important to start the intervention as early as possible, in order to help to establish the missing connections and in order to get better motor control as well as improving cognitive learning.

III. The Training Scenario

The training application was as a blank screen having one single animated object set on it (see Figure 2). The purpose here is to train the user to fixate on the object by registering the gaze points on the object in 3 consecutive frames. By doing this, the object will start to animate and after 3 seconds of continuous fixation it will change its location on the screen. The user has to follow that object with his sight(focused) for 60 seconds.

The exercise was inspired from a program for children called visual health stimulation [3], and was designed to be interactive and rewarding, offering only positive and no negative feedback. For avoiding our CP children to fall into boredom by watching the same element for a longer period, the training application was provided with a larger set of animated objects (see Figure 3) which are getting swapped after a certain number of seconds.

IV. Experiments

In order to see if such a solution is really worth trying for working with children with disabilities, the first approach was to test it on healthy people and by achieving a result it would have been confirmed that the experiment can go further with CP children as participants. In this section it will be detailed an experiment held with a group of people, in order to see how reliable is using the same calibration on multiple people.

We selected a group of 4 participants of age between 18 and 22 years old to calibrate the eye tracker and afterwards provide it for the other users to interact with the training scenario.

	P1	P2	P3	P4	P4(no glasses)
ART	20.9804	28.4314	22.5490	52.1471	26.6667
SL	129.370	101.4941	107.8136	187.2706	142.5773
ObjNr	51	51	51	34	51

	P1	P2	P3	P4	P4(no glasses)
ART	26.5882	21.4510	23.0980	89.3500	45.3333
SL	139.8307	133.8470	161.7143	231.3582	193.4644
ObjNr	51	51	51	20	39

	P1	P2	P3	P4	P4(no glasses)
ART	20.6471	23.2549	22.8235	68.5000	23.5882
SL	137.7059	116.9868	145.4623	324.6122	152.4952
ObjNr	51	51	51	26	51

	P1	P2	P3	P4	P4(no glasses)
ART	55.4688	65.9259	53.7576	40.0909	46.5526
SL	136.4295	114.6464	111.3284	124.4082	152.1299
ObjNr	32	27	33	44	38

	P1	P2	P3	P4	P4(no glasses)
ART	30.4314	59.2667	44.2	61.2759	20.9412
SL	127.9457	137.0826	135.9866	219.9844	117.5778
ObjNr	51	30	40	29	52

Figure 4: Experiment 1 results

One of the participants of this experiment was wearing glasses, having myopia, reason why he was asked to participate to each experiment twice, with and without the glasses, aiming to track down if wearing glasses has any influence on the result.

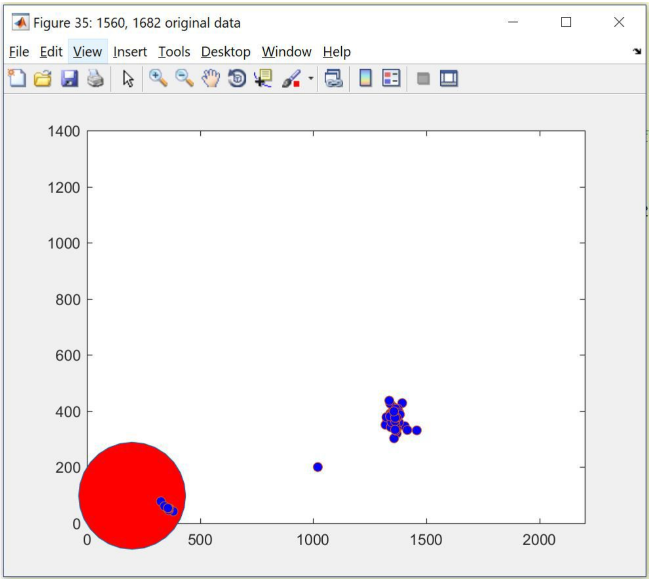

Figure 5: Sample of the collected data on user participant 4 with glasses interacting on calibration made by him without glasses

