Exploring Complexity in Health: An Interdisciplinary Systems Approach
A. Hoerbst et al. (Eds.)

doi:10.3233/978-1-61499-678-1-604

Feasibility of Eyetracking in Critical Care Environments - A Systematic Review

Andreas KLAUSEN, Rainer RÖHRIG and Myriam LIPPRANDT[1]
Department of Medical Informatics, Carl von Ossietzky University, Oldenburg

Abstract. Achieving a good understanding of the socio-technical system in critical or emergency situations is important for patient safety. Research in human-computer interaction in the field of anesthesia or surgery has the potential to improve usability of the user interfaces and enhance patient safety. Therefore eye-tracking is a technology for analyzing gaze patterns. It can also measure what is being perceived by the physician during medical procedures. The aim of this review is the applicability of eye-tracker in the domain of simulated or real environments of anesthesia, surgery or intensive care. We carried out a literature research in PubMed. Two independent researchers screened the titles and abstracts. The remaining 8 full-papers were analyzed based on the applicability of eye-trackers. The articles contain topics like training of surgeons, novice vs. experts or the cognitive workload. None of the publications address our goal. The applicability or limitations of the eye-tracker technology were stated incidentally.

Keywords. Eye Tracking, Feasibility, Usability, Medical Informatics Applications, Equipment and Supplies Keyword, Information System, cognitive workload, Surgery, Critical Care, Anaesthesia, Intensive Care, Patient Safety

1. Introduction

Nowadays, interactive medical devices and information systems are omnipresent in intensive care units, emergency medicine or operating theatres. Problems in human-computer interaction (HCI) can lead to hazardous situations for patients [1]. Those problems becomes even more dangerous for the patient especially when the physicians has to work under pressure. Therefore, an analysis of the socio-technical system is crucial for patient safety. Physiological parameters like situation awareness and assessments for cognitive workload can yield information about the stress level and awareness of a physician. To gain insight into cognitive processes like attention, workload, stress and perceived information, eye-tracking technology is the prime selection. Other technologies can also detect stress (e.g. heart rate measurement). Advantages in eye-tracking technology have resulted in quantitative data of perception and awareness which yields to an interpretation of human behavior.

The aim of this systematic review is to explore the feasibility of eye tracking technologies in intensive care, surgery or anesthesia environments. These medical disciplines make the use of eye tracking challenging. The rapid movement of the individual, the changing distances between near and far and the changing of brightness values

[1] Corresponding Author: Myriam.Lipprandt@uni-oldenburg.de

from extreme ranges of light could possibly limit the applicability of head mounted eye tracker.

2. Methods

In this systematic review the objective was to analyze the feasibility of head mounted eye tracking technologies in the field of anaesthesia, surgery or intensive care. The applicability of eye-tracking in challenging environments with changes in brightness or high movement were the objectives. The aim was to explore the feasibility of eye-tracking in these medical fields (anaesthesia, surgery or intensive care). We performed a literature search of PubMed using the following search term:

> (("Eye Tracking") OR ("Eyetracking") OR ("Eyetracker") OR ("Eye Tracker") OR ("eye-tracking") OR ("Eye-Tracking") OR ("Eye-Tracker") OR ("eye-tracker") OR ("eyetracker") OR ("eyetracking") OR ("eye tracking") OR ("eye tracker")) AND ((Medical Informatics Applications[MeSH Major Topic]) OR (Equipment and Supplies[MeSH Major Topic]) OR (Information System) OR ("Medical Devices") OR usability OR feasibility OR ("mental workload") OR ("cognitive workload") OR (Surgery) OR (Critical Care) OR (clinical reasoning) OR (review) OR (Anaesthesia) OR (Intensive Care))

We included literature in English and limited the search to articles published in the last 5 years (December 31nd 2010 to January 1st 2016), based on significant changes in eye-tracking technology especially in head-mounted eye-tracker.

Two reviewers, one computer scientist and one physician worked independently. Both screened the literature first based on titles and abstracts. Ambiguous articles were screened by reading the full paper. All conflicts were resolved in consensus process. The papers were eligible for inclusion if the eye-tracker was used for:

- Usability tests in challenging environments e.g. operation room, anaesthesia, intensive care units
- Educational purpose in anaesthesia, intensive care or surgeries
- Technical applicability and performance of eye tracker in critical care
- Only Head-Mounted Eye tracker (Glasses)

The exclude criteria contains research about e.g. eye-tracker as a diagnosis tool or eye-tracking for psychological questions (e.g. learning). All of the exclude criteria uses eye-tracker as a tool for answering research questions in various fields without referring to the medical fields of anaesthesia, surgery or intensive care. Following exclusion categories are specified: research in eye movement, rehabilitation, psychological and neurological domains and eye tracker as a medical device for communication (e.g. Brain Computer Interface). Also eye-tracker as an input device or as a diagnostic tool and settings where eye-trackers are used to gather information on a display or print sheet. In addition processing and visualization software of eye tracking data are also excluded.

