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Eye tracking and usability research: an introduction to the special issue

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Undoubtedly, there is a great potential for the eye movement research community with the ECEM as face-to-face platform and the JEMR as open access journal to bridge the gap between basic knowledge and experimental procedures, on the one hand, and the idiosyncratic requirements for a successful application of eye tracking, on the other. The current special issue of the journal is a representative – though non exhaustive – selection of recent studies that attempt to reach exactly this goal, i.e. bringing expertise in eye movement research to application domains.

The idea to use the methodology of eye movement analysis in the field of usability and human-computer interaction (HCI) is not new. In the framework of the 12th ECEM, it already has been stated that “uses of eye tracking in HCI have been highly promising for many years, but progress in making good use of eye movements in HCI has been slow to date” (Jacob & Karn, 2003, p. 573). Instead of providing a general answer to this and related questions, the current set of papers presents a state of the art overview of the progress in several particular areas, such as eye typing, reading and online search. Although overall eye tracking seems to evolve towards a promising and easy to use methodology, the emphasis of the issue rather is on highlighting and discussing specific problems for the applications. Our hope, therefore, is that the present collection of papers will help to demonstrate benefits but also limits for the current use of eye tracking in applied areas.

Efforts to understand mechanisms of eye movement behaviour have a long tradition in science (for a review see Wade & Tatler, 2005). The second half of the past century can be seen as the start of modern eye movement research. The pioneering work of Alfred Yarbus was a milestone due to the emphasis of cognitive influences on eye movements (Yarbus, 1967). His findings clearly demonstrated the importance of the task, evidenced in various different gaze patterns. In the following decades the relationship between eye movement behaviour and cognitive processes has been extensively studied (e.g. Hayhoe & Ballard, 2005; Henderson, 2003; Kowler, 1990). Research efforts resulted in profound knowledge about the underlying mechanisms of gaze control in relation to visual perception, attention, and cognition. Apart from laboratory experiments, eye movement behaviour is investigated during various tasks such as reading (Rayner, 1978, 1998), scene perception (Henderson & Hollingworth, 1999; Pannasch, Helmert, Roth, Herbold, & Walter, in press), driving (Land, 1998; Unema, Pannasch, Joos, & Velichkovsky, 2005; Velichkovsky, Rothert, Kopf, Dornhoefer, & Joos, 2002), social interaction (Schrammel, Pannasch, Graupner, Mojzisch, & Velichkovsky, in press) but also other activities of daily living (Land, 2006).

The increase in scientific knowledge is often based on previous findings and improved methods. Considering eye movement research such a progress is directly related to the achievements in the eye tracking technology. The mentioned work by Yarbus (1967) was done with a relatively primitive eye tracking device consisting of a mirror attached to the sclera of the eye by a suction cup. A bright light reflected off the mirror exposed a piece of photographic film, leaving a trace of the movement of the eye. The invasive character of this experimental setup restricted the eye movement recordings to a laboratory environment but also to a limited period of time. Subsequent systems, such as eye coils and Dual-Purkinje

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Image Tracker were more comfortable but still had certain restrictions, e.g. required the head to be fixed during the recording session. Although there is a variety of measurement methodologies to record eye movements (see for an overview Duchowski, 2007), recent developments in this technology can be seen between two extremes. At one end there are systems designed mainly for experimental research of higher temporal resolution (sample rates of ≥ 2000 Hz) and more accurate considering the spatial acuity (≤ 0.5 deg). Unfortunately, these systems are quite expensive, so that they can be afforded by research institutions and companies only. At the other end there are numerous efforts to the practical employment of eye tracking technology by developing low cost systems (e.g. Bettley, 1999; Li, Babcock, & Parkhurst, 2006). The devices of this category do not need to be of the precision as the experimental systems but should rather be of a greater flexibility in use. Due to the broad range of currently available systems different eye tracking solutions can be found depending on the case specific applications, such as usability research.

In the field of human-computer interaction usability is a core term although it is difficult to find a precise definition of its meaning. The term usability was originally derived from "user friendly" and has also been called "the capability to be used by humans easily and effectively" (Shackel, 1991, p. 24). The concept is defined as "the effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in particular environments" (ISO 9241-1, 1997). In research on human-computer interaction, usability refers to the extent to which the user and the system can "communicate" clearly and without misunderstanding through the interface. In other words, usability can be seen as the degree of compatibility of the system with the users' cognitive characteristics for communication, understanding, memory and problem solving (Goodwin, 1987).

