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研究課題名（和文）What do you understand? Toward tracking user expertise using eye tracking

研究課題名（英文）What do you understand? Toward tracking user expertise using eye tracking

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研究成果の概要（和文）：本研究は容易に身につけられるセンシングデバイスを使い、特に熟練者の認知活動をトラッキングし、理解する手立てを得ることを目標としています。認知活動の抽出だけでなくアイ・ウェア コンピューティングに特化した新たな研究領域を定義し、より自然な認知活動の理解やトラッキング手法の開発を目的としています。本研究成果として論文発表（学術雑誌2、著書1、学会発表12）だけでなくACM,UbiCompでワークショップを2014, 2015年と開催しドイツで主催したDagstuhl Seminarではアイ・ウェア コンピューティングという新たなコンセプトを打ち出した専門家と討議し新たな研究領域定義に貢献しました

研究成果の概要（英文）：In this project we focus on determining relations between easy to wear sensing technology, comprehension and other skills related to expertise. We were not only able to introduce new features and sensing modalities for tracking expertise related metrics but also to define a new research community focusing on related problems around the novel field of eye wear computing to use for unobtrusive expertise and cognitive task tracking. We co-organized several workshops co-located with UbiComp, as well as introduced the new concept "eye wear computing" for tracking expertise in a Dagstuhl Seminar http://www.dagstuhl.de/16042 . Dagstuhl Seminars are listed in the Top 200 of Computer Science conferences according to Microsoft Academic Search related to citations and are used to establish novel research directions. The major outcomes of the project are not only research publications (2 journal 1 book chapter, 12 peer-reviewed conference) but also the new formation of a research community.

研究分野： Eyewear Computing

キーワード： eye tracking　wearable computing　cognitive activity

１．研究開始当初の背景

People increasingly use computing technology to track their health and fitness progress, from simple step counting to monitoring food intake to measuring how long and well they sleep. Smartphone applications and wearable devices such as the Fitbit FLEX wristband foster better eating and exercise habits, decrease the risk of obesity-related diseases, and improve quality of life. While most of these applications focus on physical movement, such as steps taken or stairs climbed, new products such as Pulse (www.withings.com/en/pulse) also quantify physiological signals such as heart rate. Given these trends, it's only a matter of time before we see sensing technology applied to cognitive tasks.

２．研究の目的

Our overall goal is to facilitate long-term tracking of all types of mental processes, which will enable new forms of self-reflection and suggest strategies to optimize mental fitness and well-being. In this project we focus on determining relations between easy to wear sensing technology, comprehension and other skills related to expertise.

In this work we explore unobtrusive sensing modalities (especially eye movement analysis) for expertise tracking. We focus on reading comprehension and expand to other areas.

３．研究の方法

(1) Overview

We performed the research in several steps: controlled research in lab environments (2 and 3) focusing on relations of physiological signals and more real life recordings to evaluate new sensing modalities moving away from cumbersome brain interfaces to more natural, wearable devices focusing on smart eye glasses (4 and 5).

(2) General Expertise/Cognitive Load Stationary Setup

Using functional near infrared spectroscopy as a reference, we investigated the relationship between cognitive load and eye motion using features from EOG glasses and stationary optical eye tracking. 20 participants (4 females, between ages 19 and 32) performed a dual n-back memory tasks, calculations, visual search tasks, reading comprehension exercises and memory tasks.

(3) Reading Comprehension

We employed the dataset of eye movement obtained from 11 subjects who are students of graduate schools. All of them are Japanese and thus non-native of English. As the eye tracker, SMI RED250 was used. This is a stationary eye tracker with a sampling rate of 250 Hz, which is high enough to catch eye movement while reading. In the experiments, we asked the subjects to perform the task of reading parts (PART7) of TOEIC tests. Each part consists of a document with several paragraphs and four questions about it. Each question is to select from among four choices.

(4) Mobile Immersion/Mental Load

As eye blink seemed an interesting features from the initial experiments, we designed several studies to determine mental workload and other expertise tracking related cognitive tasks in a first step and then presented interventions to increase users attention and immersion. In the following we just describe the final experimental setup for the interventions due to space limitations.

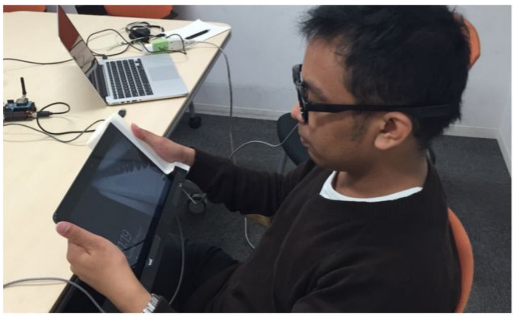

Figure 1. Experimental Setup

The Figure on top shows the setup for the immersion experiments. We presented two different short stories from the series Encounters to 8 English speakers (4 woman, 23-34 years, different nationalities) while measuring the skin temperature of the nose with our smart glasses. Each participant reads the two short stories assigned in a latin square design: one with and one without sound for control. All participant were provided with the Dell tablet connected to the tobii EyeX to trigger the sonic feedback in time (See Figure 1) The eye-tracker and temperature sensor had to be calibrated for each participant once. Following the reading exercise,

participants were asked to fill in the immersion questionnaire in paper.
The interventions are designed to stimulate mental imagery and call for the reader's attention. We put forward 3 studies with a total of 38 subjects, in order to support our claim. First we looked for data to support our novel approach in using the temperature of the nose to find immersion in reading, in order to create a literary cognitive agent capable to understand when to assist its reader. Here we found a negative correlation between immersion and nose temperature. We present our prototype for sonic and haptic

