Measuring Micro-Level Self-Regulated Learning Processes with Enhanced Log Data and Eye Tracking Data

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ABSTRACT: To advance our understanding of processes that learners engage in self-regulated learning (SRL), we need novel approaches to measurement and integration of multi-channel data. Learning analytics has been recognized as a field that can offer unobtrusive measures of SRL processes through the use of log data. However, log data are insufficiently to capture the full scope of SRL proceses. In this paper, we present the preliminary findings of a study that aimed to explore the extent to which the integration of eye-tracking data with log-data can advance detection of SRL processes such as orientation, planning and monitoring, as theorized about SRL in the literature. For detection of SRL processes in this combined eye-tracking and log data, a special library of action patterns was developed. Our results show that the joint eye tracking data and log data provided richer information about the learning areas of interest, and thus, greatly improved the granularity of measurement of SRL processes. In order to further validate the value of joining eye-tracking and log data, the future work will include the use of think-aloud data.

Keywords: self-regulated learning; enhanced trace data; eye track data; learning analytics;

1 INTRODUCTION

Self-regulated learners use cognitive processes (e.g., read, code and elaborate) to study a topic, engage in metacognitive activities (e.g., plan, monitor and evaluate) to regulate their learning, and often learn more than other learners who do not engage in the regulation processes (Azevedo et al., 2008; Bannert & Reimann, 2012). To advance research understanding of and facilitate learners' SRL processes, we need to develop novel approaches to measurement and integration of multi-channel data that are used for the study of SRL (Järvelä et al., 2018). This especially to the analysis of micro-level SRL processes, which leads to the investigation of more specific processes within each phase of SRL, e.g., goal setting SRL micro-level process within the planning phase of SRL (Siadaty, Gašević & Hatala, 2016). Unobtrusive measures of cognitive, metacognitive, motivational and affective processes can be captured during SRL through log data recorded by digital learning environments (Winne, 2010). However, simple navigational log data or time spent on pages are often not informative enough to study SRL processes (Molenaar & Järvelä, 2014). Hence, we conducted a study that aimed at addressing this problem by enhancing log data with other peripheral data such as mouse movement, mouse click, keyboard stroke, and more interestingly, eye tracking data.

The study used a pre-post design with a 45-minute learning session during which participants (36 university students) were asked to study three topics: 1) artificial Intelligence (the basics of artificial intelligence and how it will influence education in the near future), 2) differentiation in the classroom

(the concept of differentiation explains how teachers can deal with differences between students, and the idea of adaptive learning) and 3)scaffolding learning (as an important way to support students during learning and to adjust to the needs of individual students.). The learning task was to integrate the three topics into a vision essay (300-400 words long) that describes learning in school in 2035. The study used a learning environment (see Fig. 1) with five areas of interest (AOI) zones. The iMotions software system was used to record and synchronize multi-channel data with a unified timeline.

Figure 1: Learning environment (AOI) and iMotions system (synchronizing multi-channel data)

2 MEASUREMENT PROTOCOL FOR MICRO-LEVEL SRL PROCESSES

Based on the framework proposed by Siadaty, Gašević & Hatala (2016), we developed a measurement protocol for detection of SRL processes from combined log and eye-tracking data (see Fig. 2). The protocol contains i) rules for identification of SRL processes (e.g., planning) and ii) a log parser which turns raw log data into learning events or alternatively "event-ized" trace data. In order to analyze how eye tracking can provide richer information, as compared to the enhanced log data (here we include the mouse and keyboard events), we built the action library with two separate data channels (log only/log+eye track) (see Table 1). The action library provides the definition of 10 action labels, which are the codes for individual learning actions (e.g., when Learners have a quick glimpse at the timer, we label this action as "*TIMER*"). The pattern library consists of patterns of sequential actions labelled in the action library (e.g., when Learners have a quick glimpse at the timer during essay writing, we detected the learning pattern as "*WRITE_ESSAY* to *TIMER* back to *WRITE_ESSAY*"), and it was built to map learning patterns with micro-level SRL processes. The pattern library, which included cognition patterns and metacognition patterns, was based on Bannert's (2007) SRL coding scheme. The detailed pattern library is not shown in this paper due to the length restrictions.

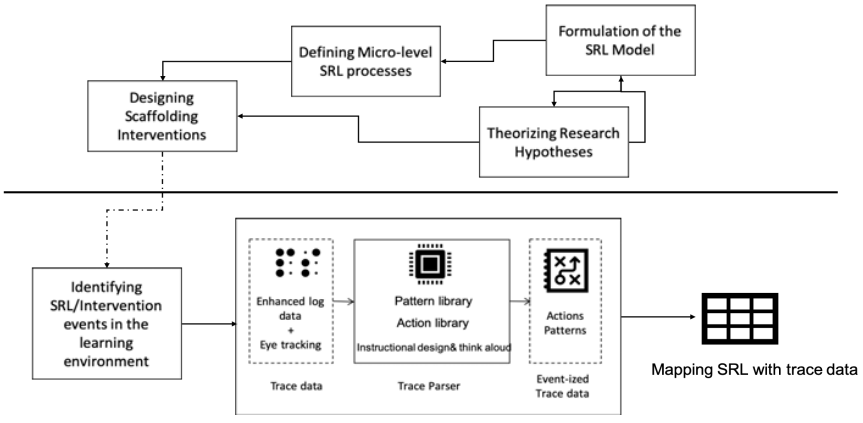

Figure 2: The Measurement Protocol of Integrating Multi-Channel Data

Table 1: Action library for detection of SRL processes from trace and eye-tracking data

