Cognitive Load Assessment from Facial Temperature Using Smart Eyewear

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ABSTRACT

In this paper we present an approach to detection and estimation of the cognitive load[8, 9] by measuring temperature changes of the forehead and the nose bridge using smart eyewear. The presented system consists of a pair of glasses with four temperature sensors attached. We have found signs of a correlation between the facial temperature changes and cognitive load using this approach, which makes it possible to develop a wearable device to quantitatively estimate cognitive engagement. Although are still working on investigating the effect on facial temperature from different types of cognitive tasks and different difficultly levels, we believe this approach could spark interesting discussions during the workshop.

KEYWORDS

Facial Thermography; Cognitive Load; Smart Eyewear; Wearable Devices

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Figure 1: Experimental prototype with two pairs of sensors for the forehead area (top) and nose (bottom).

1 INTRODUCTION

With the development social networking services, smart and mobile devices and Internet of Things appliances, people are facing an ever increasing amount of information in their daily lives. This has led to an situation where people are overwhelmed with more information than they can manage.

Therefore, it is important for us to find a way to manage our attention and find a way to better manage our attention and workload, select and process the information we actually need. The approach proposed in this paper can be used to establish an unobtrusive ground truth assessment of cognitive load in daily scenarios necessary for better computer aided attention management.

Cognitive load is often described in terms of how the selective attention and limited cognitive processing capacity are used and focused during learning and problem solving[8, 9]. In the tests discussed in present work, cognitive load was induced by tasks requiring attention, memory and basic arithmetic skills. Attention and memory are the two fundamental functions of the cognition. We include arithmetic in this study in order to verify the applicability of this approach to less abstract tasks common in e.g. education field.

In this paper, we discuss an approach with a potential to detect and measure cognitive load by measuring temperature changes of facial tissues using Jins MEME, glasses with EOG senosrs, with infrared contactless temperature sensors attached. We present some evidence of a correlation between facial temperature changes and cognitive load. We currently are working on investigating whether different tasks or difficulty levels have different effect on facial temperature as well as how it manifests between individuals.

2 BACKGROUND AND RELATED WORK

The main energy source of the brain is glucose. Around 1/3 of the energy produced from glucose and oxygen reaction is released as heat. Since the skull bones and the surrounding fat tissues act as an insulator and decrease the effectiveness of convective cooling, blood circulation becomes the main heat exchange mechanism of the brain [11]. Studies have found that, during the higher cognitive load time periods, cerebral neurons are more active than in the resting states [2, 12]. It shows that more glucose and oxygen are needed when brain is dealing with a higher workload, which means that the brain produces more heat when it is in a higher cognitive engagement.

There are certain blood vessels connecting the facial tissues with the brain.[1, 6] Therefore, instead of directly measuring the heat emissions or blood flow in certain brain areas, cognitive workload can be estimated by detecting the temperature differences between facial areas supplied by different blood vessels. In order to asses the changes of the brain heat production, temperatures of facial tissues supplied by blood from the internal carotid artery that that passes through the brain with temperatures of tissues supplied by the external carotid artery. Ophthalmic artery is connected to the internal carotid artery supplies the eyes and surrounding tissues, as well as nasal, eyebrow and forehead areas by its branches.

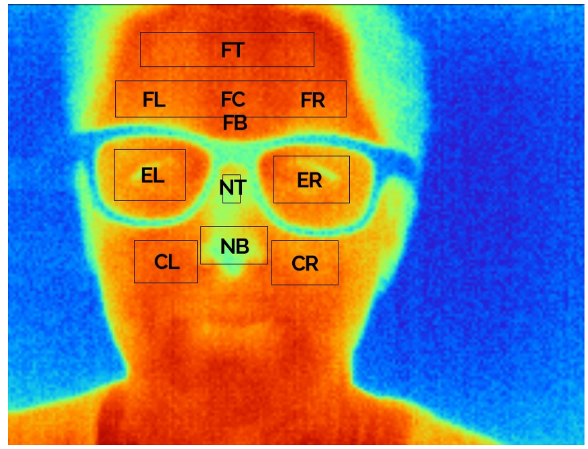

Figure 2: Facial Regions in thermal imaging.

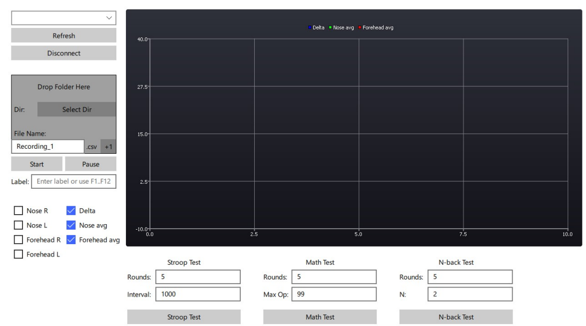

Figure 3: Recording and testing software Interface.

