Re-viewing the museum visitor's view

Daniel Wessel

Knowledge Media Research Center, Tuebingen
d.wessel@iwm-kmrc.de

Eva Mayr, Kristin Knipfer

Applied Cognitive & Media Psychology, University of Tuebingen
e.mayr@iwm-kmrc.de, k.knipfer@iwm-kmrc.de

Abstract

Eye movements are not only important in research on natural human behaviour but also in research on mobile learning. We specify what mobile eye tracking can tell us about learning on the move. Potentials and constraints of mobile eye tracking as methodological approach for research on mobile learning are discussed. Exemplary data from our study are presented in which a small sample of visitors explored a museum exhibition with a mobile eye tracker. We argue that mobile eye tracking is a powerful data collecting method in research on mobile learning despite some limitations.

1. Mobile eye tracking in research on mobile learning

Why are eye movements interesting for mobile learning? "Eye movements provide an unobtrusive, sensitive, real-time behavioural index of ongoing visual and cognitive processing" (Henderson, 2003, p. 498). Most daily tasks involve visual input and people typically look at objects to acquire information. Thus, eye movements are not only important for research on natural human behaviour but especially on (mobile) learning.

1.1 History

Research on eye movements dates back to the early 20th century. It focused on scene perception and reading (for an extensive review see Rayner, 1998). Eye tracking was used only for the limited purpose of laboratory studies. Only in recent years researchers addressed more complex, daily activities in natural environment (e.g., Land & Hayhoe, 2001). This was enabled through the development of light-weight, *mobile* eye tracking technologies (Pelz et al., 2000).

1.2 Potentials

Data richness. Mobile eye tracking provides rich data about natural behaviour at a higher level of detail and accuracy than questionnaires or observation. In contrast to other tracking methods like logfiles, eye tracking additionally provides insight into planning behaviour that does not finally result in action.

Data validity. In contrast to external observation or retrospective questionnaires/interviews, mobile eye tracking gathers data *online* during actual behaviour and from the acting subject's perspective. The method provides insights into unconscious information processing that lie beyond introspectively accessible processes (Pelz et al., 2000). Validity of eye gaze recording is higher than validity of external observation which can only determine which direction a person is looking at but not where the eyes are fixated.

Non-reactive measurement. Data collecting methods like questionnaires and interviews are considered to be highly reactive (Fritsche & Linneweber, 2006). In contrast, eye movements are natural behaviour that can hardly be manipulated by the tracked subject.

Statistical analysis. Like logfile analysis, eye tracking obtains highly structured data that allow for further statistical analyses, for example occurrences of specific events or gaze sequences like “scan patterns” (Henderson, 2003).

1.3 Constraints

Covert attention and mental spotlight. “The window of attention set by the parietal scan can take on different apertures, to encompass anything from a finely localized object to a global view of the surrounding scene.” (Treisman, 2006, p. 4). Similarly, text reading research states that fixations do not directly indicate where the ‘mental spotlight’ currently is, i.e. what information is currently processed (for a review of different hypotheses concerning the relation of ‘eye’ and ‘mind’ see Kliegl, Nuthmann, & Engbert, 2006). Therefore, eye tracking delivers accurate data about fixations but does not always lead to correct conclusions regarding the focus of attention.

Limited conclusions on cognitive processing. Information about subjects’ attitudes or reasons for their (visual) behaviour is limited because cognitive processes cannot be observed directly through eye tracking. “Whereas a given cognitive event might reliably lead to a particular fixation, the fixation itself does not uniquely specify the cognitive event” (Hayhoe & Ballard, 2005, p. 190). Eye movements are determined by two processes: bottom-up, stimulus-lead processes (salience) and top-down, cognitively-lead processes (knowledge, goals, cp. Henderson, 2003). Whereas influence of bottom-up processes can be modelled (Turano, Geruschat, & Baker, 2003), data on a person’s attitudes or reasons for specific behaviour cannot be obtained as cognitive processes cannot be observed directly through eye tracking. Interpretations of eye movements are often based on assumptions and heuristics about underlying cognitive processes. This limits the validity of conclusions on underlying cognitive processes.

Obtrusiveness of measurement. The eye tracker itself is obtrusive: Participants know that their gazes are tracked, and looking through goggles might be unfamiliar. Other people who see the eye tracker will probably interact differently with a person wearing an eye tracker. These factors could influence behaviour during eye tracking.

Selective sampling. Mobile eye tracking devices are difficult to calibrate for persons with glasses or corneal irregularity. Visually impaired people are excluded from eye tracking studies and therefore generalisation to these people might be limited.

