Brain Rehabilitation in Clinical Trials Setup by Eye-Tracking

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Keywords: Brain rehabilitation, Neurology, Stroke, Human-computer interaction

Abstract: The number of patients with traumatic brain injury in Germany is about 280,000 per year. Eighty percent of the patients hospitalized in these cases exhibit minor traumatic brain injury, while approximately 10 percent are suffering from moderate and another 10 percent from severe traumatic brain injury. The goals of rehabilitation are to help survivors become as independent as possible and to attain the best possible quality of life. For the last few years, eye tracking has been used as an assistive tool, especially as a tool for alternative communication. Within the paper we explore new patent pending approach in brain injury rehabilitation. However, eye tracking questionnaire need a full implementation into clinical studies and medical documentation systems. In this paper we present integration of cognitive test into eye tracking technology based on electronic case report form.

1 INTRODUCTION

Increasing number of people who undergo brain damage is one of the most characteristic features of our contemporary society. “Brain injury” is a term used in terms of traumatic brain injury (TBI), a cerebral stroke, or changes occurring in the brain that are consequent from cerebral hypoxia (e.g. due to perinatal incidents, sudden cardiac arrest (SCA) or suicidal strangulation). These examples of TBI lead to serious neurological disorders directly related to cognitive disturbances and need to be assessed in an objective way.

Neurological rehabilitation pursues different goals for recovery that can be divided into several steps: in the acute phase of TBI restitution of neurobiological processes should be facilitated by different therapeutic strategies. If improvement of functional deficits is not achieved or is not expected to occur (e.g. because of a large brain lesion), it should be aimed at compensation strategies, for instance by the use of assistive tools. Individuals may need to learn how to communicate and express their own feelings. If sensomotor, language or cognitive deficits cannot be compensated, the patient’s environment should be adapted to his needs (Turner-Stokes, 2007). As recently recommended for stroke patients, the patient’s functional and cognitive status must be accurately assessed within the first few days after stroke to identify special needs for further therapeutic and rehabilitative strategies (Hebert, 2016).

Eye tracking technology might be useful in several steps of brain rehabilitation process, from diagnosis to therapeutic implications, especially when eyeballs movements is the only channel of communication. Nowadays eye tracking technology is well-known and it is reasonable to use it in medical purposes, especially in supporting neurological examination of patients with serious communication barriers (Doležal, 2015) (Kunka, 2014). Therefore, within the paper we present a new approach for objectivized neurological assessment procedure based on tests included in a case report form and adopted for eye tracking.

Patients with cognitive disturbances originating from TBI, should be immediately assessed in regards to the extensiveness of the damage and the level of their consciousness. Properly conducted diagnostics is absolutely crucial, since the whole rehabilitation management will be later based on it. Furthermore, the proposed approach based on eye

Kunka B., Kosikowski R., Barlinn J. and Kozak K.
Brain Rehabilitation in Clinical Trials Setup by Eye-Tracking.
DOI: 10.5220/0006227500890094
In *Proceedings of the Fifth International Conference on Telecommunications and Remote Sensing (ICTRS 2016)*, pages 89-94
ISBN: 978-989-758-200-4

tracking technology supporting diagnosis of neurological patients could be also employed at their intensive rehabilitation by stimulating particular structures of the central nervous system (CNS).

Neurorehabilitation concerned with cognitive functions stimulation is very important. It is a time-consuming process requiring cyclic, systematic work and motivation of all involved people. When the CNS is constantly stimulated by different stimuli and intellectual efforts, the repair mechanism can be activated in a damaged brain. The main mechanism is neuroplasticity which could compensate damaged brain centers' functions due to creation of new neural connections. Repair mechanism of brain consists of reorganization, adaptation, changeability, self-repair, learning and remembering of neurons (Doležal, 2015).

It is worth mentioning that cyclic monitoring and observation of rehabilitation progress would be also supported by proposed in this paper neurological assessment utilizing eye tracking system.

Eye tracking is a technology allowing for determining user's gaze direction (it measures coordinates of eye fixation point). Eye tracking follows the path of an observer visual attention thus it enables controlling of mouse cursor in the system, as well as detection and analysis of user's regions of interests.

Currently eye tracking interfaces are based on video processing. They utilize near-infrared technology along with a high-resolution camera to track gaze direction.

In the paper we focus on the remote eye trackers, especially on the C-Eye system described in C-Eye System section.