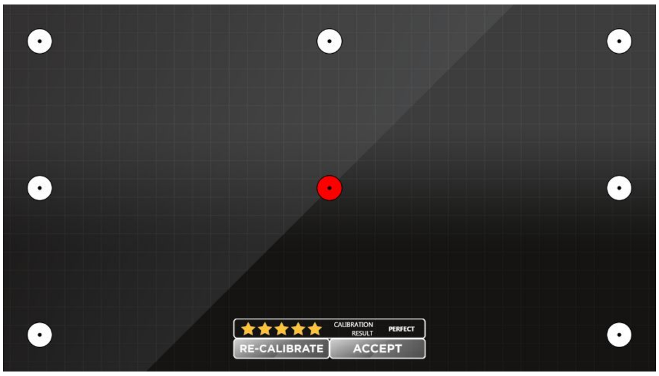

Figure 6: The Eye Tribe basic calibration procedure

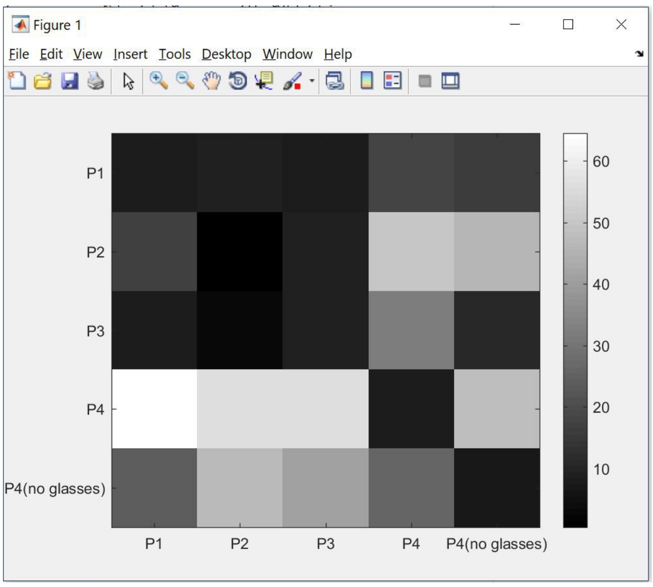

Figure 7: Experiment 1 - Average Reaction Time Histogram

Out of this experiment it was extracted for each frame a set of data containing the center location of the object, the gaze location of the user and the time of the frame from application start. Out of this data, the following metrics were estimated:

1. *Average Reaction Time(ART)* - calculated as being the time from the time of spawning the object until the system detects the user focusing it. The lower this time it is, the better is the reaction time of the user and the better is the calibration.
2. *Scattering Level (SL)* - Showing how much the gaze points are varying upon fixating on an object. This distance is basically the average distance between each pixel and the center position of the cluster (in pixels).
3. *Number of objects interacted with (ObjNr)* - The number of objects the user managed to interact with within the recording time (30 seconds) - maximum 49

V. Experiment 1: Using the calibration from a person to another

By working with people it comes easy to see that not everyone can perform a calibration, fact that rises the question if there is any chance to see any similarities between calibrations that would allow a person to use the eye tracker calibrated by someone else. Testing this theory was done by asking each of the participants to complete the basic eye tracker procedure offered by The Eye Tribe device. This procedure consists of looking at a white dot which is spawning in one of the 9 positions represented in figure 6. What followed was that all the participants were asked for each of the calibration to use the application, verifying how other calibrations compare with their own.

Figure 4 is displaying the performance of the first approach, the green columns indicating the person who made the calibration for each table. A big conclusion that can be taken from the beginning is that people who have sight problems will have difficulties in most of the cases when using other people's calibration, no matter if they use or not their glasses.

It is evidenced that the first 3 participants have very close performances as a result of being able to use the eye tracker calibrated by another of them. It can easily be concluded that the first 3 participants with no sight problems can use each other's calibration to receive the same performances just as they would use their own calibration. On the other hand all these participants had difficulties collaborating with participant 4. Not only the rest of the users, but even participant 4 himself had difficulties in completing the exercises when wearing his glasses on a calibration made by him without glasses.

Figure 5 indicates clearly the detection problem, the red circle illustrating the object on the screen, and the blue points the detected gaze locations for every frame performed by participant 4 with glasses as user, on a calibration made by himself without glasses. Clearer can be seen in Figure 8 that the focusing location was not interpreted correctly by the Eye tracker, most of the detected gaze coordinates being at around 500 pixels away (on a 4k screen resolution).

What happened in experiment 1 is illustrated in Figure 9, the screen shape seen by the system from the calibrator (the user performing the calibration) and the user's point of view differing. The first screen is how the calibrator's gaze locations are interpreted by the screen, the colored object being exactly what he sees. When it comes to someone else to use the same calibration, the system interprets that his gaze location to be a bit translated, just like the red object from the same screen.

