Facial Temperature Sensing on Smart Eyewear for Affective Computing

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Abstract
We present a system for tracking positive cognitive and emotional states for affective computing, which uses contactless temperature sensors on eye glasses to monitor changes in facial temperature. First user tests show promising results for identifying different likability of video content reflected in changes of facial temperature. In contrast to the related works that focuses on detecting negative states, our approach aims at identifying positive affects. In combination with additional physiological sensor readings our proposed system allows the maintenance and retention of highly enjoyable and productive states.

ACM Classification Keywords
H.5.1 [Information interfaces and presentation (e.g., HCI)]:

Author Keywords
Ubiquitous Computing; Affective Computing; Sensing; Productivity; Pleasure

Introduction and Motivation
One of the major steps in the evolution of human-computer interaction (HCI) is the introduction of physiological computing. Real-time measurements and analysis of physiological signals through sensors help opening up an implicit communication channel between computers and their users. Awareness of the user's emotional and

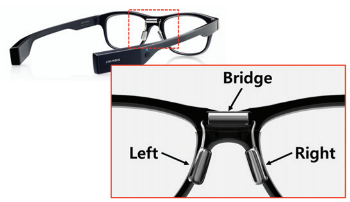

Figure 1: J!NS MEME and closeup on the EOG electrodes

cognitive state allows computers to react and adapt in real time, and therefore maximize HCI performance efficiency and communication. Ubiquitous computing enables us to make use of computational power in everyday situations and liberate experiments and application scenarios from the necessity for heavy stationary devices in controlled laboratory environments.

So far, most affective computing systems aim at boosting the performance efficiency by identifying negative states and intervening, e.g. when frustration builds up due to a boring task. In contrary to this we aim at identifying positive affects and pleasure through physiological sensing on the face. We are utilizing J!NS Meme smart glasses (Figure 1) customized with contactless infrared temperature sensors to measure changes in facial temperature in the nose and forehead region.

We are aware that interventions to tackle negative states such as frustration and loss of attention are the current "gold standard" in affective computing, but believe that the recognition and retention of positive affects offers an alternative way to maximize productivity and pleasure, which is one of the main goals of physiological computing in HCI [4]. We hereby focus especially on maintaining extremely productive and enjoyable periods, such as the volatile flow state described by Csikszentimihalyi.

Related Works

Physiological computing has two goals: (1) the increase of efficiency of performance, and (2) improving the pleasure derived from interacting with computers through monitoring and processing physical sensor data from the system user. Consequently, data describing negative and/or positive affects are used as input modalities that trigger specific reactions of the system, e.g. intervention when frustration levels are high [4]. Even though many studies limit HCI and affective computing to the recognition of negative emotions, research has shown that also positive affect has a direct influence on our performance, especially when it comes to learning [2]. The pinnacle combination of high performance and positive feeling is described by Csikszentimihalyi as the flow state. It is therefore the optimal state affective computing could induce, or help to retain for the user, in an HCI scenario [3].

Recent studies on sensing of emotional responses in everyday scenarios mainly focus on electro-dermal activity, which requires sensors in contact with the skin of a user [6]. Our concept of using facial temperature is justified by its relatively easy implementation and the possibility of contactless sensing capabilities. It is a well established fact that cognitive activity relates to cerebral blood flow and heat exchange[8]. During higher cognitive loads (e.g. studying) cerebral neurons are more active than in resting states, producing more energy that is released as heat through the vascular system in the face. Studies investigating facial temperature changes have already been done [9], but so far none of them has approached a mobile, unobtrusive solution for everyday usage.

