CEREBRAL PALSY AND EYE-GAZE TECHNOLOGY. INTERACTION, PERSPECTIVE AND USABILITY. A REVIEW

REMUS NERIȘANU[1], RALUCA-ANDREEA NERIȘANU[2], IONELA MANIU[3], BOGDAN NEAMȚU[4]

[1,3,4]Research and Telemedicine Center in Neurological Diseases in Children, Pediatric Clinical Hospital Sibiu,
[2,3,4]"Lucian Blaga" University of Sibiu

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Abstract: *The perspective of our review evaluated the interaction of cerebral palsy with eye-gaze interaction, the main tool of assistive technology, supporting communication and personal development for degrees of disability that involve motor impairment. Purpose: Bringing in the main field, alternative possibilities from the literature for better integration of the disabled. Methods: Systematic review. Results: We revealed the substantial impact of assistive technology on cerebral palsy patients, grade of integration, easing caregiver's dedication, the devotion of training and the companionship being vital to reduce the level of abandonment. Conclusion: Primordial eye-gaze interaction initiated the idea of infrared eye-trackers for better solutions in the field of communication, personal interaction with others, personal development and even employment. The eye-tracking industry has its popularity cost-depending, for the present, being in the range of expensive for disabled people. For cerebral palsy, eye-gaze has little steps, but with a crucial impact on quality of life.*

INTRODUCTION

Cerebral palsy according to an accepted report in 2007 is the most common cause of childhood "permanent disorder, of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fatal or infant brain."(1) It is not a disease in the traditional sense, but describes a clinical aspect of children who share the aspects non-progressive brain injury, lesion acquired ante-, perinatal or in the early postnatal, on the infant's brain. Affection causing limitation in activities, because of the motor disorders, accompanied by disturbances of communication, coordination, sensation, perception, cognition, behaviour, epilepsy, musculoskeletal and respiratory problems. All these factors and distribution classify cerebral palsy as a functional disability.

Reaching the needs of disabled people especially those with cerebral palsy is not a resource-full domain. It involves however several outstanding technologies but with a high-cost making it hard to get. So the situation is challenging.(2)

The management main goals in of cerebral palsy are enhancing children's neurological development to maximize their mobility, reducing spasticity, hypertonia, speech therapy for better communication, physiotherapy for scoliosis and respiratory deficiencies because of musculoskeletal problems and other co-morbidities. In the multidisciplinary part we must take action and consider the rapid evolution of technology, especially assistive technology. Tools like wheelchairs/electric wheelchairs, AAC technology, Text-to-speech devices, were highlighted in our review, the actual resources in the literature.

PURPOSE

Our systematic approach brings some insights on cerebral palsy clinical picture and management plan from a technological point of view. In particular it describes how an everyday computer could be enhanced with the novelty of technology in eye tracking materials, software and hardware that could build a new future of communicating through AAC and text-to-speech devices for disabled persons. It could be a convenient and an affordable solution in a country with a low income per person in which even a medium wage family couldn't afford a world class device that will bring a way of communicating, especially through eye-gaze.

To this goal, we made the review of disease prevalence and clinical aspects with a focus of available devices of the past years in the context of communication, learning, expressing feelings, desires and basic needs.

MATERIALS AND METHODS

The systematic review brought in front the usability of eye-gaze devices with infrared, AAC (augmentative and alternative technology), text-to-speech solutions and other manageable assistive technology for cerebral palsy patients mostly, but with the inclusion of its applicability to other motor impairments.

The literature that was studied is from PubMed Central, PubMed, Science Direct, Scopus, Springer, Google Schoolar, Mendeley, Sage Journals, The Lancet Journals, Hindawi, Wiley Online Library, Biomedcentral and we identified over 30 articles on eye tracking, assistive technology, augmentative and alternative communication alternatives, eye-gaze interaction, cerebral palsy, text-to-speech device

RESULTS

Most of the authors present cerebral palsy life expectancy to be dependent on the frequency and complication of comorbidities; a majority of people with severe comorbidities live to adult life.(3)

The prevalence is 2,1 of 1000 new-borns(4) and an estimated 17 million people are affected worldwide.