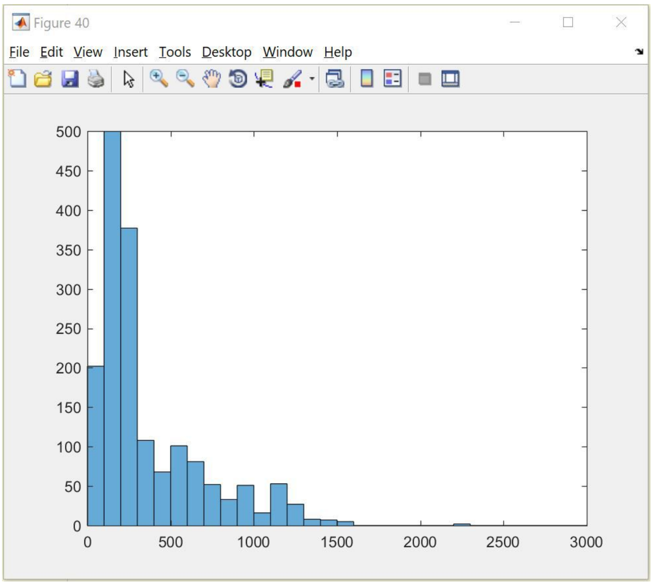

Figure 8: Histogram with the distance between the object and every gaze point for user and calibrator participant 4 without glasses

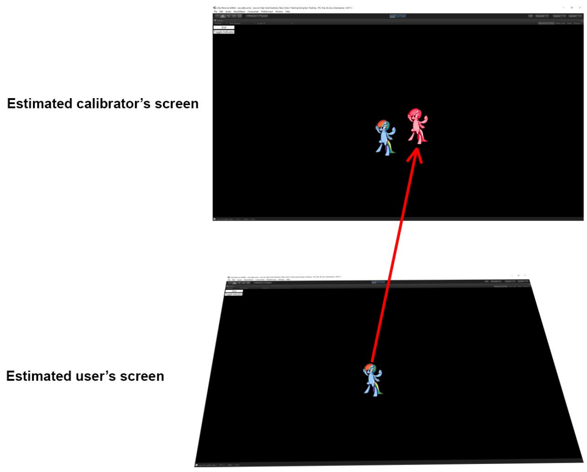

Figure 9: View of the screen from the system's point of view in first experiment

VI. Experiment 2: Using a 2 step calibration

The user coordinates are seen as the ones corresponding to the second screen, which is the reason why when displayed on the current calibration screen the gaze locations are not the same. The approach for the second experiment was having a simple adjustment setup, a point pattern matching that can be implemented for matching the gaze coordinations to the points seen by the eye tracker. The experiment was conducted in the same way the first one was, with the addition that the tester's gazing position is changed to fit the current calibration with the help of an affine transformation.

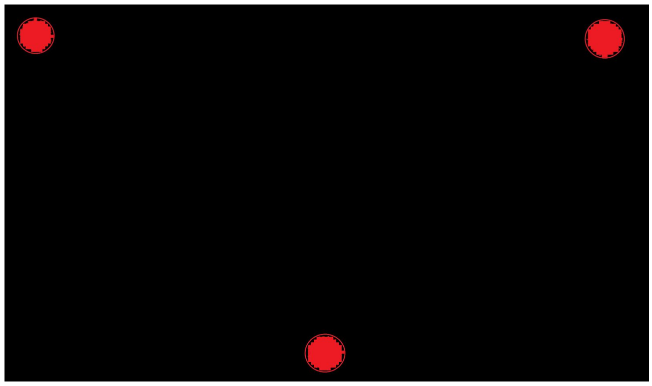

Figure 10: Recalibration positions for experiment 2

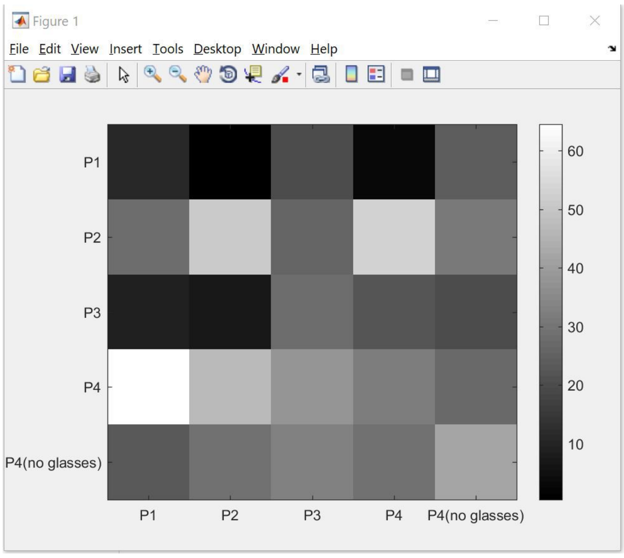

Figure 11: Experiment 2 - Average Reaction Time Histogram

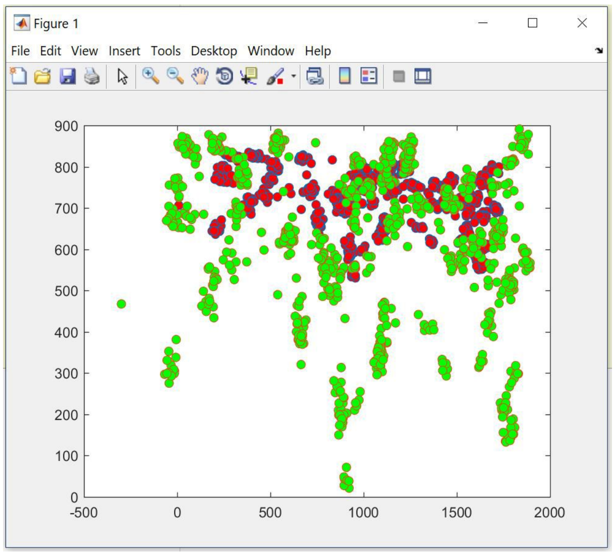

Figure 12: Transformation gaze points from user's to calibrator's coordinate system