Eye tracking technology has many applications in different areas. The most known are related to human-computer interaction (HCI), entertainment (Drewes, 2010), (Jacob, 2003), and research, including psychology and neuroscience (Kooiker, 2015), (Hahn, 2015), as well as medicine (Kunka, 2014).

Neuroscience and psychology employ eye tracking technology to analyze the scan paths (gaze patterns) and heat maps to gain deeper insights into cognitive processes underlying attention, learning, and memory. Another research shows that eye tracking gives us insights into i.a. word processing, particularly how eye movements during reading are affected by the emotional content of the texts (Urry, 2010).

Eye tracking in combination with standard research methods or other biometric sensors can also support diagnosis of neurological diseases such as Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), Schizophrenia, Parkinson's (PD), and Alzheimer's disease (AD). It is worth mentioning that iMotions exists (iMotions, 2016). It is the integrated web biometric research platform integrating best-in-class biosensors and synchronizes eye tracking, facial expression analysis, EEG, GSR, EMG, ECG and surveys. iMotions platform helps its users conduct state-of-the-art human behavior research in the areas of psychology, neuroscience, human factors engineering, education, health, business and HCI. The platform is used worldwide by leading universities such as Harvard, Yale and Stanford.

This section presents possibilities of eye tracking technology offered to different branches, especially for specialized medical examinations and objective assessment of the measured data. It has been proven that eye tracking can be successively used both in diagnostic and therapeutic applications.

A case report form (or CRF) (Bellary, 2014) is a paper or electronic questionnaire specifically used in clinical trial research. The Case Report Form is the tool used by the sponsor of the clinical trial to collect data from each participating site. All data on each patient participating in a clinical trial are held and/or documented in the CRF, including adverse events. Originally all case report forms were made on paper. But recently there is a changing trend to perform clinical studies using an electronic case report form (eCRF). Commonly encountered challenges in CRF designing are consistency in the design, collection of precise data and user-friendliness also from assisting devices. These challenges can be overcome by proper planning by a using clinical supporting system. This way of working has many advantages: faster and efficient, high security, environmentally friendly. In this paper we present integration of cognitive test into eye tracking technology based on electronic case report form.

In this paper we present a concept of integration of eCRF with eye tracking technology for clinical trials in TBI rehabilitation.

2 C-EYE SYSTEM

Clinical trials involves many steps, one of the most time-consuming elements of conducting clinical studies is the entry of clinical data onto case report forms (CRFs). Traditionally, this is done by clinical research coordinators (CRCs) at various research centers who use a pen to write the data on paper-

based CRFs, which are then faxed to clinical monitors (CRAs) where they are examined for potential errors that may skew the accuracy of statistical data required to evaluate a drug's performance. The most important for facilitating study management are electronic data capture by users (doctors and patient) and clinical trial management software. This paper describes the advantages of integration C-Eye and study management.

As eCRFs are created within the C-Eye user interface, all the field definitions, data types, control positions, and validation rules are stored in a single table that saves CRF definitions for all trials, no matter how different they are. Data on patient-specific CRFs is stored in a similar manner – all field values are checked for data type compliance at the application level and written to a table as records that can easily be extracted using a single reporting tool for all trials. Elements of the system for study management in TBI domain:

2.1 Data Capture Section

A data element in an eCRF represents the smallest unit of observation captured for a subject in a clinical investigation. Examples of data elements include IQ test, color recognition, object recognition, or other clinical observations made and documented during a study Data capture interface allow:

1. Electronic Source Data Origination
2. Test Data Capture
3. Data Element Identifiers
4. Modifications and Corrections
5. Use of Electronic Prompts, Flags, and Data Quality Checks in the eCRF

Many data elements in a clinical investigation can be obtained at a study visit and can be entered directly into the C-Eye eCRF form by an authorized data originator. This direct entry of data can eliminate errors by not using a paper transcription step before entry into the eCRF.

The forms with eye tracking system are providing a possibility to collect specific records:

- Heat maps: aggregations of gaze points and fixations revealing the distribution of visual attention.
- Scan paths (or Fixation sequences): sequence representing the order of subjects' looking and how much time they spend
- Time of interesting: parameter quantifies the amount of time that subjects have spent on Areas if Interest (AIOs) being predefined subregions of displayed content (e.g. subregions representing the right answer)
- Time To First Fixation (TTFF): the time to first fixation indicates the amount of time it takes a respondent to look at a specific AOI.

Typically, images (eye motion, eye symptoms, face images) are not included as data elements in an eCRF, but rather the clinical interpretation of the image is included as a predefined data field.

