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Eye-tracking assistive technology: is this effective for the developmental age? Evaluation of eye-tracking systems for children and adolescents with cerebral palsy

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Objective The main purpose of this study is to better understand whether eye-tracking technologies might be considered as a valid tool for enhancing communication and facilitating the process of rehabilitation, in order to improve the empowerment of persons in developmental age.

Main content The differences between the performance of subjects with cerebral palsy or similar movement disorders and the performance of subjects without disabilities while executing an eye pointing task has been analysed.

Results show that the performance of users with cerebral palsy had a significant difference in terms of efficiency compared to those without diagnosed body impairments, which showed both lower completion times and no errors during the entire test session.

Conclusions We argue that the issues emerged during the interaction should lead future studies to focus on the analysis of the usability of these systems with respect to users with neurological diseases in developmental age.

Keywords Eye-tracking, assistive technology, developmental age, cerebral palsy

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Introduction

In recent years, eye-tracking systems have become an important tool to improve the quality of life and enhance the autonomy of persons with disabilities needing alternative input devices [3, 4]. The literature on eye-tracking shows a widespread dissemination of experimental studies which are mainly focused on the analysis of the cognitive processes involved in visual tasks, e.g. scene perception and visual tracking [5, 11, 15]. However, there are few studies that investigate the implications connected to the use of eye-tracking systems as an assistive technology for communication and rehabilitation of individuals in developmental age [8, 9].

Due to the lack of both a unified assistive technology assessment model and *long delivery times* (COGAIN reports 2009, www.cogain.org/wiki/COGAIN_Reports) [17], only a small number of people with neurological diseases characterized by the complete loss of communication abilities, e.g. spinal lesions, amyotrophic lateral sclerosis (ALS) or Locked-in syndrome, do actually use eye input devices to control the environment and communicate in everyday life, even though a wide range of potential eye control users could benefit from augmentative and alternative communication (AAC) through these systems. This consideration is especially true regarding persons in developmental age, who particularly need to further their interaction and communication abilities to improve their social, emotional, educational and creative development in society [9, 10].

Although a great number of experimental studies focuses on eye-tracking systems as tools for analysing the interaction between children with visual interfaces for the investigation of cognitive and emotional processes [7, 12, 20] there is little reference to the role of the eye-tracking technologies in both the AAC and rehabilitation for children and adolescents with cerebral palsy [6, 13, 16].

The main purpose of this study is to better understand whether eye-tracking technologies might be considered as a valid tool for enhancing communication and facilitating the process of rehabilitation, in order to improve the empowerment of persons in developmental age. Starting from this perspective, the aim of this work is to analyse the interaction process of children and adolescents with disabilities with the eye-tracking assistive system with no preliminary training. In particular, the differences between the performance of subjects with cerebral palsy or similar movement disorders and the performance of subjects without disabilities while executing an eye pointing task has been analysed.

1. Methodology

The interaction between participants and the eye-tracking system has been investigated while they were performing an eye-pointing task on a visual interface composed by four displays subsequently showed in order of complexity (figure 1). Recording data provided both a qualitative and quantitative means of monitoring each trial.

1.1. Equipment

The experiment was carried out using the portable eye-controlled communication device MyTobii P10, which is an integrated system composed by a 15” screen, an eye control device and a computer. Both the distance and the body position of each subject to the eye-tracking system have been adjusted during the calibration, according to the participants' postural needs. Each session was recorded on an Apple MacBook Intel Core 2 Duo laptop. In order to analyse the eye-fixation-point data, screen-recordings obtained by the mean of the CamStudio 2.0 open source software (http://camstudio.org/) were used.

1.2. Materials

Each display has been designed through the software iAble®, a sensory application which allow the symbolic, textual and on-screen keyboard communication from SR Labs – one of the European leaders in development and implementation of multimodal and high-accessibility electronic systems based on eye-tracking technology. In accordance with the accessibility specifications defined by the World Wide Web Consortium we used the ContrastA software (http://www.dasplankton.de/contrast), which follows both the accessibility guidelines WCAG 2.0 for the luminance ratio and the accessibility guidelines WCAG 1.0 for the brightness and the color. Moreover, the colour and shape parameters have been set by following the reference literature on shape and colour recognition [1, 2, 19] (figure 1).