There are many evaluation tools and techniques available for the measurement of usability (for reviews see Folmer & Bosch, 2004; Hornbaek, 2006). Following sporadic early efforts to apply eye movements data when users interact with technical devices such as cockpit controls in airplanes (Fitts, Jones, & Milton, 1950), the mentioned achievements in the technology made video-based eye tracking to an essential tool for the evaluation of usability (e.g. Bernhaupt, Palanque, Winckler, & Navarre, 2007; Jacob & Karn, 2003; Poole & Ball, 2004).

However, considering the usability concept in a broader sense, we think that eye tracking can provide more than just another additional evaluation technique (e.g. Velichkovsky & Hansen, 1996). Traditional usability testing focus on the investigation of software interfaces by the application of different methods. The fact that measuring eye movement behaviour can provide very fast and accurate allocation of (visual) attention makes eye tracking a promising candidate for future developments in several domains.

From the today's perspective we think that eye tracking will play an essential role in the following domains. Eye tracking will become of increasing importance (as it also was used previously in research) as a *diagnostic tool and source of information about mode of processing* (e.g. Velichkovsky, Joos, Helmert, & Pannasch, 2005; Velichkovsky et al., 2002). The use of this information will provide the base for the implementation of eye tracking in *attentive interfaces and advanced assistant systems* (e.g. Selker, 2004; Vertegaal, Shell, Chen, & Mamuji, 2006; Vertegaal, Velichkovsky, & Van der Veer, 1997). In line with attentive interfaces but another domain of application will be the use of gaze as *means for communicative interaction* (e.g. Bates, Donegan, Istance, Hansen, & Räihä, 2007). It is obvious that these domains share some overlap, at least that eye tracking will be the key method to improve future applications. However, also for these developments the compliance with the usability is of major importance.

This special issue brings together a group of investigators, all of whom study critical issues in the field of eye tracking and usability research. Topics include representative selections from the three domains introduced above. The paper by **Castellini** describes how eye tracking can be integrated in human-robot interaction. The author investigates the contribution of eye movement data in the construction of an intelligent robotic artifact trying to grasp objects in a teleoperation setup. The feasibility is demonstrated and the improvement can be seen as another contribution in terms of an advanced assistant system. The study by **Zambarbieri, Carniglia and Robino** analyses eye movement behaviour while reading an online newspaper. From the experimental results suggestions for the presentation of online material are discussed. Moreover, the task clearly influences the interaction with the presented material. Eye tracking data in this investigation also provides information about the

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processing mode. **Hyrskykari, Ovaska, Majaranta, Räihä and Lehtinen** explored the use of eye tracking in usability testing comparing concurrent and retrospective thinking aloud. The results emphasize on the combination of eye movement analysis and retrospective verbalization and suggest that this procedure can actually replace collecting the conventional think-aloud protocol during the test. In consideration of the application domains, the contributions from **Zambarbieri, Carniglia and Robino** and **Hyrskykari, Ovaska, Majaranta, Räihä and Lehtinen** are nice examples that eye tracking can be used as diagnostic tool. Analysis of eye movements can provide access to human information processing – not only in rather artificial laboratory environments but also in everyday tasks like online reading or online search.

The two papers by **Huckauf and Urbina** and **Helmert, Pannasch and Velichkovsky** examine particular issues of eye typing approach. **Huckauf and Urbina** suggest a new method for object selection in such interactive tasks in order to get rid of current problems with a pure dwell time selection. **Helmert, Pannasch and Velichkovsky** scrutinized dwell time based selection by the application of smoothing and delaying algorithms. Both contributions support the idea that eye tracking technology can be applied as means for communicative interaction. Moreover, **Helmert, Pannasch and Velichkovsky's** contribution also uses eye movement parameters as source of information about mode of processing and therefore represents an example of the already discussed overlap between the domains.

Finally, the work by **Pannasch, Helmert, Malischke, Storch and Velichkovsky** compares two different types of eye typing application designed to improve communication facilities of patients suffering from amyotrophic lateral sclerosis (ALS). With four ALS patients as participants, this study particularly emphasises the importance of eye tracking as a tool for new forms of interaction. The intended target population for eye typing are patients who are suffering from motor neuron diseases with ALS as a prominent example. Overall, the results of this work do not only demonstrate the feasibility of the participative design strategy in development of eye typing systems but also provides essential new information on the usability of eye typing communication interfaces for this unique group of users.

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