3. Results

3.1. Study selection

The search strategy in PubMed generates 383 papers. No duplicates were detected. The titles and abstracts were revised based on the inclusion und exclusion criteria. During the review process we categorized beside of the ex- and inclusion criteria all papers. Most of the paper were assigned to the category "perception and cognition". This category contains also papers about workload during e.g. medical processes or educational purpose. The second highest papers were in the category "eye-tracker for diagnosis", where mostly patient wear the eye-tracker. The other categories were "eye-tracker as medical product", "eye-tracker as a communication tool", "control device" or "comparison between experts and novice".

In our initial database were 383 abstracts. We excluded in the first iteration 363 articles that did not match with our include criteria. After reading the remaining 28 articles, we exclude 20 papers based on refined criteria (figure 1). The use of head-mounted eye-tracker in real or simulated environments was crucial for this review. Articles using stationary eye-tracker or scenarios using assessing only displays were excluded.

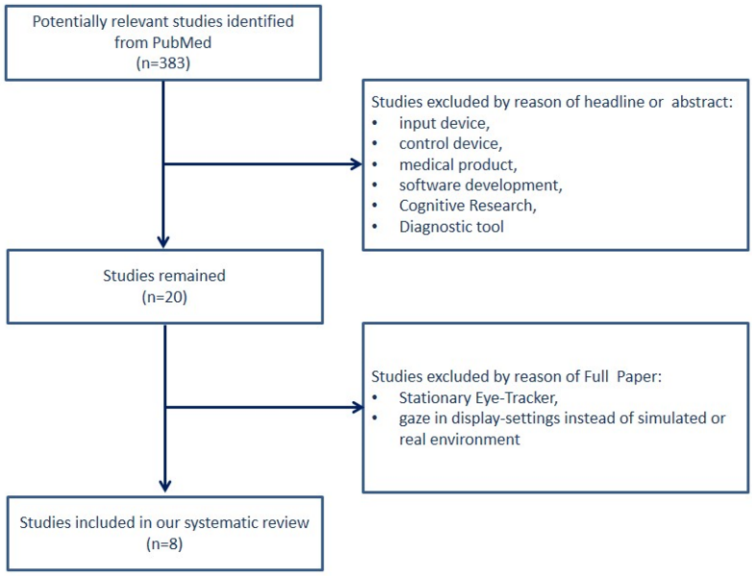

Figure 1. PRISMA flowchart

3.2. Reported Outcomes

The remained publications uses eye-tracker in the medical domain of anaesthesia, surgery or intensive care in real or simulated environments. The objectives of these articles were "research in training of surgeons" [2] or "differences in novice vs. experts" [3–5]. The gaze behaviour as a parameter for situation awareness or visual attention for workload was analysed in [6–8]. One article measures the differences between simulated surgeries and real surgeries [9] (see Table 1).

Table 1. Overview on the studies which were included in the systematic review

Ref	Aim	Scenario and Environment	Data Collection	Limitations
[6] [7] [8]	Measuring workload and visual attention in anesthesia simulated environments	Simulation of an induction of anesthesia with a full-scale simulator	Pupil size, saccade, fixation, visual attention, Region of Interest (ROI)	Marginal disturbance through the eye tracker
[5]	Examination of information acquisition strategies in expert and competent non-expert intensive care physicians	Simulation of an Infant with monitoring of vital parameters in pediatric intensive care unit.	Gaze Fixation, saccades, blinks, dwell time, Area of Interest (AOI)	Exclusion of some eye-tracker data through calibration failure
[2]	Examine the use of eye-trackers for improving surgical training	Surgeons Vigilance in simulation settings. Virtual cholecystectomy with a patient simulator	Blink and gaze	Calibration process was extensive, quality of recording data were noisy and the resolution was insufficient
[9]	Assessment of visual control during simulation and live operations	Real transurethral resection of the prostate	Gaze fixation, search rate,	
[4]	Eye movement of perfusionists during surgery	Real cardiac surgery	AOI, fixation, transitions	
[3]	Differences in gaze behavior of junior surgeons in comparison to experts	Real open inguinal hernia repair surgery	AOI, Fixation, dwell, pupil size, pupil entropy, pupil rate of change	Three cases out of 25 were discarded due to poor eye tracking data

4. Discussion

None of the publications focus on our objective to identify the applicability of head-mounted eye-tracker in intensive care environments. All the remaining articles mention the limitations as a side note.