From this stage, 3 calibration points were established just as Figure 10 indicates. At the beginning of this experiment the object was situated in each one of these 3 locations, and the user was asked to confirm verbally the moment he looks at the object. At his signal the assistant of the experiment will register the coordinates that the user is gazing upon, repeating this for all 3 points.

After receiving these coordinates an affine transformation will be applied on them in order to receive the *a*, *b*, *c*, *d*, *e*, *f* and *g* parameters from the transformation function in Figure 11, allowing us to easily transform any *(x, y)* pair of coordinates from user's to the calibrator's coordinate system *(x' , y')*.

$$x' = ax + by + c \quad (1)$$
$$y' = dx + ey + f \quad (2)$$

	P1	P2	P3	P4	P4(no glasses)
ART	44.2000	39.1556	38.2826	35.8776	40.0909
SL	139.8247	114.4652	132.1383	150.8032	151.3299
ObjNr	40	45	46	49	44

	P1	P2	P3	P4	P4(no glasses)
ART	53.7576	68.5000	41.0465	61.2759	43.0732
SL	173.2766	193.2426	171.9413	300.0240	200.0199
ObjNr	33	26	43	29	41

	P1	P2	P3	P4	P4(no glasses)
ART	43.0976	43.0976	42.0238	45.3333	38.2826
SL	145.8811	134.8228	137.5577	206.1268	158.1126
ObjNr	41	41	42	39	46

	P1	P2	P3	P4	P4(no glasses)
ART	74.2500	65.9259	46.5526	50.6286	41.0233
SL	120.6320	109.9045	135.2194	143.9500	142.1490
ObjNr	24	27	38	35	43

	P1	P2	P3	P4	P4(no glasses)
ART	50.6571	55.4688	44.1750	49.1944	47.8378
SL	148.1782	126.1047	131.2368	196.1750	142.0893
ObjNr	35	32	40	36	37

Figure 13: Experiment 2 results

		Experiment 1	Experiment 2
ART	Statistical error	18.8347	9.8607
	Mean	39.7327	48.1123
SL	Statistical error	47.7962	39.0653
	Mean	151.3408	156.2082
ObjNr	Statistical error	10.2499	6.5171
	Mean	42.24	38.08

Figure 14: Statistical errors and means of the results of the experiments

By transforming the coordinates of a participant to the calibrator's coordinate system the difference between them can be seen in Figure 12, result quite expected and indicating the detected problem from figure 9. Here the red coordinates represent the raw gaze points (from user's coordinate system) taken by the eye tracker and the green ones are the results of the affine transformation.

Surprisingly, the results of this experiment were not as expected, but actually less accurate than the ones of the previous experiment. We can support this statement just by looking at the SL from both of the experiments. The SL in the second one is larger, except for participant 4. By analyzing Figure 13 we can notice that only participant 4 when wearing glasses managed to have better results compared to the previous experiment. This improvement is caused not only because of a better ART (see Figures 6 and 11), but also because of him succeeding to fixate on more objects in the available time.

The same conclusion was also depicted by analyzing figure 14. Despite the lower statistical error of our results, the means show that in the second experiment the reaction time is worse, the data is even more scattered and the number of detected objects is lower.

VII. Feedback

Despite the calibration problems faced, the system was positively evaluated, not only by other healthy people, but also by a group of 20 children, both healthy and with mild-level CP. 90% of these subjects had very good results in trying to interact with the system and also offered advice for making it more interactive. Most of the boys asked for adding superheroes and football players to the object dataset, whereas girls asked for princesses, pretty ponies and theme songs in the background.

VIII. Conclusion

Based on the experiments discussed in this paper, in an already known and controlled environment, the idea of adapting Eye Tracker calibrations for multiple people is a viable solution. Since the eyes and the head of the user is fixed it is highly probable that a simple adaptation of an already set calibration can be a good solution for setting up devices for the general use of people with difficulties in setting it up by themselves. By relating the experiments with many other subjects, the extra data provided can be a very reliable source in achieving the goals.

The fact that children are interested in using this application shows that merging this approach with a gamified version would probably be one of the most interesting future research directions.

Acknowledgment

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