Limited temporal accuracy. The temporal resolution depends on recording. A 50 Hz PAL DVCR tape saves two camera images by alternating frames. This results in a resolution of 25 Hz. Since fixations as short as 33 ms were observed (Pelz et al., 2000), some fixations can be missed.

Limited spatial accuracy. Eye tracking works best if the system is calibrated to the fixation distance - but fixation distances vary continuously in natural environments. As a consequence accuracy might be worse than with eye tracking on computer screens.

Laborious data analysis. Automatic data analysis like in static eye tracking is difficult because the background changes constantly and persons' behaviours and gazes differ from each another. Therefore, each eye tracking video has to be analyzed manually unless software is developed that can recognize elements in the video feed and combine this information with eye tracking data. Thus, many studies use only short tasks where similar eye movements can be expected (e.g., Land & Hayhoe, 2001) which limits generalisation of eye tracking data for more complex (learning) tasks.

Price. Mobile eye trackers are very expensive – the version used in this study costs about 24 000 €.

Ethical concerns. Given the existence of unconscious or uncontrolled eye movements, even participants who have previously agreed may reveal information they would rather have kept private.

2. Re-viewing the museum visitor's view - an explorative study

2.1 Aim of the study

To gain insight into mobile learning in science museums, we equipped some visitors with a mobile eye tracker. Our approach was mainly exploratory: Eye tracking allowed us to re-view the visitors' view – beyond observational or questionnaire methods. We wanted to examine what eye movements tell us about exploration behaviour and cognitive elaboration on exhibition content.

2.2 Method

Our sample consisted of three students who visited a small exhibition about nanotechnology with an ASL MobileEye eye tracker (see figure 1). They were instructed to visit the exhibition as they would normally do in a science museum. Prior to exploration of the exhibition the eye tracker was calibrated for a distance that visitors would probably keep while looking at exhibits.

Figure 1. ASL MobileEye eye tracker (initial design October 2004).

Recordings were transformed into .avi-files and analysed by one rater with Videograph©. Similar to Turano and colleagues (2003), we did not analyse eye movements based on xy-coordinates but on categories. For our purposes, fixations within the same category were of higher interest than proximity of fixations. Also, background changes influence xy-coordinates but not categories. The categories were developed according to the visible elements of the exhibition (see figure 2). Each exhibit or text unit was a category. Categories might be grouped in larger categories like “exhibits with corresponding labels”, “all labels”, or “exhibits on the same concept” afterwards.

Figure 2. Exhibition wall categories (left) and sample eye tracking image (right). On the eye tracking image the red crosshair (a) shows where the measured eye is fixated at this moment, the purple circle (b) shows the position of the pupil and the small purple cross (c) the position of the master spot.

After exploration of the exhibition, a structured interview provided insight into visitors’ subjective experiences and introspective thoughts on reasons for their exploration behaviour and on ongoing cognitive processes.

2.3 Exemplary Results and Discussion

Individual scan patterns indicate that exhibits that conceptually belong together are likely to be fixated successively (see figure 3) and also several times alternately (see figure 4). This may indicate that people integrate multiple information units into an underlying concept (Rayner, Rotello, Stewart, Keir, & Duffy, 2001) or at least do not process these information units independently from each other (Schwonke, Renkl, & Berthold, 2007). Our exit interview also showed a different explanation for alternate fixation of objects: One participant stated that she was not comparing the content but the design when confronted with her eye movement episode.

Figure 3. Sequence of one participant focusing on three exhibits conceptually belonging together and exploring them successively (the plotted arrow shows the scan path).