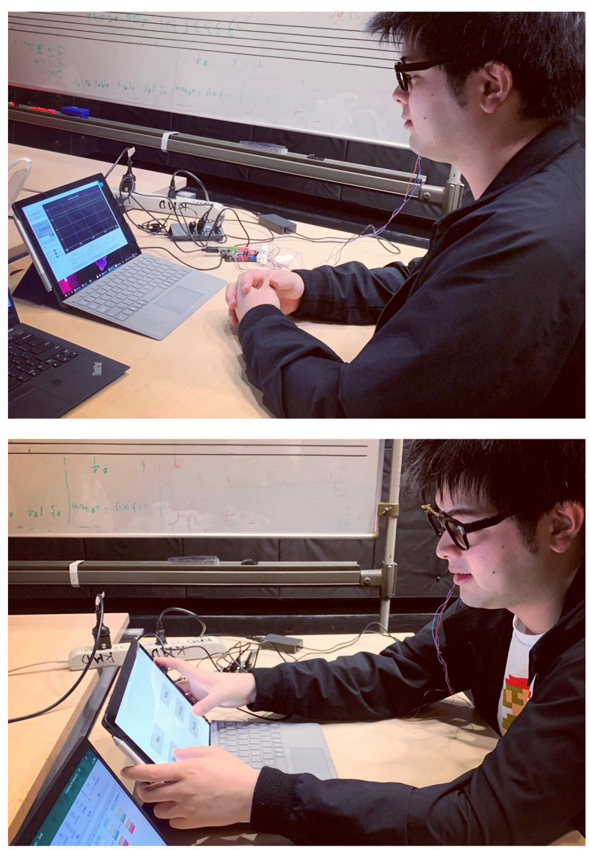

Figure 4: Participant during the study.

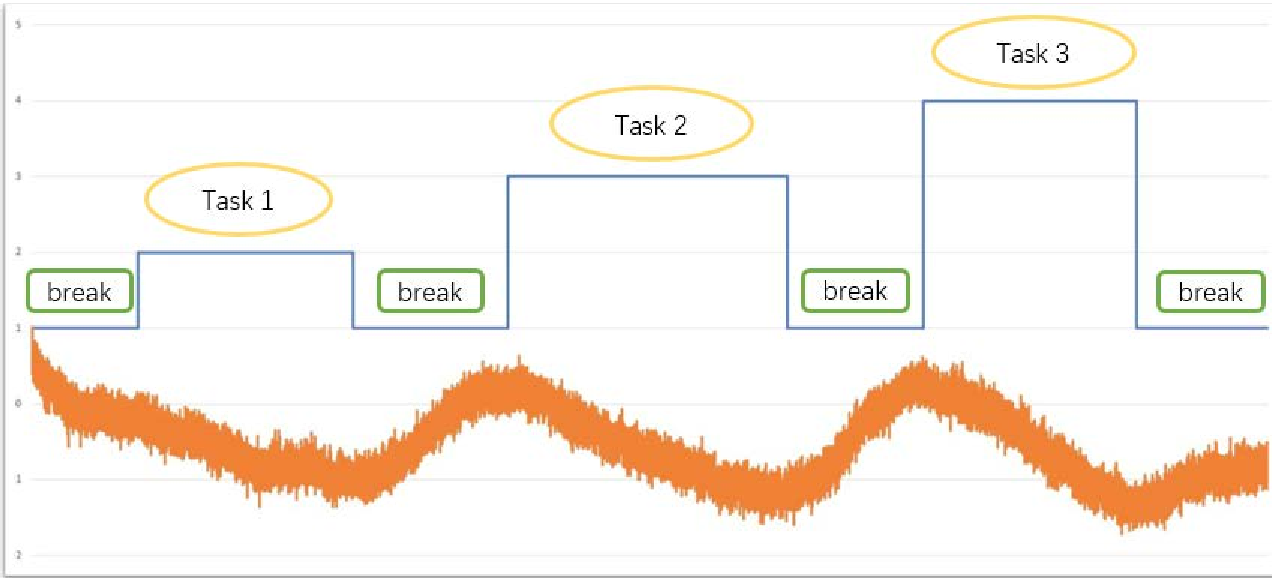

Figure 5: Example recording. Task 1 - Stroop test; Task 2 - Math test; Task 3 - N-back test. Blue line - data label representing participant's activity at the sampling time. Orange line - difference between the nose and the forehead temperatures in °C.