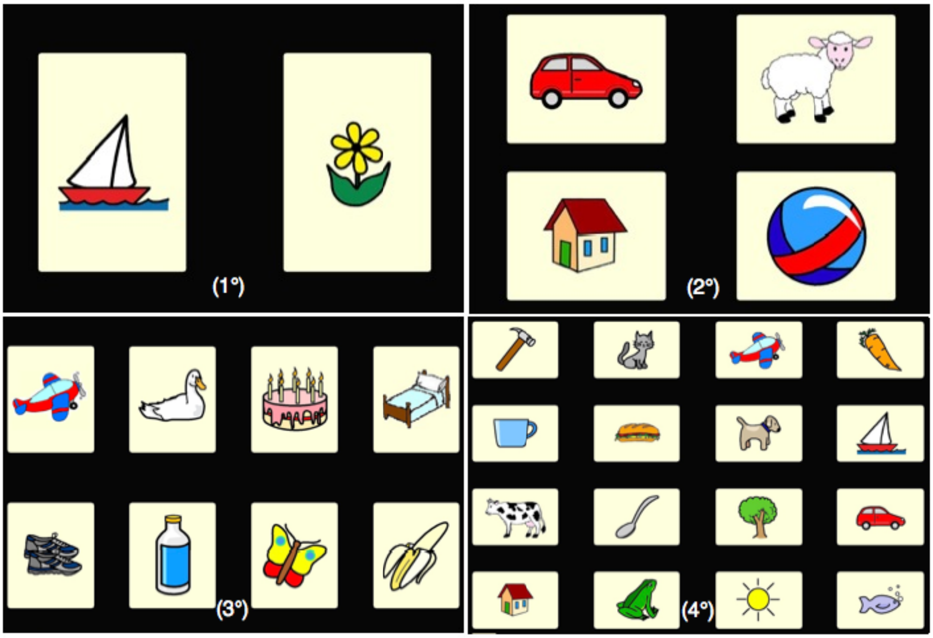

Figure 1. Eye-pointing grids.

1.3. Participants

We involved ten participants between the ages of 4 and 14, divided into two groups: 5 subjects with cerebral palsy and 5 without disabilities. The parents of the participants gave their written informed consent after the testing procedure was explained to them. Both a full optometric evaluation and the *Vineland Adaptive Behavior Scales – Interview Edition* (VABS) [18] has been administered for each participant. Parents were asked to provide us the descriptive diagnosis, the ICD-9 codes and the therapy given to their children. Moreover, we asked whether subjects have ever experienced the interaction with a computer system.

1.4. Procedure

Two experimental groups were involved in an eye-pointing task on four grids composed by multiple numbers of icons, which have been presented in ascending order (figure 1) For each participant, the experimental session consisted of:

i. both a preliminary calibration phase and the adjustments of the device;
ii. an about 3/5 minutes trial test which enable the subject to become familiar with the system;
iii. the sequential administration of four interfaces composed respectively by 2, 4, 8 and 16 icons.

A standard scenario was presented in a verbal mode to each subject, which were asked both to identify and select with the eye pointing device a given target icon. Both the session and the screen-actions were recorded. During each session a developmental neuro-psychomotor therapist and two cognitive psychologist experts in psychotechnologies monitored the entire interaction process by means of direct observation techniques**.** Subsequently, both the video-recordings and the screen-recordings were subsequently analysed by the research team.

1.5. Observation methods

Two different methods have been used to investigate the components of the user-technology interaction:

i. the unstructured direct observation method, which has been used to investigate any issue emerging during the interaction process in order to highlight the critical issues that may arise from the experimental setting. The categorization of the issues was based on an analysis sheet developed following the ten heuristics offered by Nielsen [14]
ii. the indirect observation method, which has been followed after the experimental sessions to investigate the interaction by means of both the task analysis and the performance analysis. It permitted us to measure the effectiveness, the efficiency and the qualitative components of the interaction for each participant;

Any problem encountered during each experimental session has been identified by following the usability guidelines provided by Nielsen to check both interaction problems and accessibility violations [14].