The incriminated etiologies of cerebral lesions are the

[4]Corresponding author: Bogdan Neamțu, Str. Pompeiu Onofreiu, Nr. 2-4, Sibiu, România, E-mail: bogdanneamtu76@gmail.com, Phone: +40773 994375

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following:

a) during pregnancy or at birth - prematurity + low weight; intrauterine infections with rubella, cytomegalovirus, toxoplasmosis (agents causing chorioamniotitis); cranial-frontal presentation of the fetus; hypoxia at birth due to prolonged labor; congenital cranial malformations; alcohol / drug use, thyroid hormones and estrogen.

b) at birth or early life: prolonged jaundice, gas poisoning (methyl mercury, carbon monoxide, butane), cerebral tumors, hypoxia, thrombophilia.(2,5)

The clinical manifestations include movement disorder, dysfunctional abilities and several other limitations of different parts of the body. In the present there is no known cure, only several clinical relieves, symptomatic interventions and managerial therapy with multidisciplinary participation.

The motor types of cerebral palsy are: 1) spastic (85-91%); 2) dyskinetic (4-7%), including dystonia and athetosis; - 3) ataxic (4-6%), 4) hypotonic (2%).(6)

By topography of affected cerebral territory we have a categorization by:

a) Spastic with hemiplegia (38%), diplegia (37%) and quadriplegia (24%)

b) Dyskinetic, ataxic and hypotonic affects all limbs which makes it quadriplegic.(6)

Regarding the therapy, there is a zealous implication in stem-cell therapy for a near-future.(7,8) There is also an example given by Graham et al. 2016 (2) about magnesium sulphate administration during premature labour and also applying cooling to high-risk infants with a result in reducing the rate and severity of cerebral palsy.

Medical invasive treatment for some of the affections involve, Botulin toxin, Baclofen injections for spasticity, dystonia, benzodiazepines (Diazepam) for muscle relaxation and as hypnotic, surgery for articular luxation, physiotherapy for spasticity, vertebral affections, mobility and other comorbidities.(2)

The results of several studies showed improvement in eye gaze and AAC performance for patients with physical impairments, bringing a plus to communication, creativity and unlocking cognitive potentials.(9,10,11,12) With user-friendly grids (like Grid 3 from ThinkSmartBox™ or Gazespeaker- free source), children were helped to reduce restrictions of their activities and adult patients could express their own wishes and could speak to their surrounding caregivers in a convenient manner, helping to integrate a new way of education through eye technology. In the case of cerebral palsy, most of the authors put in front strabismus and epilepsy, their subject of medical integration with AAC being almost manageable without any interference with the eye-tracker device's function ability. A possible explanation resides in the fact that eye-gaze can focus only on the physiological eye, eliminating the fear of refusal.(8)

The principle of how eye-tracking works is not complicated, there is an infrared device, with a camera that detects and tracks the eye movements by an algorithm which implies pupillary (black or white) and corneal reflection, obtaining the user's eye patterns, 3D model and the user's head position in relation with the source. Patient's positioning is by choice of device, either in front of the computer with the eye tracker mounted underneath it or with the user having the eye trackers attached to eyeglasses.(13,10,14)

The experience in integration of cerebral palsy and infrared eye-tracking technology is important. There is a direct proportion in the communication between capable personnel, care-givers and users of technology, to ensure that patients interact with eye-gaze AAC devices and adapt to the way they want to express their thoughts. Participation on activities made a huge difference in integration (15), with the attention on disappointment and abandonment.(16,17,18)

Figure no. 1. Example of a basic eye-tracker mounted under the monitor

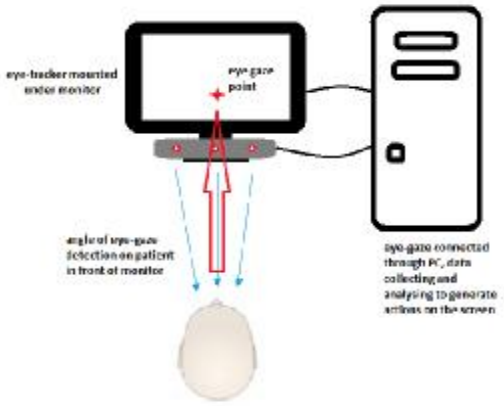
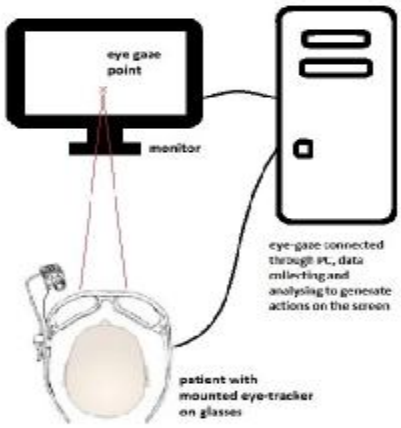


