The Exploration of Feeling of Difficulty Using Eye-Tracking and Skin Conductance Response

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Abstract. Metacognitive experience (ME) plays an important role in self-regulated learning. To date, through mainly self-reporting methodology, metacognition assessment lacks objective evidence and therefore hinder the discussion of its subjective and implicit nature. In exploring ME, eye-tracking and skin conductance response (SCR) offer certain advantages over self-reporting methods. However, to date, most studies tend to focus on utilizing these measures to explore metacognitive skills (MS) rather than ME. Also, while some studies do explore ME with these measures tend to utilize the data from a summative perspective rather than aligning the data with the real-time ME behaviours. Based on previous works in this field, this research will discuss how feeling of difficulty (i.e. a type of ME) functions in real-time based on the hypothesis that eye-tracking and SCR data can provide objective measures. Through such, a better understanding of how FOD functions could be gained and therefore contribute to the support of learners' metacognitive competencies.

Keywords: Metacognition · Metacognitive experience · Feeling of difficulty (FOD) · Eye-tracking · Skin conductance response (SCR)

1 Introduction

Metacognition is a complex and multifaceted construct, which can be defined as "thinking about thinking (Flavell 1979, p. 906)". In addition, metacognition has the characteristic of being both a domain-general and domain-specific skill that functions on both conscious and unconscious levels (Brown 1987; Efklides and Misailidi 2010). However, while metacognitive skills (MS) is widely discussed, metacognitive experience (ME) on the other hand receive lesser attention (Efklides 2006). Furthermore, the assessment of metacognition is dominated by self-reporting methodologies which lack objective evidence. As a result, this doctoral research has the following two aims. The first is to target the lesser attention ME, especially feeling of difficulty (FOD), and untangle its fuzzy construct while discuss it in a versatile yet unified way by including methodologies and insights from different disciplines. Secondly, with the support of biometric data such as *eye-tracking data* (e.g. De Rooij et al. 2018; Nelson et al. 2013; Chua and Esolinger 2015) and *skin conductance response* (SCR) data (e.g. Lakie 1967; Morris et al. 2008), a more exhaustive ME assessment might be achieved through combing these kinds of objective evidence with the traditional self-reporting methodologies.

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2 Literature Review

Metacognition is comprised of *metacognitive knowledge* (MK), which refers the offline knowledge of cognition, *metacognitive skill* (MS), which supports the control of cognition, and *metacognitive experience* (ME), which is the product of online cognition monitoring (Efklides 2009; Flavell 1979). Among these components, what apart ME from the rest is it is both affective and cognitive in nature (Efklides 2005). Taking FOD as an example, from the affective perspective, it is represented in the form of negative emotion and, from a cognitive perspective, it indicates how well a cognitive process is performed. It is this affective nature of FOD enables the possibility of utilizing eye-tracking and SRC data, which has strong indication for emotion, for its assessment. However, from a study design point of view, what factors trigger FOD is a major issue here. According to Efklides (2005), cognitive discrepancy/interruption (i.e. the lacking cognitive processing fluency) is a particularly influential factor (Efklides and Misailidi 2010). That is, FOD is likely to occur when a cognitive processing result contradicts with what one has planned. For example, when solving a math problem, a learner may initially plan for taking it casually as s/he used to be good at math but later feel frustrated as this problem is actually beyond s/he math ability. However, assuming a stimulus can correctly trigger FOD, another issue here is how to address the functioning of unconscious FOD. According to Efklides (2005), it is when a feeling is strong enough to be aware can FOD emerge on a conscious level. This implies that FOD might emerge on an unconscious level and cannot be reported by one as the "feeling" is not yet felt. This is another reason for including biometrical evidence which may fill the gap for illustrating the whole FOD occurrence process (i.e. from unconscious to conscious level) before one can report the arise of FOD. A pilot study involving an eye-tracker was conducted based on the theoretical framework discussed above. Nonetheless, as the study tasks (i.e. learning material drawn from an online math learning platform called Mathigon and the topic of graph theory was chosen as it includes different types of learning tasks such as reading comprehension, multiple-choice and learning games) was presented in a rather exploratory environment, it was hard to pinpoint the exact FOD arising period from the eye-tracking data. For instance, the increasing pupil size pattern can be found and related to the time when a FOD stimulus is presented (see Fig. 1). Furthermore, a fluctuated pupil pattern can be spotted which may indicate one is regulating their learning process affected by the arise of FOD and attempting to guide the process back on track. However, this interpretation is only a speculation and is even harder for the participant to report. For example, in Fig. 1, the red box on the left indicating when the participant shifts her focus from reading text to the diagrams below and try to figure out what these diagrams mean. From the self-report by her, the difficulty level was increasing and therefore FOD arise. Yet, there was no explanation given by the participant about the three peaks circled in the left red box of Fig. 1. As a result, the revised study proposal in the later section needs to set the study setup more strictly to minimize other factors that could potentially contribute to the forming of FOD.