Our Approach

We are aware of the fact that the literature describes facial temperature changes mainly as an indicator for cognitive workload. Nevertheless, during a former set of studies where we used a thermal camera, we recognized trends between enjoyed movie trailers and changes in facial temperature readings using a thermal IR camera. We have used movies, because related works revealed that they are effective in psychophysiological experiments [5, 6]. Our former study aimed at identifying regions of interest (ROI) on the face that on the one hand present temperature

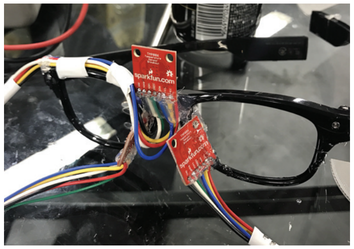

Figure 2: Prototype 1: Contactless Infrared Sensors on J!NS Meme smart wear

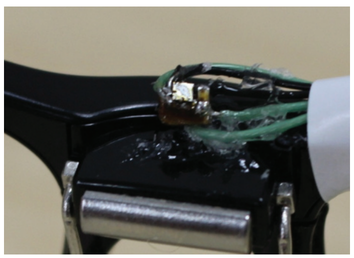

Figure 3: Prototype 2: Small Contactless IR temperature sensors on J!NS Meme bridge

changes related to cognitive activity. The pivotal regions on the human face are located on the forehead right between the eyebrows, on the sides of the nose, and on the nasal bridge. Therefore, most eyeglass frames constitute the ideal means to carry contactless temperature sensors [7].

We attached contactless IR sensors to the bridge of J!NS Meme smart glasses, which are natively equipped with electrooculography (EOG) sensors around the nose for measuring eye movements, blink, and head postures, in addition to motion sensors (accelerator and gyroscope) and a Bluetooth LE (low energy) module [1]. The development of our prototypes can be seen in Figures 2 and 3. After an initial setup with rather obtrusive sensor installations, we achieved a small, unobtrusive solution for temperature sensing. Picture 3 shows the bridge carrying the sensor for the forehead region. Our setup consists of a Laptop and J!NS MEME glasses extended by the heat sensor module. We use sensor modules with TI TMP006 IR contactless thermopile sensors.

User Test and Results

In order to avoid any interferences with our temperature sensors, we decided to run the pre-tests without using neither of the other sensors installed in the glasses. It is clear that facial temperature changes alone are not sufficient to identify affective states, but because of their direct relation to cognitive activity, they become crucial when describing performance and affect.

We used the first of our two prototypes for the pre-test. We presented the wearers with two blocks of four mainstream film trailers and asked them to rank the videos according to their liking after watching each block. During the whole experiment we logged temperature changes on the lateral sidewalls of the nose as well as on the forehead above the bridge of the glasses. We then compared the ranking to logged temperature readings. The missing robustness of our system did not allow for a longer user study, but the graphs from the first three candidates reflect the different preferences of video content, cf. Graph 4 - Graph 6. As an example, the temperature difference between forehead and nose increases by 0.6°C for the most enjoyed video, whereas the second ranked video causes a 0.6°C decrease, followed by another 0.8°C decrease for the video on the third rank. A one-way ANOVA for the first three candidates was still insignificant. Therefore, it is necessary to conduct a bigger user study with a robust setup, which we are building right now.

Application and Future Work

Work Environments

When the system (glasses connected to mobile device or computer) recognizes that the user is entering the highly productive and pleasurable flow state, it can block notifications and possible distractions in order to avoid that the user is being pulled out of the experience. Similarly, environmental settings such as screen brightness and played background music can be stored and reset when it becomes obvious that the user is drifting out of a productive and enjoyable state.