Figure no. 2. Example of a basic eye-tracker mounted on eyeglasses



Eye tackers, as an example, can be built from a simple web-cam and photodiodes, a pair of eyeglasses frames and by connecting to a computer via ITU GazeTracker Software, a freeware(19) Or they can be built under or integrated in a monitor/tablet with licenced software for the best data exchange between patient and device.(20,10)

DISCUSSIONS

The way eye tracking helps and facilitates speech and motor control is a thing of the future, still in development and an act of integration for patients and caregivers. Access technologies for communication started from a simpler and slower task (which takes minutes for only one word) like the E-tran boards. There were also apps built from the same principle, for phones to speak in pairs of words which mimic the same principle as E-tran.(21) There was an imperious need for a pathway of signal processing and AAC holistic system for better speech and writing with a solution found in eye-gaze tracking(11) So, based on the same principle of eye tracking with gaze physical boards and on the principles of Purkinje eye reflections, took birth infrared technology and researches that reached the state of great tracking of eye-movements, saccades and metrics.(22,23,24,25,26,14) The eye tracking technology

became an on-screen grid, text-to-speech device which you could use to write words, phrases on the computer and a speaking synthetized voice would help the speech impaired patient to talk correctly or completely, depending on his disabilities (dysarthria, aphonia). The technology is not all body positioning dependent, there are a lot of possibilities and it is available in eyeglasses mounting, monitor/tablet attached, for different aspects of the patient's needs, and also the entire device can be mounted on the wheelchair or on the bed.(27,11)

For example in a patient with tetraplegia because of a cervical spine lesion could easily use a low-cost eye-tracker attached to eyeglasses while he's bed-levelled with an arm-mount device over him.(28,29,30,31)

In our review, we noticed that on gaze-based technology spastic and diskinetic patients had great interaction with monitor/tablet mounted eye-trackers (desktop mounted).(10) There are a wide spectrum of devices for patients, from symbol-grid systems with text-to-speech to minimalistic games for toddlers and patients who can execute simple tasks, (11,30) and to read.(20)

We should acknowledge the potential of Brain Computer Interface (BCI), which can be adjusted with an eye tracker or work individually.(32) The BCI is a non-invasive next-step in thought expressing, with the principle of EEG interpreting, it is developed to perceive intentions via brain wave-length, deducting and converting into simple commands on a computer. Adjusting this kind of technology with eye-tracking could simplify many tasks for the disabled and help them be more independent.(33,32,34,35)

One of the limitations of the eye-gaze devices is the price range, even though eye tracking is well adapted for disabled children and adults and there are defects on accuracy and sampling rate of gazing,(36,10,14) for low-cost eye-trackers (<60Hz). The main marketed devices (middle and high-priced) for disabled have integrated environment control and algorithm for diskinetic movements. Another limitation is the level of interaction and support from trained personnel, teachers, parents, caregivers and patients which brings discrepancy in the best result for the one who needs it the most, the patient.(18)

There are a lot of people from Romania who could benefit from AAC technology, it depends on the institutionalisation of patients, their needs and possible benefits. A recent study from last year in UK, showed that 536 of 100.000 need AAC equipment and health support.(37) Showing the high prevalence of people needing technology to have an attenuated to normalised life.

CONCLUSIONS

Cerebral palsy seems like a hope-amputee for many of the patients and those who become their personal assistant for life, but that is not the case, especially in the era of technology, adaptation by everyone's needs and bringing the right results for personal development, makes eye-gaze technology one of the best potentials in communicating and letting the patient feel more independent.

Eye-tracking, even that it has a decade and a half of studies, still holds a grand potential in bringing assistive technology to a new level. True potential doesn't mean high-access to the disabled population, this is a thing to keep in mind and to bring it in front, to sensitise the people and leaders who can bring the best plan of financial support. By the proofs of the review and the potential that stands in eye-gaze technology many domains may benefit in the future, with eliminating the borders of human interaction and purpose-giving life. People with disability could even apply for full integrated jobs, become artists or making their own business, using only eye-trackers.