In [7] the questionnaire shows that the head-mounted eye-tracker was more than marginal disturbing while working (mean value). The mobility was restricted marginally. The eye-tracker restricted the treatment of the patient slightly. In [9] shows that the eye movement in a simulated setting were higher than in the real operation setting. This leads to different interpretation based on a higher stress level and complexity during medical procedures. Applications of eye-tracker in real environments are still rare [4] and are not the main objective in research.

5. Conclusion

The eye-tracking device gives important insight into cognitive processes and makes this technology suitable for the use in different domains. This review has shown that eye-tracker can be used as an input device for people with disabilities [10] or as a diagnostic tool for patients with e.g. depression [11]. The main application for eye-tracker is for cognitive science.

The use of eye-tracker in highly challenging medical situations e.g. surgeries, intensive care or anaesthesia where health professionals work under stress are rare. What kind of eye-tracker is reliable and applicable to these environments is still unanswered. Further research is needed to analyse the interaction between humans and the computer (social-technical systems) in critical care environments, especially to evaluate the usability of new medical devices.

References

[1] Rogers ML, Patterson E, Chapman R, Render M. Usability Testing and the Relation of Clinical Information Systems to Patient Safety. Ft. Belvoir: Defense Technical Information Center; JAN 2005.

[2] Atkins MS, Tien G, Khan RSA, Meneghetti A, Zheng B. What do surgeons see: capturing and synchronizing eye gaze for surgery applications. *Surg Innov* 2013;**20**:241–8. doi:10.1177/1553350612449075.

[3] Tien T, Pucher PH, Sodergren MH, Sriskandarajah K, Yang G, Darzi A. Differences in gaze behaviour of expert and junior surgeons performing open inguinal hernia repair. *Surg Endosc* 2015;**29**:405–13. doi:10.1007/s00464-014-3683-7.

[4] Tomizawa Y, Aoki H, Suzuki S, Matayoshi T, Yozu R. Eye-tracking analysis of skilled performance in clinical extracorporeal circulation. *J Artif Organs* 2012;**15**:146–57. doi:10.1007/s10047-012-0630-z.

[5] McCormack C, Wiggins MW, Loveday T, Festa M. Expert and competent non-expert visual cues during simulated diagnosis in intensive care. *Front. Psychol*. 2014;**5**:17. doi:10.3389/fpsyg.2014.00949.

[6] Schulz CM, Schneider E, Fritz L, Vockeroth J, Hapfelmeier A, Brandt T, et al. Visual attention of anaesthetists during simulated critical incidents. *British Journal of Anaesthesia* 2011;**106**:807–13. doi:10.1093/bja/aer087.

[7] Schulz CM, Schneider E, Fritz L, Vockeroth J, Hapfelmeier A, Wasmaier M, et al. Eye tracking for assessment of workload: A pilot study in an anaesthesia simulator environment. *British Journal of Anaesthesia* 2010;**106**:44–50. doi:10.1093/bja/aeq307.

[8] Schulz CM, Schneider E, Kohlbecher S, Hapfelmeier A, Heuser F, Wagner KJ, et al. The influence of anaesthetists' experience on workload, performance and visual attention during simulated critical incidents. *J Clin Monit Comput* 2014;**28**:475–80. doi:10.1007/s10877-013-9443-8.

[9] Vine SJ, McGrath JS, Bright E, Dutton T, Clark J, Wilson MR. Assessing visual control during simulated and live operations: gathering evidence for the content validity of simulation using eye movement metrics. *Surg Endosc* 2014;**28**:1788–93. doi:10.1007/s00464-013-3387-4.

[10] Cipresso P, Carelli L, Solca F, Meazzi D, Meriggi P, Poletti B, et al. The use of P300-based BCIs in amyotrophic lateral sclerosis: From augmentative and alternative communication to cognitive assessment. *Brain and Behavior* 2012;**2**:479–98. doi:10.1002/brb3.57.

[11] Armstrong T, Olatunji BO. Eye tracking of attention in the affective disorders: A meta-analytic review and synthesis. *Clinical Psychology Review* 2012;**32**:704–23. doi:10.1016/j.cpr.2012.09.004.