Labels	Action definition	Data	Examples
TASK_INSTRUCTION	Learners read or re-read the general instructions page and the essay rubric page	log only	Learners open essay rubric page to understanding the task
		log+eye track	Learners read essay rubric with fixation task requirements
LEARNING_GOAL	Learners read or re-read the learning goals page	log only	Learners open and read learning goal page
		log+eye track	Learners open and read learning goal page with fixation
RELEVANT_READING	Learners read and learn relevant content for the first time	log only	Learners open and read relevant content page (e.g., AI definition)
		log+eye track	Learners read relevant content with fixation in the reading zone
RELEVANT_RE-READING	Learners re-read and review for relevant content which they have read before	log only	Learners re-open "AI definition" page during essay writing
		log+eye track	Learners re-read preceding part of the page with overlap fixation
IRRELEVANT_READING	Learners read pages which are not relevant to the learning goal and essay writing	log only	Learners open and read relevant content page (e.g., Turing Test)
		log+eye track	Learners read irrelevant content with fixation in the reading zone
IRRELEVANT_RE-READING	Learners re-read pages which are not relevant to the learning goal and essay writing	log only	Learners re-open "Turing Test" page after reading other pages
		log+eye track	Learners re-read preceding part of the page with overlap fixation
NAVIGATION	Learners view or glance at catalogue zone or overview page, or quickly navigate through pages	log only	Learners quickly click through pages to overview materials
		log+eye track	Learners fixate at catalog zone after reading through one page
WRITE_ESSAY	Learners write, edit, re-write the essay, or stay in the essay page to think about essay writing	log only	Learners type and write sentences in the writing zone
		log+eye track	Learners fixate at the writing zone without typing
NOTE	Learners add, delete, write, edit or read notes	log only	Learners click in the note zone to create a new note after reading
		log+eye track	Learners fixate at notes they took before during essay writing
TIMER	Learners check timer during the learning task	log only	Learners use mouse click or scroll at the timer zone
		log+eye track	Learners have a quick glimpse at the timer

3 PRELIMINARY RESULTS OF THE CASE STUDY

In order to show some preliminary results, here we use participant P25 as a case study. P25 left 25235 rows of enhanced log data (21,982 mouse moves/clicks/scrolls; 3,019 keystorkes, and 250 BrowserNav/Scrolls), and 7325 rows of fixation data (with more than 1.2 million rows gaze data), in a 45 minutes learning session. All ten labels from the action library (Table 1) were detected based on the enhanced log data of P25: P25 spent approximately 4 minutes in the beginning to read the task instruction and the learning goal, then spent almost 30 minutes to read or re-read the content with note-taking, and finally, spent approximately 10 minutes in the end to write the essay. The timeline of the learning processes is shown in Figure 3, based on "log only" or "log+eye tracking".

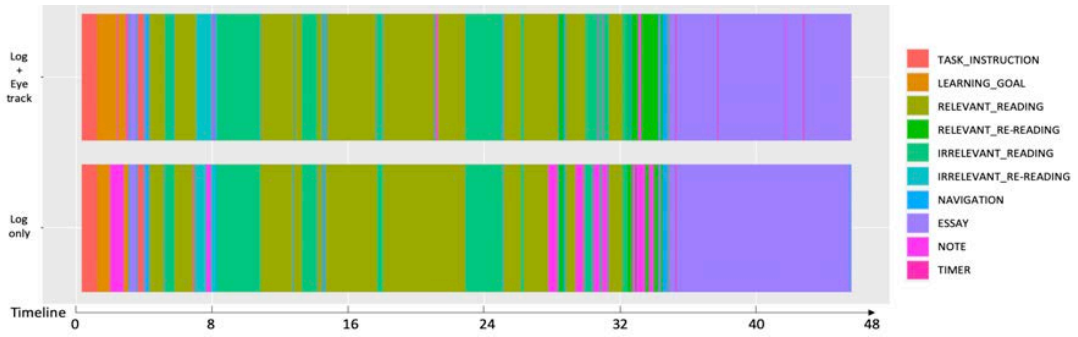

Figure 3: Learning processes detected from multi-channel dataset

From the "log only" data, we detected micro-level SRL processes: in the planning phase—taking notes while reading the learning goal page (*LEARNING_GOAL* to *NOTE* back to *LEARNING_GOAL*); in the orientation phase—navigating through many reading pages after reading the task instruction page (*TASK_INSTRUCTION* to *NAVIGATION*). We also detected cognition patterns, such as elaboration patterns (e.g., *RELEVANT_READING* to *RELEVANT_RE-READING*) and organization patterns (e.g., *RELEVANT_READING* to *NOTE* back to *RELEVANT_READING*) in the reading stage. However, we were able to find many more detailed SRL processes when adding eye tracking data into enhanced log data, especially more monitoring patterns such as a quick glimpse at the timer to monitoring the time process during writing (*WRITE_ESSAY* to *TIMER* back to *WRITE_ESSAY*).

4 DISCUSSION AND NEXT STEPS

In this study (Project name: FLoRA, funded by ORA; BA20144/10-1, NWO 464.18.104, ES/S015701/1), we proposed a measurement approach for detection of theoretically meaningful micro-level SRL processes from enhanced log data and eye tracking data, such as orientation, planning and monitoring. In general, the addition of eye tracking to log data to enrich information about the learning area of interest, greatly improved the measurement of temporal patterns such as checking notes/timer with just a glimpse and without mouse clicks/moves. In order to further triangulate our findings, in the future work we will also integrate think-aloud data into our multi-channel dataset. We will use think-aloud data to shed more light on the measurement of SRL processes, and more importantly, to validate the inferences drawn from the trace data.

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