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REFERENCES

1. Rosenbaum P, Paneth N, Leviton A, Goldstein M, Bax M, Damiano D, et al. A report: The definition and classification of cerebral palsy April 2006. Dev Med Child Neurol. 2007;49(SUPPL.109):8–14.
2. Graham HK, Rosenbaum P, Paneth N, Dan B, Lin J-P, Damiano DL, et al. Cerebral palsy. Nat Rev Dis Prim [Internet]. 2016;15082. Available from: http://www.nature.com/articles/nrdp201582
3. Wimalasundera N, Stevenson VL. Cerebral palsy. Pract Neurol [Internet]. 2016;16(3):184–94. Available from: http://pn.bmj.com/lookup/doi/10.1136/practneurol-2015-001184
4. Oskoui M, Coutinho F, Dykeman J, Jetté N, Pringsheim T. An update on the prevalence of cerebral palsy: A systematic review and meta-analysis. Dev Med Child Neurol. 2013;55(6):509–19.
5. Morris C, Baxter P, Rosenbaum P, Paneth N, Leviton A, Goldstein M, et al. The definition and classification of cerebral palsy contents foreword historical perspective definition and classification document. Dev Med Child Neurol. 2007;49(109):1–44.
6. Mcintyre S, Badawi N, Goldsmith S, Hines M, Karlsson P, Novak I, et al. Australian Cerebral Palsy Register: Report 2016. Aust Cereb Palsy Regist. 2016;64.
7. Novak I, Walker K, Hunt RW, Wallace EM, Fahey M, Badawi N. Concise Review: Stem Cell Interventions for People With Cerebral Palsy: Systematic Review With Meta-Analysis. 2016;1014–25.
8. Nguyen LT, Nguyen AT, Vu CD, Ngo D V., Bui A V. Outcomes of autologous bone marrow mononuclear cells for cerebral palsy: an open label uncontrolled clinical trial. BMC Pediatr [Internet]. 2017;17(1):104. Available from: http://bmcpediatr.biomedcentral.com/articles/10.1186/s12887-017-0859-z
9. Borgestig M, Sandqvist J, Parsons R, Falkmer T, Hemmingsson H. Eye gaze performance for children with severe physical impairments using gaze-based assistive technology—A longitudinal study. Assist Technol. 2016;28(2):93–102.
10. Wilkinson KM, Mitchell T. Eye Tracking Research to Answer Questions about Augmentative and Alternative Communication Assessment and Intervention. Augment Altern Commun [Internet]. 2014;30(2):106–19. Available from: http://www.tandfonline.com/doi/full/10.3109/07434618.2014.904435
11. Myrden A, Schudlo L, Weyand S, Zeyl T, Chau T. Trends in Communicative Access Solutions for Children With Cerebral Palsy. J Child Neurol [Internet]. 2014;29(8):1108–18. Available from: http://journals.sagepub.com/doi/10.1177/0883073814534320
12. Murphy J, Boa S, Enderby P. Testing the Reliability and Validity of the Therapy Outcome Measure for AAC. 2014 [cited 2017 Oct 30]; Available from: http://www.talkingmats.com/wp-