Other branches of the common carotid artery provide supplies to the face and the scalp. Besides this, the increase of sweating in certain facial areas can also play a role in the blood cooling and facial temperature. In the fields of HCI and engineering this principle has been used since 80s [3]. There were also previous attempts to build eyewear-like devices with thermophile sensors[7], the presented system is much smaller and does not require alterations to traditional glasses rim. Also in the approach section we present our experimental setup for much more thorough investigation of the phenomenon.

Based on the results of a previous study, the facial tissues closed to nose bottom (NB), nose top (NT) and forehead center (FC) have the most significant temperature differences (See Fig.2)[10]. In that study, they measured cognitive engagement of individuals by logging thermographic data from infrared imaging and electrooculographic readings from Jins MEME. Fig.2)[10].

3 APPROACH

Related studies have shown that temperature of different facial areas will change when the individual is performing tasks that require a certain concentration. As we have previously described in the related work section, the temperature of center of the forehead and nose areas have the most evident temperature changes. Based on that, we decided to measure the temperature differences between the forehead and nose bridge. In order to do that we developed a setup to measure the temperature changes of these areas. The setup consists of a pair of Jins MEME glasses with four infrared contactless temperature sensors attached, two for the forehead area and two for the nose bridge area (See Fig.1). Sensors were used in pairs in order to decrease the noise in the recorded data and for redundancy purposes.

In total we used three tasks to induce different types of cognitive loads: Stroop test for attention[5], and n-back test for memory[4] and a simple arithmetic test. All these tests are commonly used in neuropsychological testing. In Stroop test, participants needed to choose the correct color based on the ink color instead of the meaning of the word. In math test, participants were asked to finish some basic addition operation of random N-digit numbers. In N-back test, participants had to remember the position of a visual stimuli on a 3 by 3 grid. Timings for each exercise and number of the iterations of the task were set by the experimenter from the GUI.

4 EXPERIMENT PROTOCOL

During the experiment, participants were wearing the glasses while performing the given tests (See Fig.4). Each of the three tasks was given twice in different difficulty levels: simple and hard, making six tests in total. During the simple Stroop test participants were presented with the word for 2 seconds followed by 2 seconds of blank screen, 75 iterations in total. The hard Stroop test was presenting the word only for 1.5 seconds with 1.5 second breaks between the words, 150 iterations in total. The simple math test was requiring the user to type in the result of addition of 2 random one digit numbers and continued for 5 minutes, the hard math test was identical except the numbers were from the range of 0..99. The simple n-back was 2-back, and the hard n-back was 3-back. The marker presentation time and grid size was identical for both N-back tests.

Each of the tests took about five minutes. Before and after each test, participants were given a five-minute break during which they still had to wear the glasses for baseline measurement. In the middle of the experiment, participants were given half an hour break where they were allowed to leave the room. No recording was made during the break period. The whole experiment lasts around 100 minutes including the 6 five-minute tests, 8 five-minute baseline breaks and a thirty-minute halftime break.

12 participants, with an average age of 24.6 years, volunteered to take part in this study. Each participant has given their informed consent and was permitted to quit the study at any time for any reason. Each participant was rewarded with a 1000 JPY gift card. Gender distribution is 1:1. Participants' hours of sleep and self reported levels of tiredness were recorded for reference in our further analysis.

5 PRELIMINARY RESULTS

Figure 5 represents a recording from one participant. The orange line represents the temperature difference between the nose and the forehead areas (temperature of the nose minus the forehead) (See Fig.5). During the task the nose gets colder and the forehead area slightly warmer. During the break time, the temperature readings quickly tend toward the thermal balance point. Exact thermal balance depends on individual vascular structure, ambient temperature, humidity and other factors. This general trend appears in other participants' data as well, which presents possible evidence that the correlation between the facial temperature changes and cognitive load exits and can be used for cognitive load assessment.

The temperature differences between the forehead and nose bridge becomes bigger when participants are performing a harder task compared to simpler tasks or resting time. In the case if the task is too hard for the participant (especially 3-back) the temperature changes also don't seem to be very evident, presumably because the participant is not capable of handling the task. This means it is with high possibility that we can use the presented approach to estimate cognitive load and this can be a step towards developing a wearable device capable of enabling people to optimize their limited cognitive abilities for a more productive lifestyle. So far, we haven't determined a typical trend or relationship for the different types of cognitive task and different difficulty levels of the same task. We are still working on further data analysis.

6 CONCLUSION AND FUTURE WORK

From the recorded data, we can tell that the presented system is performing properly and is capable of recording data in lab environment. Further tests in-the-wild conditions are still necessary as well as elaborate numerical analysis of the recorded data. Based on the data overview done by now, there is some evidence that there is a correlation between cognitive load and facial temperature changes.

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