2.2 Data Review

To comply with the requirement to maintain accurate clinical test, clinical investigator should review and electronically sign the completed eCRF for each subject before the data are archived or submitted to clinical research organization (CRO). To comply with the requirement to maintain accurate test histories, data elements might call for modification or correction during data review. Either the clinical investigator can enter the revised data element. Modified and/or corrected data elements must have data element identifiers that reflect the date, time, originator, and reason for the change, and must not obscure previous entries.

If changes are made to the eCRF after the clinical investigator(s) has already signed, the changes should be reviewed and electronically signed by the clinical investigator(s).

2.3 Retention of Records by Clinical Investigator

The clinical investigator(s) should retain control of the records (i.e., completed and signed eCRF or certified copy of the eCRF).

2.4 C-Eye System as Study Management Interface

The C-Eye system is a fully integrated certified medical device supporting the evaluation of the state of consciousness of patients suffering from any central nervous system disorder, enabling neurorehabilitation for people with neurological dysfunctions and impaired development. The C-Eye system also supports alternative communication thanks to eye tracking technology implemented as a remote interface.

The evaluation and neurorehabilitation of a patient suffering from neurological disorders and impaired development consists in performing special tasks based on multimedia contents. The subject establishes interaction with contents displayed on the screen using their sight, i.e.: graphics, photographs and captions. This way, specific centers of the central nervous system are both evaluated and stimulated, especially centers responsible for sight, hearing, speaking and cognitive functions.

As presented in the Figure 1, the system consists of the processing unit (PU), which is the integrated into the touch display (TD) and the speakers (S), which are integrated into the touch display (TD).

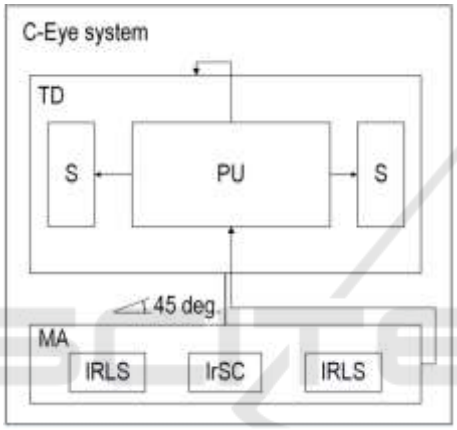

Figure 1: C-Eye – structure of the system

The system is equipped with two infrared light sources (IRLS), that enable to indicate the visual fixation point position through generating infrared light reflections, that are reflected from the surface of subject's cornea and acquired by the infrared sensitive camera (IrSC). The infrared light sources (IRLS) are integrated with the infrared sensitive camera (IrSC) in the way that the infrared light sources (IrLS) are located symmetrically and uniaxially on the both sides of the camera (IrSC) and put together into the longitudinal cover to be formed into the movable attachment (MA). The movable attachment (MA), which is connected with the processing unit (PU) and located in the lower part of the display (TD), is up and down tiltable in a range of 45 degrees in relation to the perpendicular location of the attachment towards the display (TD).

The patient with potential cognitive disordered is located before the C-Eye system. The C-Eye is attached to the movable extension arm and adjusted to the subject through the adjusting movements of the movable extension arm in this way, that the subject is located 60 cm before the system. The C-Eye is parallel to the patient's interpupillary line, so that the patient's eyes are situated in the angle of view of the camera (IrSC), as it was presented in Figure 2.

Figure 2: Examination session with the C-Eye system

2.5 C-Eye and Integrated Medical System for Study Management

There are a set of many tasks included in eCRFs that can be fully, objectively performed only with support of eye tracking technology. The C-Eye and eCRF approach assist the physician to use as system in clinical practice. C-Eye could be a platform for a comprehensive patient management and the integration of study documentation into clinical practice – orientation guide for ideal progression control of the therapy. The current version of the C-Eye contains various tasks that correspond to the tasks located in specific subsections of the eCRF being used in everyday clinical practice. C-Eye combines clinical documentation, medical records register, specific therapy documentation, and research projects in one platform. It is necessary to adapt some of them to the structure and template of content presentation to the C-Eye system. Adaptation of eCRF tasks being dedicated for eye tracking-based interaction is associated with content development and its proper implementation. There is a scope for interdisciplinary cooperation between AssisTech engineers and representatives of the medical world.