2. Results

2.1. Descriptive analysis of participants

Participants were divided into two groups, one without disabilities (control group, CtrlG) with a chronological age between 4 years e 7 months and 13 years and 11 months and one with a diagnosed *congenital quadriplegia (*ICD-9 code *343.2 corresponding to the* ICD-10 code *G80.0,* Spastic quadriplegic cerebral palsy) (experimental group ExpG) with a chronological age between 7 years and 11 months and 11 years and 5 months. The VABS data, which have been calculated by following the chronological classification, showed scores of equivalent age between 2 years and 3 months and 8 years and 9 months (mean equivalent age M=51,2 months) for the CtrlG and scores between 3 years and 7 months and 13 years and 9 months for the ExpG (mean of the equivalent age M=106,6 months) (figure 2). For each group, the 80% of participants stated to regularly use computer.

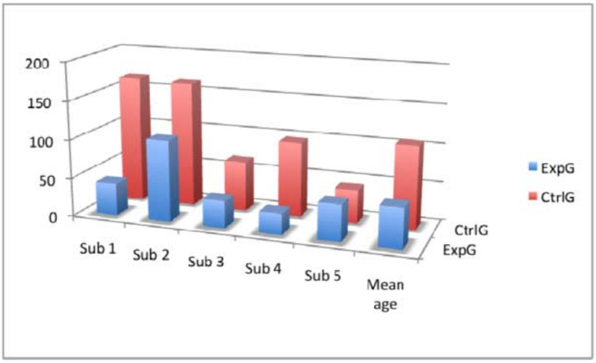

Figure 2. VABS' scores (months).

All participants received a careful optometric evaluation. An overview of the results shows that the 90% of all participants have a right ocular dominance. All the participants without disabilities were found to have straight eyes; whereas the Cover Test showed that 2 participants with cerebral palsy have an exo-deviation at 50 cm. Visual acuity and refractive error were within the normal range for all subjects, except for one participant with cerebral palsy that showed mild myopia, which was previously corrected through the use of corrective eyeglasses.

2.2. Performance data

The average of total times taken to carry out the performance was 57.8 seconds for the ExpG and 14.2 seconds for the CtrlG. Figure 3 shows the average time spent by both groups for completing the task for each grid.

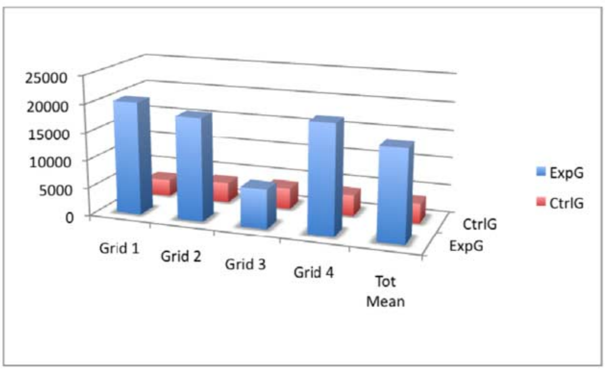

Figure 3. Means of completion times for each grid (ms).

The ExpG performed a total score of 4 errors; whereas the group of CtrlG showed no errors during the performance. Each problem found during the interaction with the eye-tracking system was matched with Nielsen's heuristic list: the group with cerebral palsy found 4 types of problems during the performance, whereas participants without diagnosed body impairments did not found any type of problem. For each problem, its frequency (*f*) during the performance of each participant has been calculated. The usability problems found were related to following heuristics: operability (*f*=3), error tolerance (*f*=5), flexibility (*f*=6), understandability (*f*=1) (figure 4).

