Eye Tracking and the Learning System: An Overview

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1 Introduction

In everyday and learning tasks, the eyes have, firstly, the roles of locating and recognizing objects and then, secondly, directing the actions to make use of them (Land & Tatler 2009). The use of eye tracking can reveal important aspects about students' learning processes. Because eye tracking provides insights into the allocation of visual attention, it is very suited to study differences in learners' attentional processes. In this section of the book, the contributions focus on the visual processes that occur when participants are performing a task.

Eye-tracking research in the area of learning has been dominated by the use of eye tracking in investigating reading. During learning tasks, students use their eye movements to accommodate incoming stimuli, and if the information is in printed form, linguistic factors such as the frequency of words, the difficulty of the text and the background knowledge of the learner influence eye-movement patterns (Rayner 2009). Much research has been analytical, focussing on variables and components such as word frequency (White 2008), perceptual scans in reading, cognitive processes in reading (Rayner 2009), word predictability (Drieghe et al. 2005), number of meanings (Folk and Morris 2003), phonological properties of words (Ashby 2006) and semantic relations and word familiarity (Williams and Morris 2004). These valuable data have provided much useful information on how readers process text. The chapters in this part focus on the interaction between the learner and the stimulus in the context of task-oriented activities using eye-tracking methodology.

The use of eye-tracking methodologies is of increasing importance in many new technology-based research approaches in learning and education. The area of *Teaching Analytics*, for example, investigates the sort of data and information that

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teachers receive in dynamic learning environments (Reimann et al. 2013) and the Conferences of the Computer Supported Collaborative Environment held under the auspices of the International Society of the Learning Sciences (ISLS). Significant data are sourced from eye-tracking data analysis in collaboration with repertory grid analysis (Reimann et al. 2012).

Teaching and learning analytics generally offers new tools and resources, partially based on eye tracking, to allow teachers deeper insights into the learning process and to access new knowledge of how to provide feedback and guidance to learners. There are a number of learning analytics research groupings such as the Multimodal Learning Analytics Group at Stanford University (Worsley and Blikstein 2013; Blikstein 2013). Learning analytics researchers utilise eye-tracking methods to comprehensively and systematically describe, investigate and characterise the student learning process.

Studies of learners' cognitive and perceptual processes are taking research into a new phase of investigation, due mainly to the capability of eye-tracking software to produce data. These data can illustrate what learners are visually attending to (e.g. the Broadbent chapter which reports on what nursing students focus on when analysing an electrocardiogram (ECG)), the order in which they do it (e.g. school students in the Knight an Horsley chapter reading a passage and answering comprehension questions) and the length of time learners devote to a task (e.g. higher education students composing a response online as reported in the Persaud and Eliot chapter).

2 Research on the Mechanics of Reading Comprehension

Eye-tracking methodologies enable researchers to track a reader's eye movements, as well as their fixations (Rayner 1998) with saccadic movements between sentences and fixation times providing insights into comprehension activity. When completing a comprehension task, it is not easy for learners with learning and reading difficulties to determine which parts of the text are most relevant (and hence need to be attended to). By examining the eye movements of skilled and weak readers during a comprehension task, it is possible to compare the different strategies used by the different readers. These data can provide important insights into the attentional processes used by effective readers and then be applied to generate strategies to improve weak students' comprehension monitoring skills. For example, Van Gog et al. (2009) have indicated that a useful strategy to enhance novice (our equivalent of weak readers) attentional skills so that they perform more expertly (our equivalent of skilled readers) with better learning outcomes may be not only to model skilled readers' strategies and actions but also to display and discuss their eye movements.

Knight and Horsley analyse the mechanics of reading comprehension used by 15 skilled and weak readers completing a standardised comprehension test (National Assessment Program—Literacy and Numeracy (NAPLAN)) that is administered by all schools to determine students' reading and comprehension skills. *The* chapter outlines the use of eye tracking and electroencephalogram (EEG) methodologies

that have been used to develop a model of the mechanics of reading. The model has added a set of macro-reading behaviours revealed during the development of the model to the micro-reading behaviours of reading individual words and phrases established by previous eye-tracking research into reading behaviour (e.g. Rayner 1998, 2009; Liversedge et al. 2011).