Interactive Learning Environments

The system also enables teachers to react to the classroom and study climate by giving real time feedback from students wearing the glasses. Special tasks, physical activities, or topic changes can be utilized by the teacher to keep students in a positive and productive state. An automated system enables more efficient studying at home due to the possibility for the system to identify higher engagement levels during preferred learning styles (reading, listening, watching, writing, etc.) and repeating this favored

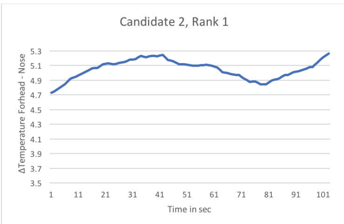

Figure 4: Difference in facial temperature between forehead and nose averages for candidate 2 while watching video ranked most enjoyable

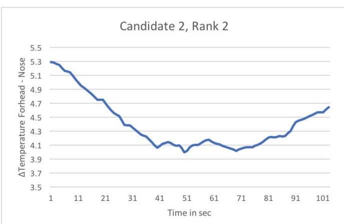

Figure 5: Difference in facial temperature between forehead and nose averages for candidate 2 while watching video ranked 2nd

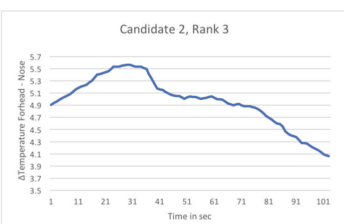

Figure 6: Difference in facial temperature between forehead and nose averages for C2 while watching video C2 ranked 3rd

form when a decrease in performance is identified.

Entertainment
Especially with virtual reality in sight, sensing on head-mounted devices has the potential to enable physical signals as implicit input modalities for film or game experiences. Identified higher pleasure with a certain scene or atmosphere can be used in adaptive storytelling models.

Prospective
The temperature data will be extended by EOG readings and can be completed with galvanic skin response measurements. A first test of the J!NS sensors showed that they can be used for Galvanic Skin Response measurements (GSR), and therefore allow us to render an even more accurate image of users' affective state.

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REFERENCES
1. O. Amft, F. Wahl, S. Ishimaru, and K. Kunze. 2015. Making Regular Eyeglasses Smart. *IEEE Pervasive Computing* 14, 3 (2015), 32–43.
2. F Gregory Ashby, Alice M Isen, and others. 1999. A neuropsychological theory of positive affect and its influence on cognition. *Psychological review* 106, 3 (1999), 529.
3. Mihaly Csikszentmihalyi. 1991. *Flow: The Psychology of Optimal Experience*. Harper Perennial.
4. Stephen H. Fairclough. 2009. Fundamentals of physiological computing. *Interacting with Computers* 21, 1-2 (2009), 133. DOI: http://dx.doi.org/10.1016/j.intcom.2008.10.011
5. Christine Lætitia Lisetti and Fatma Nasoz. 2004. Using Noninvasive Wearable Computers to Recognize Human Emotions from Physiological Signals. *EURASIP Journal on Advances in Signal Processing* 2004, 11 (2004), 929414. DOI: http://dx.doi.org/10.1155/S1110865704406192
6. Fernando Silveira, Brian Eriksson, Anmol Sheth, and Adam Sheppard. 2013. Predicting Audience Responses to Movie Content from Electro-dermal Activity Signals. In *Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '13)*. ACM, New York, NY, USA, 707–716. DOI: http://dx.doi.org/10.1145/2493432.2493508
7. Benjamin Tag, Ryan Mannschreck, Kazunori Sugiura, George Chernyshov, Naohisa Ohta, and Kai Kunze. 2017. Facial Thermography for Attention Tracking on Smart Eyewear: An Initial Study. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '17)*. ACM, New York, NY, USA, 2959–2966. DOI: http://dx.doi.org/10.1145/3027063.3053243
8. Huan Wang, Bonnie Wang, Kieran P Normoyle, Kevin Jackson, Kevin Spitler, Matthew F Sharrock, Claire M Miller, Catherine Best, Daniel Llano, and Rose Du. 2014. Brain temperature and its fundamental properties: a review for clinical neuroscientists. *Frontiers in Neuroscience* 8 (2014), 307. DOI: http://dx.doi.org/10.3389/fnins.2014.00307
9. Robert B. Zajonc, Stephanie Murphy, and Marita Inglehart. 1989. Feeling and facial efference: implications of the vascular theory of emotion. *Journal of Applied Physiology* 96, 3 (1989), 395–416.