Research Traineeships proposal format

1. Project title

Supporting metacognitive awareness and control with pupil size sonification

2. Coordinators

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3. Project Summary

Background

This project aims to develop a novel way to augment metacognition. Metacognition has been defined as the *awareness* and *control* one has of one's own cognitions [1]. Awareness of one's own cognitions can enable a degree of control over the way one thinks and acts and can help to adapt effectively to changing task demands [4]. Our approach is grounded in the link between dilation of the eye's pupils and a variety of cognitions; and the role of embodied information in metacognitive awareness and control. That is, pupil dilation associates with the amount of information passed to working memory [3]; and rapidly tracks changes in related cognitions [7], including attentional focus and distractibility [5], depth of thinking [2], and cognitive load [6]; and some physiological changes can function as embodied information that has relevance for metacognition [10], e.g. becoming aware that one is sweating due to a difficult exam [9]. We cannot however, perceive our own pupil dilations. Given the associations between pupil dilation and cognition, it could be a rich source of embodied information if made perceivable that can help augment metacognition. In this project, we explore how to make pupil dilation perceivable by mapping the pupil size to sound (sonification), in a manner that augments metacognitive awareness and control.

Our own preliminary studies [8] suggest that pupil dilation sonification has the potential to support metacognitive awareness and control. While "listening to their pupil size" during a mathematics task, correlations between changes in sound and cognition emerged spontaneously, which brought these cognitions into awareness. People could also control the sound by changing their cognitive process, suggesting the sound can act as a reference signal to explore new strategies for metacognitive control. While our preliminary studies shows great promise, three issues need to be addressed to better understand and realise the potential of pupil dilation sonification for supporting metacognition. First, participants reported negative associations with the sounds itself. In its current state, the sound can be experienced as both annoying and distracting (and thus can have a negative influence on cognition). Second, our preliminary study did not yet include a control group. This is needed to find out whether the sonification indeed supports metacognitive awareness. Finally, a better understanding of the regulation process and strategies that support the regulation of cognitive processes has to be obtained.

In order to further explore the potential of using pupil dilation information to support metacognitive awareness and control, we propose the following two studies, which address these issues and for which we would like to request two student assistants.

Study 1

The first study calls for a design research approach that aims to develop a pupil dilation sonification that achieves two design goals: (i) minimise distractibility, and (ii) maximise the user's ability to correlate the sound easily with their own internal cognitive processes (e.g., attentional focus, depth of thinking). The *research goal* of this study is to develop a pupil dilation sonification that minimises distractibility, while maximising the user's ability to correlate the sounds with their own cognitive processes. The study takes the format of an user-centered design study. This entails that various different mappings are tested and improved with a small convenience sample in an *iterative process* (n=5 for each iteration, for 5 iterations). Repeated testing allows the researcher to narrow down the sound design to one approach and refine the mapping, as to achieve the research goal. Prior to this, there will be a participatory design session, where participants engage in the development of the sonification in collaboration with the researcher, which will lead to several settings that can be evaluated and refined in the user-centered design study. Evaluation in each iteration will be done via self-report on the degree of distraction caused by the sound (Likert scale), and by writing down the correlations between the sound and cognitive processes the participants experienced, and reporting the magnitude of each of those correlations. These are the dependent variables, whereas the sonifications used are the independent variables. However, the exact format of the study should be determined later to adapt to the specific interests and strengths of the student assistant.

Study 2

The second study calls for two empirical experiments. The mapping developed by the design student will be applied and evaluated with respect to its ability to (i) evoke metacognitive awareness and to (ii) guide metacognitive control. The following *research questions* will be answered.

RQ1: Does the sound signal elicit metacognitive awareness?
RQ2: Does sound signal facilitate metacognitive control?
RQ3: What strategies that can be used for metacognitive control when using the sound?

To answer RQ1 we propose a between-subject design where one group uses the pupil dilation sonification, and another group uses a "fake pupil sonification", i.e. hearing sounds that are not correlated with pupil size. This is the independent variable. We will use a convenience sample (n=60). Participants engage in a variety of thinking tasks that are known to involve the cognitions that also associate with pupil dilation. These tasks include mathematics tasks (e.g. to target focusing, depth of thinking) and reading tasks (e.g. to target distractibility and mind wandering). Afterwards participants self-report on the cognitions that came into awareness, which are then clustered based on type of cognitive (e.g. focus, distraction) (RQ1). These are the dependent variables. This study will indicate whether pupil dilation sonification can elicit metacognitive awareness.

To answer RQ2 and RQ3 we propose a variation on the previously proposed study. Again the same between-subject design, independent variable, type of sample, and thinking tasks are used. However, in this study participants are asked to change the character of the sound by adapting the way they do their thinking task. For instance, if pupil dilation would be mapped to the volume of the sound, participants would be asked to try and increase and decrease the sound's volume while engaging in the task (but this depends on the sonification developed in study 1). After the task, they self-report on their ability to influence and control the sound (RQ2), and describe the strategies they applied to achieve this (RQ3). The strategies are clustered based on type and can thus be compared between the experimental conditions. These are the dependent variables. This study will indicate whether and how the pupil dilation sonification can facilitate metacognitive control.

Note that the study design can be flexible and adapted to the interests and strengths of the student.

Collaboration

For this project to succeed, it lead to a well designed pupil dilation sonification, and a study of its effects on metacognition. In order to achieve this, we need to conduct design research as well as experiment as typically done in cognitive science. A collaboration with experts in both fields (New Media Design on the one hand and Cognitive Science and Artificial Intelligence on the other hand) is thus needed to make this project a success.

Goal

The ultimate goal of this project is to augment metacognition using pupil dilation sonification technology. In order to achieve this, we aim at developing (i) a mapping between pupil dilation and sound that minimises distractibility, while maximising the user's ability to correlate the sounds with their own cognitive processes and (ii) create a system that evokes cognitive awareness and enables regulation of cognitive processes.

4. Project timeline

The project will take a year and is divided into two blocks of six months.

1. First six months: The New Media Design student assistant uses a user-centered design approach to arrive at a mapping between pupil dilation and sound that is both effective and neutral. The student will pursue the research goals presented above.
2. Second six months: The Cognitive Science student assistant conducts two small studies that focus on (1) awareness and (2) regulation. In these experiments, the mapping developed by the design student will be applied. The student will answer the following research question presented above.

5. Research Trainee Profile

Profile Study 1 (MSc NMD track)

This study calls for a student assistant with a strong background in user-centered research methods, such as taught in the New Media Design MSc track (a new MSc track within the Communication and Information Science MSc). The student should be able to address user experience and sound design issues.

Profile Study 2 (MSc CSAI track or ReMa)

This study calls for a student assistant with a strong background in cognitive science, preferably one with interest in new technology, such as found in the new Cognitive Science and Artificial Intelligence MSc track. The student should be able to address the topic of metacognition and conduct/contribute to behavioural studies.

References

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