content/uploads/2014/11/TOM-AAC-Final-report-Oct-2014.pdf
13. Pavlas D, Lum H, Salas E. How to Build a Low-Cost Eye-Tracking System. Ergon Des Q Hum Factors Appl [Internet]. 2012;20(1):18–23. Available from: http://journals.sagepub.com/doi/10.1177/1064804611428928
14. Hansen DW, Ji Q. In the Eye of the Beholder: A Survey of Models for Eyes and Gaze. IEEE Trans Pattern Anal Mach Intell. 2010;32(3):478–500.
15. Griffiths T, Addison A. Access to communication technology for children with cerebral palsy. Paediatr Child Health (Oxford) [Internet]. 2017;27(10):470–5. Available from: http://linkinghub.elsevier.com/retrieve/pii/S1751722217301452
16. Foley A, Ferri BA. Technology for people, not disabilities: Ensuring access and inclusion. J Res Spec Educ Needs. 2012;12(4):192–200.
17. Hurst A, Tobias J. Empowering individuals with do-it-yourself assistive technology. Proc 13th Int ACM SIGACCESS Conf Comput Access ASSETS 11 [Internet]. 2011;11–8. Available from: http://dl.acm.org/citation.cfm?id=2049541
18. Karlsson P, Allsop A, Dee-Price B-J, Wallen M. Eye-gaze control technology for children, adolescents and adults with cerebral palsy with significant physical disability: Findings from a systematic review. Dev Neurorehabil [Internet]. 2017;0(0):1–9. Available from: https://www.tandfonline.com/doi/full/10.1080/17518423.2017.1362057
19. Mantiuk R, Kowalik M, Nowosielski A, Bazyluk B. Do-it-yourself eye tracker: Low-cost pupil-based eye tracker for computer graphics applications. Lect Notes Comput Sci (including Subser Lect Notes Artif Intell Lect Notes Bioinformatics). 2012;7131 LNCS:115–25.
20. Biedert R, Buscher G, Dengel A. Using eye tracking to enhance the reading experience. Informatik-Spektrum. 2010;33(3):272–81.
21. Zhang X, Kulkarni H, Morris MR. Smartphone-Based Gaze Gesture Communication for People with Motor Disabilities. Proc 2017 CHI Conf Hum Factors Comput Syst - CHI '17 [Internet]. 2017;2878–89. Available from: http://dl.acm.org/citation.cfm?doid=3025453.3025790
22. Gredebäck G, Johnson S, Von Hofsten C. Eye tracking in infancy research. Dev Neuropsychol. 2010;35(1):1–19.
23. Perreira M, Silva D, Courboulay V, Perreira Da Silva M, Ould Mohamed A. A history of eye gaze tracking Abdallahi Ould Mohamed. 2007;1–26. Available from: http://hal.archives-ouvertes.fr/docs/00/21/59/67/PDF/Rapport_interne_1.pdf%5Cnhttp://hal.archives-ouvertes.fr/docs/00/36/10/88/PDF/Rapport_interne_2.pdf
24. Pfeiffer UJ, Vogeley K, Schilbach L. From gaze cueing to dual eye-tracking: Novel approaches to investigate the neural correlates of gaze in social interaction. Vol. 37, Neuroscience and Biobehavioral Reviews. 2013. p. 2516–28.
25. Villanueva A, Daunys G, Hansen DW, Böhme M, Cabeza R, Meyer A, et al. A geometric approach to remote eye tracking. Univers Access Inf Soc. 2009;8(4):241–57.
26. Zhou X, Cai H, Li Y, Liu H. Two-eye model-based gaze estimation from a Kinect sensor. In: 2017 IEEE International Conference on Robotics and Automation (ICRA) [Internet]. IEEE; 2017 [cited 2017 Oct 30]. p. 1646–53. Available from: http://ieeexplore.ieee.org/document/7989194/
27. Edge TE, Edge T, Led T. The Eyegaze Edge ® : How does it work ? What do you need to know ? Eye tracking overview. :1–6.
28. Lupu RG, Bozomitu RG, Păsărică A, Rotariu C. Eye tracking user interface for Internet access used in assistive technology. 2017 E-Health Bioeng Conf EHB 2017. 2017;659–62.
29. Huang B, Lo AHP, Shi BE. Integrating EEG information improves performance of gaze based cursor control. Int IEEE/EMBS Conf Neural Eng NER. 2013;415–8.
30. Borgestig M, Sandqvist J, Ahlsten G, Falkmer T, Hemmingsson H. Gaze-based assistive technology in daily activities in children with severe physical impairments–An intervention study. Dev Neurorehabil [Internet]. 2017;20(3):129–41. Available from: https://www.tandfonline.com/doi/full/10.3109/17518423.2015.1132281
31. Kim ES, Friedlaender L, Kowitt J, Reichow B, Naples A, Gearty GV, et al. Development of an Untethered, Mobile, low-cost Head-Mounted Eye Tracker. Proc Symp Eye Track Res Appl - ETRA '14 [Internet]. 2014;247–50. Available from: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899694671&partnerID=tZOtx3y1
32. Kim M, Kim BH, Jo S. Quantitative Evaluation of a Low-Cost Noninvasive Hybrid Interface Based on EEG and Eye Movement. IEEE Trans Neural Syst Rehabil Eng. 2015;23(2):159–68.
33. Al-Abdullatif A, Al-Negheimish H, Al-Mofeez L, Al-Khalifa N, Al-Andas L, Al-Wabil A. Mind-controlled augmentative and alternative communication for people with severe motor disabilities. Innov Inf Technol (IIT), 2013 9th Int Conf. 2013;107–12.
34. Popa L, Selejan O, Scott A, Mureşanu DF, Balea M, Rafila A. Reading beyond the glance: eye tracking in neurosciences. Neurol Sci. 2015;36(5):683–8.
35. Khushaba RN, Wise C, Kodagoda S, Louviere J, Kahn BE, Townsend C. Consumer neuroscience: Assessing the brain response to marketing stimuli using electroencephalogram (EEG) and eye tracking. Expert Syst Appl [Internet]. 2013;40(9):3803–12. Available from: http://dx.doi.org/10.1016/j.eswa.2012.12.095
36. Kok EM, Jarodzka H. Before your very eyes: The value and limitations of eye tracking in medical education. Med Educ. 2017;51(1):114–22.
37. Creer S, Enderby P, Judge S, John A. Prevalence of people who could benefit from augmentative and alternative communication (AAC) in the UK: determining the need. Int J Lang Commun Disord. 2016;51(6):639–53.