Conducting full adequate and objective neurological assessment of patient after TBI requires efficiency evaluation of the communication senses (vision and hearing). Sometimes patients who have suffered craniocerebral injury experience visual impairment, and hemispatial neglect, unilateral

(partial) visual inattention (agnosia), and unilateral "neglect" of space occurs. Due to the preliminary assessment we may take into account the patient's difficulties with perception in the half of space opposite to the damaged brain hemisphere.

In the next step, we may conduct simplified hearing examination. It is very important, as patients following craniocerebral trauma are auditory oversensitive (Landon, 2012). At times, such sounds cause physical pain, and significantly reduce the patient's comfort. Therefore, it is very important to adjust loudness of all sounds produced by the C-Eye system to suit the patients' needs.

The C-Eye can effectively expand the use of existing assessment forms for cognitive functions of patients that have been deprived contact with the world and increase the efficiency of their evaluation. Especially, the following sections of Assessment Forms for Cognitive Rehabilitation should be mentioned here: attention problems, visual processing problems, memory problems, information processing problems, executive functions problems. Cognitive assessment procedure adopted to the C-Eye system with considering objectivized evaluation of the communication senses was presented in Figure 3.

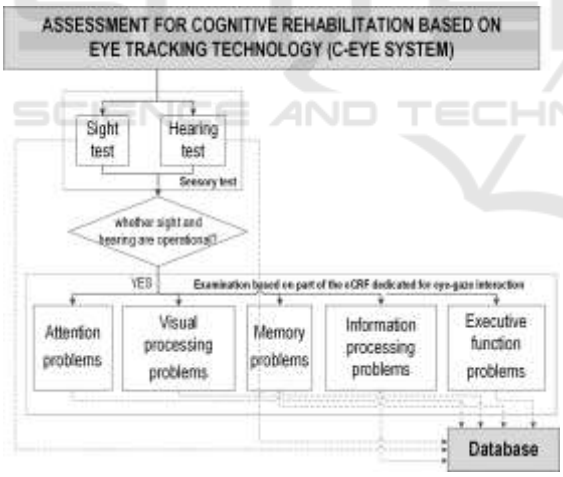

Figure 3: Adaptation of eCRF test to the C-Eye system

Furthermore, the C-Eye can be an effective tool for rehabilitation that allows to perform the following exercises dedicated for patients communicating by eyeballs movements, as well as engaged in Cognitive Stimulation Program (Ribeiro, 2011) at home: spatial/writing skills, search and find, recall of pictures and places, recall of story material, visual scanning, language exercises, categorization exercises, reading comprehension, time sense. It is worth mentioning that the C-Eye being a medical device is simple to use - feature especially important in everyday practice. It doesn't require any software installation or configuration. The C-Eye is fully operable couple seconds after turning it on, and does not require calibration procedure which, in fact, would disqualify the use of the system in case of patients in severe state after TBI. Our approach presented in the paper is comprehensive. We propose employing specialized eye tracking system for holistic assessment, as well as neurorehabilitation (Figure 4).

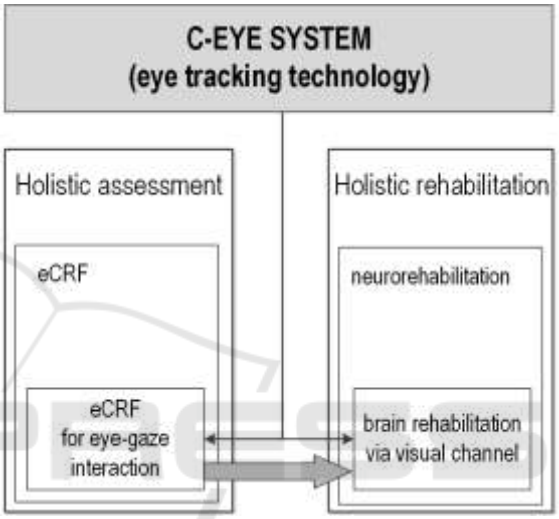

Figure 4: C-Eye system in neurorehabilitation and cyclic, constant assessment based on profiled eCRF

3 RESULTS

Cognitive Test data includes all information in original records and certified copies of original records of rehabilitation procedure, observations in a rehabilitation and diagnostic after TBI.

Access to cognitive test data is critical to the review and inspections of clinical investigations. The review of cognitive test data by both the clinic and sponsor is important to ensure adequate protection of the rights, welfare, and safety of human subjects and the quality and integrity of the clinical investigation data. Cognitive clinical test should be attributable, legible, contemporaneous, original, and accurate and must meet the regulatory requirements for record keeping.