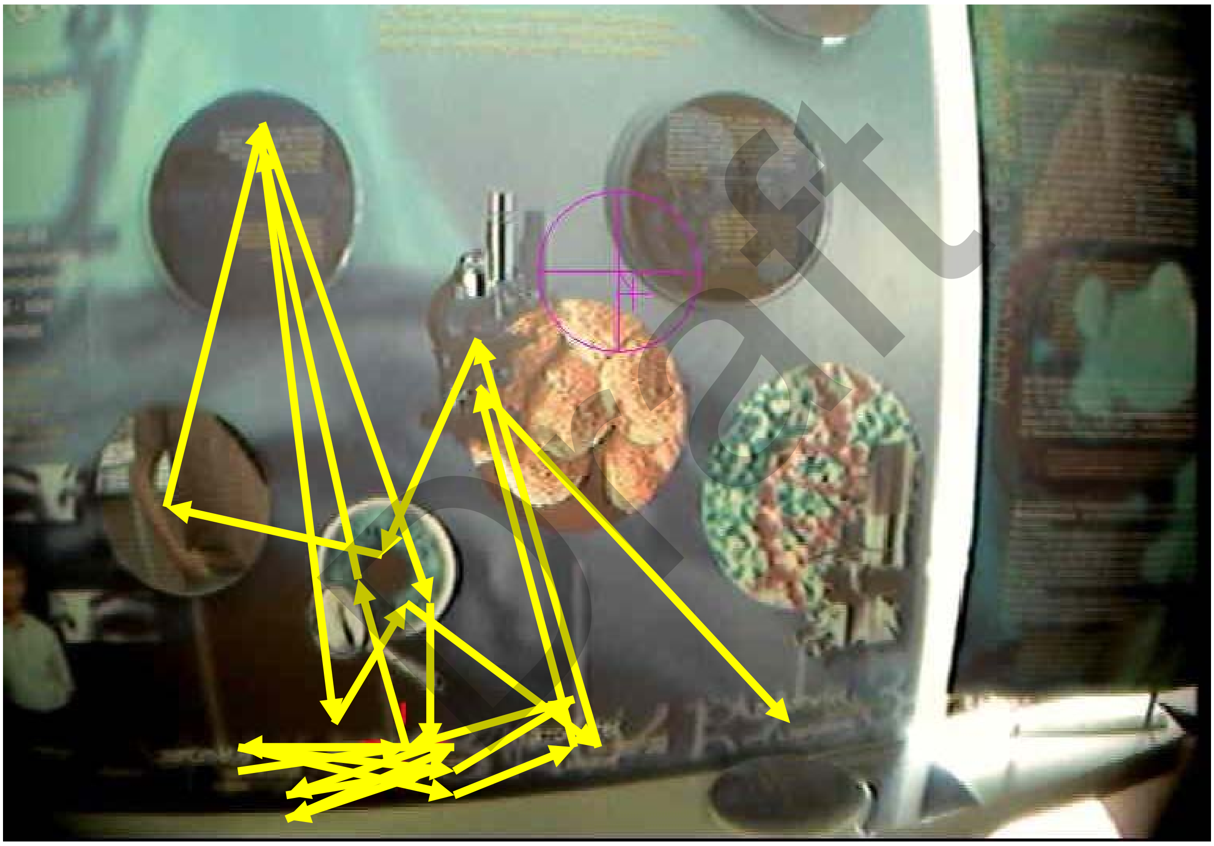

Figure 4. 17-seconds episode of one participant fixating objects conceptually belonging together several times alternately (the plotted arrow shows the scan path).

Analysis across all individuals showed that overall, some exhibits were less likely to be explored than others. This might be due to limitations in exhibition design as research showed that probability of visual exploration depends on graphical salience of objects (e.g., Holsanova, Rahm, & Holmqvist, 2006). An alternative explanation is that these parts of the exhibition were attended to without direct fixations (cp. Treisman, 2006).

A common pattern we identified was that all participants first scanned each exhibition wall as a whole, and then began to explore single exhibits in their vicinity. Research suggests that the first process serves as initial selection of information and visual search - and is rather automated. At early processing stages, pictorial information or text is quickly skimmed and scanned before late processing like reading text or exploring details of objects occur (Holmberg, 2004). However, Holsanova and colleagues (2006) found multiple reading patterns for newspaper readers. More subjects are necessary to validate the assumption of a common elaboration pattern within the context of our exhibition.

3. Conclusion

Eye tracking is not a stand-alone-method but should be combined with other methods for valid interpretations. Conclusions from eye movements on underlying cognitive processes are error-prone. Clear hypotheses about cognitive processes and their influence on eye movements are indispensable. Interview and questionnaire data about a person's interests and knowledge can be used to examine hypotheses with the data at hand.

An important question is whether data should be analysed intra- or interindivdually. As eye tracking data is very rich, big samples are rare (for an exception see Wooding, 2002) and the degree to which results from small samples can be generalised is limited**.** Still, case studies can provide important insight how information is processed and how informal and implicit learning happens on the move.

Further technical development of mobile eye tracking devices will probably eliminate some of the technical constraints reported above. Still, software is needed to analyse real-world-videos with changing angles, views, distances, and objects to reduce complexity of analysis of eye tracking data.

Despite some limitations, we think that mobile eye tracking is a powerful data collecting method in research on mobile learning. In our exploratory study we gained valuable insight on the exhibition itself and on the exploration behaviour of its visitors which we would have hardly achieved otherwise.

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