Chapter 52
Reliability and Validity of Low Temporal Resolution Eye Tracking Systems in Cognitive Performance Tasks

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ABSTRACT

Eye tracking experiments are an important contribution to human computer interaction (HCI) research. Eye movements indicate attention, information processing, and cognitive state. Oculomotor activity is usually captured with high temporal resolution eye tracking systems, which are expensive and not affordable for everyone. Moreover, these systems require specific hard- and software. However, affordable and practical systems are needed especially for applied research concerning mobile HCI in everyday life. This study examined the reliability/validity of low temporal resolution devices by comparing data of a table-mounted system with an electrooculogram. Gaze patterns of twenty participants were recorded while performing a visual reaction and a surveillance task. Statistical analyses showed high consistency between both measurement systems for recorded gaze parameters. These results indicate that data from low temporal resolution eye trackers are sufficient to derive performance related oculomotor parameters and that such solutions present a viable alternative for applied HCI research.

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INTRODUCTION

Multiple studies have suggested the use of eye movement based measures as a tool to objectively monitor cognitive state and performance (e.g. de Rivecourt, Kuperus, Post, & Mulder, 2008; Stern, Boyer, Schroeder, Touchstone, & Stoliarov, 1994, 1996) due to the obvious and tight connection between eye movements and cognition as well as the predominantly visual nature of the tasks. For example, dwell time has been used as a global measure to assess workload or vigilance by evaluating points of interest and distribution of visual attention (Ahlstrom & Friedman-Berg, 2005; Alfredson, Nählinder, & Castor, 2003; Lavine, Sibert, Gokturk, & Dickens, 2002; Marshall, 2007; Stern et al., 1994, 1996). Furthermore, results from psychological research indicate that information from oculomotor parameters, i.e. fixations and saccades, can be used to assess cognitive performance (de Rivecourt et al., 2008) and fixations provide information about cognitive demands in reading (Rayner, 1998, 2009), process modelling (Pinggera et al., 2013), and visual search (Liversedge & Findlay, 2000). They are also sensitive to task specific involvement of memory (Geyer, von Mühlenen, & Müller, 2007) and may be used as indicators of hazard perception (Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003; Velichkovsky, Rothert, Miniotas, & Dornhöfer, 2003). Saccades provide information about central activation and fatigue (Galley, 1989; Schleicher, Galley, Briest, & Galley, 2008) as well as shifting of the focus of attention (Chapman & Underwood, 1998; Underwood et al., 2003). Furthermore, gazing patterns are related to personality (e.g. Nitzschner, Nagler, Rauthmann, Steger, & Furtner, 2015; Rauthmann, Seubert, Sachse, & Furtner, 2012).

Hence, eye tracking has repeatedly been used to examine human behaviour in various areas of application, including the interweaving domains of usability and human-computer interaction (HCI; Bulling & Gellersen, 2010; Goldberg & Kotval, 1998; Hutchinson, White, Martin, Reichert, & Frey, 1989). Goldberg (2000) has associated eye tracking methods to criteria of good usability and has stated that eye tracking is an excellent indicator of visual clarity of an interface and a good indicator for cognitive resources and flexibility of use. In brief, HCI and usability research has benefited greatly from eye tracking research (e.g. Benel, Ottens, & Horst, 1991; Goldberg, Stimson, Lewenstein, Scott, & Wichansky, 2002; Harris & Christhilf, 1980; Hendrickson, 1989; Josephson & Holmes, 2002). However, the interaction with smartphones, tablets, and other mobile devices is often hard to investigate by oculomotor parameters because such interactions take place in everyday life (e.g. texting while roaming through streets or being routed to a destination by tablet). Thus, this form of ambulatory assessment has specific requirements for data collection. Convenient systems for field research include head-mounted eye trackers (e.g. Duchowsky, 2007) and eye tracking goggles (e.g. Bulling & Gellersen, 2010). Yet, such systems are quite expensive and not affordable to everyone. Furthermore, the required hardware changes the appearance of the person wearing it and, thus, influences social interactions. It may also impede movement, inconvenience the subject and reduce the visual field. These factors are likely to influence human behaviour not only in public settings. Hence, affordable, practical, and unobtrusive systems are needed for applied research in mobile HCI (e.g. smartphone –integrated solutions). However, such systems may not be able to deliver the high temporal resolution provided by modern, sophisticated eye trackers and, thus, have to fall back to low temporal resolution eye tracking methods. Recent research comparing low and high temporal resolution video based systems indicate satisfactory data quality of specific systems (e.g. ‘EyeTribe’: Ooms, Dupont, Lapon, & Popelka, 2015; Popelka, Stachon, Sasinka, & Dolezalova, 2016; ‘TobiiEyeX’: Gibaldi, Vanegas, Bex, & Maiello, 2016). However, for a valid statement about the potential use of such