Capturing eye tracking cognitive test data electronically and transmitting it to the eCRF will help:

- Eliminate unnecessary duplication of data
- Reduce the possibility for transcription errors
- Encourage entering source data during a subject's visit, where appropriate
- Eliminate transcription of source data prior to entry into an eCRF
- Facilitate remote monitoring of data
- Promote real-time access for data review
- Facilitate the collection of accurate and complete data

4 CONLUSION

Cognitive Stimulation and rehabilitation allows for great flexibility so that patients can tailor their program of rehabilitation and follow individual schedules. TBI survivors may participate in an intensive level of therapy several hours per week or follow a less demanding regimen. Eye tracking rehabilitation efforts to address the continuum-of-care needs of TBI patients are being developed. Eye tracking service providers and researchers will need to put in place service delivery plans backed by strong research components, which include control populations, prospective evaluations, and rigorous methodology for the assessment of functional vision. In conclusion, our study yielded relevant information related to a structured TBI rehabilitation service and represents an alternative for patients and families afflicted by TBI, enabling the generation of clinical protocols in eCRF Format.

ACKNOWLEDGMENTS

We are very grateful to GoGlobal Team from Fraunhofer Center for International Management and Knowledge Economy for their insights and consultancy into the German medical system and the role cognitive devices in this country.

REFERENCES

Turner-Stokes L, Disler PB, Nair A et al. *Multidisciplinary rehabilitation for acquired brain injury in adults of working age*. Cochrane Database Syst Rev 2007; 2: CD004170

Hebert D, Lindsay MP, McIntyre A, Kirton A, Rumney PG, Bagg S, et al, Canadian stroke best practice recommendations: Stroke rehabilitation practice guidelines, update 2015. Int J Stroke. 2016 Apr 14. pii: 1747493016643553.

J. Doležal, V. Fabian, *Application of eye tracking in neuroscience*, Clinical Neurophysiology, Volume 126, Issue 3, pp. e44, 2015.

B. Kunka, T. Sanner, A. Czyżewski, A. Kwiatkowska, *Consciousness study of subjects with unresponsive wakefulness syndrome employing multimodal interfaces*. In: Ślęzak, D., Tan, A.-H., Peters, J.F., Schwabe, L. (eds.) BIH 2014. LNCS, vol. 8609, pp. 57–67. Springer, Heidelberg (2014).

H. Drewes, *Eye Gaze Tracking for Human Computer Interaction*, LFE Medien-Informatik der Ludwig-Maximilians-Universität, Monachium 2010.

R. J. K. Jacob, K. S. Karn, *Eye tracking in Human-Computer Interaction and usability research: ready to deliver the promises (section commentary)* in "The Mind's Eyes: Cognitive and Applied Aspects of Eye Movements", (J. Hyona, R. Radach, H. Deubel), Elsevier Science, Oxford 2003.

M. J. G. Kooiker, J. J. M. Pel, J. van der Steen, *The Relationship Between Visual Orienting Responses and Clinical Characteristics in Children Attending Special Education for the Visually Impaired*. Journal of Child Neurology, 30(6), 690–697, 2015.

N. Hahn, J. Snedeker, H. Rabagliati, *Rapid Linguistic Ambiguity Resolution in Young Children with Autism Spectrum Disorder: Eye Tracking Evidence for the Limits of Weak Central Coherence: Rapid lexical ambiguity resolution in ASD*. Autism Research, 8(6), 717–726, 2015.

H. L. Urry, *Seeing, thinking, and feeling: emotion-regulating effects of gaze-directed cognitive reappraisal*, Emotion, 10(1), pp. 125-135, 2010.

iMotions platform, available at: https://imotions.com/, last access: April 14th, 2016.

S. Bellary, B. Krishnankutty and M. S. Latha: *Basics of case report form designing in clinical research*. Perspect Clin Res. 2014 Oct-Dec; 5(4): 159–166.

J. Landon, D. Shepherd, S. Stuart, A. Theadom, S. Freundlich, *Hearing every footstep: Noise sensitivity in individuals following traumatic brain injury*, Neuropsychological Rehabilitation, 22(3), pp. 391-407, 2012

F. R. Freire, F. Coelho, J. R. Lacerda, M. F. da Silva, V. T. Gonçalves, S. Machado, B. Velasques, P. Ribeiro, L. F. Hindi Basile, A. Maynart, P. Oliveira, Wellingson S. P., P. A. Medeiros Kanda, R. Anghinah: *Cognitive rehabilitation following traumatic brain injury.* Dement Neuropsychol 2011 March;5(1):17-25