The analysis of variance (ANOVA), carried out by StatSoft Sewss Statistica 7.0 on the task completion times, showed a significant difference between the two groups (*ExpG*CtrlG*) ($F(1,8)=8.2755$; $p=.02062$) (figure 4); whereas no significant differences within the grids was found ($F(3, 24)=.42656$; p=ns). Furthermore, no interaction effect *Group*Grid* was found ($F(3, 24)=.48277$; p=ns).

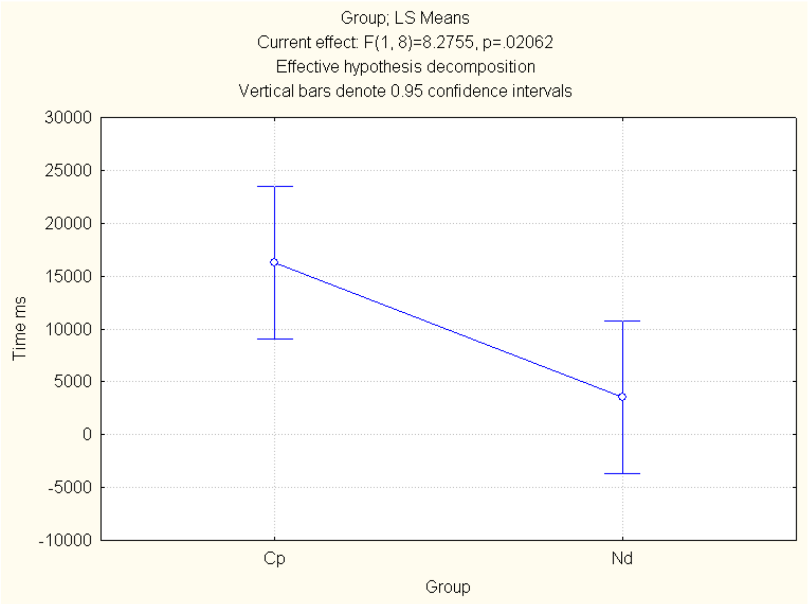

Figure 4. ANOVA (ExpG*CtrlG).

2.3. Discussions

An overall view of the results shows that the performance of ExpG participants had a significant difference in terms of efficiency compared to those of CtrlG, who showed both lower completion times and no errors during the entire test session. Errors, which have been performed only by participants with cerebral palsy (ExpG), were related to the following usability issues of the system: operability, error tolerance, flexibility and understandability. However, the analysis of the interaction effect *Group*Grid* showed no significant difference. Taken together these data suggest that the eye-pointing system must be improved to be more adaptable, in order to support both cognitive and motor functions of people with disabilities, without any need of a preliminary training or adaptation of body posture. Additionally, since no interaction *Group*Grid* effect was found, problems related to the interface used should be excluded. Anyway, it is important to note that the greatest frequency of errors was found during the performance of a participant with a chronological age of 11 years and a *VABS'* score of 2 months and 11 months with both a quadriplegia and exo-deviation. This participant showed several body movements and difficulties in maintaining the gaze on the eye-fixation-point target. However, since the sample of participants was a small group, a larger number of subjects will be *required to* confirm our findings.

3. Conclusions

The main purpose of this study was to investigate whether eye-tracking technologies might be considered as a valid tool for enhancing the process of communication to improve the empowerment of persons in childhood and adolescence.

The interaction process of two groups, one with cerebral palsy (ExpG) and one without diagnosed body impairment (CtrlG), has been evaluated while participants were executing an eye pointing task through an eye-tracking device. Both groups received no training before the performance. Findings show that, compared to the CtrlG, the ExpG's performance had a significant difference in terms of efficiency, showing both higher completion times and errors. However, further developments aiming to analyse the comparison between different commercial eye-tracking systems (e.g. ERICA, Alea) with a larger number of subjects are necessary to investigate more deeply the effectiveness of the current eye-tracking systems.

Since eye-tracking devices seem to be a powerful support to enable communication in persons in developmental age, we argue that the issues emerged during the interaction should lead future studies to focus on the analysis of the usability of these systems with respect to users with neurological diseases in developmental age, in order to promote their cognitive and social empowerment.

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