Early data report that skilled readers scanned quickly, continuously and consistently from the comprehension questions to the text, suggesting that what they believe to be a critical part of a text is aligned to comprehension questions. On the other hand, weak readers were reading linearly, displaying frustration and "giving up" on the task.

3 Eye-Tracking Research in Investigating Learning from Complex Visual Displays

Eye-tracking research has shown that the distribution of attention to a task is influenced by one's expertise (Charness et al. 2001). Van Gog, Paas and Van Merrienboer (2005) report that individual variation also occurs between individuals with smaller differences in expertise. Eye-tracking technology is used in the study reported here to investigate the cognitive processes used by nurses as they analyse the information provided in ECG displays of physiological data. Attention to the visual display is critical for patient care, and the research presented in this chapter by Broadbent explores the visual behaviour of novice (22 first-year students who often experience high cognitive load during new tasks), student nurses (18 final-year students) and 9 experienced nurses as they read ECGs.

Using a gaze model (Wolfe 1994) of novice and experts and applying it to reading visual displays, the author analyses the nurses' eye movements as they view four different ECG reports and answer multiple-choice questions on the medical condition that each display represents. The results report clear distinctions between the way in which the three groups approach the identification and assessment of areas of interest (AOIs) on ECGs. This research has broad application in nursing education and, in the current context, provides much useful data about what nursing students have learned in a real-life, non-threatening application of their skills.

4 Eye Tracking and the Development of Self Regulation

Eye-tracking research methodologies offer new approaches to investigating students' self-regulated learning behaviour. The need to examine the processes in the development of self-regulation to manage their own learning in a higher education online context is the focus of this chapter by Persaud and Eliot.

Hyona (2010, p. 173) suggests that "the eyes are guided both endogenously (i.e. to meet the learner's task-relevant goals) and exogenously (i.e. by perceptually sa-

lient stimulus characteristics)". Bearing this in mind, Persaud and Eliot firstly report eye-movement data in the e-learning environment to identify what 11 first-year higher education students attend to and what they ignore whilst navigating through online learning tasks. Then to clarify participants' visual behaviour during the activity, and to better understand students' fundamental cognitive processes involved in composing a text, the researchers also used stimulated recall interview data to supplement and produce a more detailed description of the task behaviours.

Preliminary results report that working collaboratively with other students is influenced by how their work will be received by others and how students wanted to be perceived by others. Interestingly, the authors report that students' eye movements during text composition (where they either looked at the monitor or looked at the keyboard) affected their cognitive and metacognitive processes as they composed text.

5 Eye Tracking on Websites

This chapter reports on usability testing by multilingual (English, Malay, Mandarin and Tamil) people as they navigate websites. Using eye-tracker data complemented with Think Aloud feedback, the authors report data on participants' fixation count, fixation duration, time to first fixation and mouse click-related data as they interact with a web interface. The consistent results from the Think Aloud and eye-tracking data enabled the moderator to conclude that one website had a more efficient navigation strategy than other sites. This research has implications for how to enhance the design and navigation of websites as learners/consumers visualise and process displays.

6 Conclusion

Mayer (2010, p. 170) has stated that "A serious challenge for eye-tracking researchers is to find the sometimes-missing link between eye-fixation measures and learning outcome (or cognitive performance) measures". Steps to meet this challenge have begun as the eye-tracking methodology used in each of the chapters in this part of the book provide a valuable insight into the cognitive and visual processes used in learning and to the improvement of cognitive performance. The studies, although few in number, have provided an overview of the potential of eye-tracking technology to impact learning and thus teaching in naturalistic settings.

For the final word on the future of eye-tracking research and the study of learning processes, we cite the work of Van Gog and Scheiter (2010, p. 98) who assert: "With technological developments making eye tracking more accessible (i.e. not only making equipment more affordable, but also making it easier to gather and analyse data), we believe that different applications of eye tracking will continue to increase in our field to study learning processes and improve the design of instruction".

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