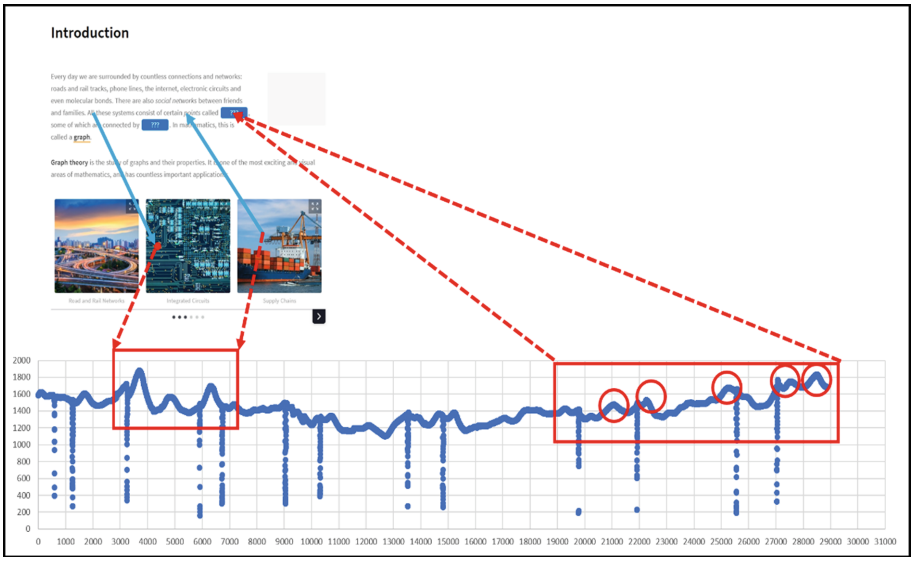

Fig. 1. A sample of the learning material and the pupil size data

3 Methodology

3.1 Research Aims, Hypothesis and Questions

As mentioned previously, to date, there exists an extensive body of metacognition research apply eye-tracking and SCR, which demonstrate the potential of including biometrical evidence to support metacognition assessment. As a result, along with the discussion above, the proposed research aims at investigating how eye-tracking, SCR and self-report can be adopted for exploring FOD on both a conscious and unconscious level. The hypothesis made here is through the design of the activities (see next section for more detail), participants' FOD can be elicited and the data acquired can indicate both the occurrence and intensity of FOD. Two overarching questions provide the focus for this research: (1) Does triangulate eye-tracking, SCR and self-report data can provide indications about how FOD functions?; (2) can the acquired data illustrate the whole FOD arising process both consciously and unconsciously? In sum, the implication from this research may support learners to better understand their FOD functioning and subsequently promote self-regulated learning. Moreover, data from eye-tracking and SCR regarding FOD functioning can shed light on metacognition assessment by providing a more objective perspective.

3.2 Study Design

Participants will be recruited who are in university or graduate level. Metacognition plays an important role in life-long learning (Evans 2018) and it is a lack of ability among the target group (Jaberi and Gheith 2015). As being the last stop of formal

education, the potential contribution of this study can support improving metacognitive competence and therefore benefits to the target group. To ensure that FOD behaviours can be observed, both the claims of cognitive discrepancy can trigger FOD (Efklides and Misailidi 2010) and learning-through-teaching can promote metacognitive awareness (Leelawong and Biswas 2008) are adopted. The stimulus will be drawn from Mathigon (Legner 2012) which was used in the pilot study. The context is graph theory and networks which includes four topics. However, to deliver the stimulus in a more restricted way, instead of letting participants explore the given task freely, the learning material from Mathigon will be divided into smaller pieces and each study trails will only last for a certain time (this will be determined by conducting another pilot study). The participants will first get familiar with the given task on a pc connected to an eye-tracker and an SCR equipment. Eye-tracking and SCR data along with screen and video recording of the interaction will be recorded. These data will be used for supporting the later stimulated recall interview (SRI) at the end of each study phases. Participants will then explore the given task as teachers and later report difficult parts spotted with according FOD level rating. Next, participants will take problems that aim at causing cognitive discrepancy and later report the accordingly FOD level rating.

3.3 Data Analysis

Eye-tracking features will be selected based on Eivazi and Bednarik (2011) with the focus on pupillary data along with mean and sum fixation duration, mean between fixation and total eye-movement path distance, number and rate (divided by the duration) of fixations, fixation position within the trails, and pupil dilation. SRC data will be analysed according to Whittlesea and Rayner (1993) work. The reason for applying two types of biometric instruments that both related closely to emotion assessment is to minimize other factors that could influence FOD. That is, to triangulating eye-tracking data, SRC data along with the self-report FOD level, the affective nature of FOD can be focused. Through such, the first research question might be answered through the triangulated data. And the second research question might be tackled via exploring the data's pattern in a set time to see if there are any features can be spotted before FOD is reported.

4 Conclusions

The current proposal aims at exploring the potential of including eye-tracking and SCR together into metacognition research. Besides discussing metacognition from different yet related disciplines, the main goal here is to access metacognition functioning from a more objective perspective. In this way, the implication can be drawn from in assisting learners' metacognitive competence while providing a new approach to metacognition assessment which can be beneficial for their self-regulated learning.

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