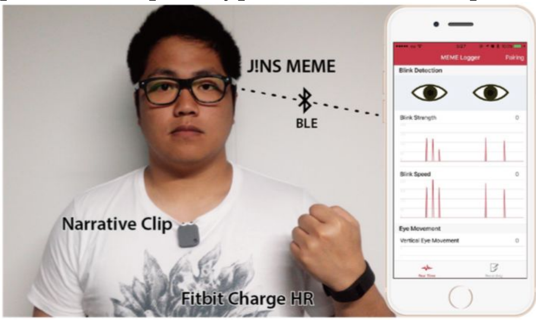

Figure 2 Long Term Recording

interaction in four original short stories, and a classic short story augmented with verbal and non-verbal sonic stimuli.

(5) Long term tracking study
To investigate daily natural reading activities, we created a long-term dataset. We asked 5 participants to record their lives using consumable sensors: J!NS MEME, Fitbit Charge CR, Narrative Clip and Tobii eyeX. The dataset contains 16 hours of controlled reading, 286 hours of natural reading, 112 hours of social interaction and 374 hours of other activities.
The Figure above shows the setup for the long term studies.

4．研究成果

(1) Overall results
We were not only able to introduce new features and sensing modalities for tracking expertise related metrics (comprehension, mental load, immersion) but also to define a new research community focusing on related problems around the novel field of eye wear computing to use for unobtrusive expertise and cognitive task tracking. We co-organized several workshops co-located with UbiComp (http://recall-fet.eu/wahm2014/, http://kaikunze.de/events/wahm2015/), as

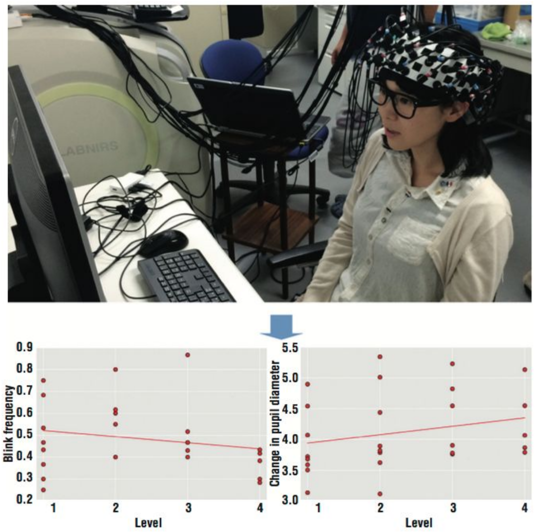

Figure 3 Cognitive Activity

well as introduced the new concept in a Dagstuhl Seminar http://www.dagstuhl.de/16042 . Dagstuhl Seminars are listed in the Top 200 of Computer Science conferences according to Microsoft Academic Search related to citations and are used to establish novel research directions.
The major outcomes of the project are only research publications but also the new formation of a research community.

(2) General Expertise/ Cognitive Load Stationary
Our ANOVA tests confirmed a relationship between the task difficulty as an independent variable and the change in pupil diameter, $p < 0.05$, with $F = 6.89$, $F_{crit}(3, 4) = 6.59$ (where denotes the F-distribution cumulative distribution function); and normalized blink frequency $p < 0.05$, $F = 6.63$, $F_{crit}(3, 4) = 6.59$, both separately considered as dependent variables. The Pearson product-moment correlation revealed good positive correlation for task difculty and change in pupil diameter ($r = 0.71$), and decent negative correlation for task difculty and normalized blink frequency ($r = -0.53$).
The Figure above shows the setup and a summary of our findings related to mental load recognition.

(3) Reading Comprehension
From the experiments, we have found that the following two features are informative: the sum of fixation duration, and the sum of the velocity of saccades. By using these features the proposed method is to estimate the class of English skill from among low, middle and high, which are de

ned based on the scores of English standardized test called TOEIC. From the experimental results with 11 subjects and 10 documents, we have been successful to estimate the class with the accuracy of 90.9%.

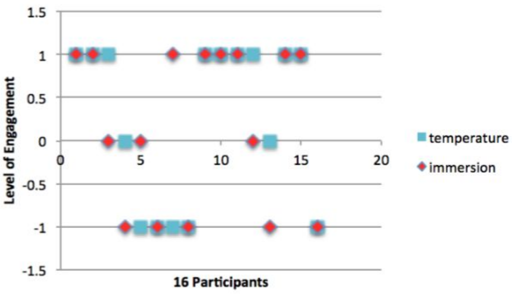

Figure 4. Immersion and Temperature Relation.

(4) Mobile Immersion/Mental Load
Correlations between nose temperature and subjective immersion for all subjects.
We investigated the temperature of the nose to find engagement in real time. Overall temperature was a good indication of immersion (see Figure 4). The effects of the sonic cues were clear when comparing the data to the control group, as control had only slight changes in temperature, which were consis- tent with subjective immersion. The nose temperature as a measure for engagement worked on nineteen out of a total of twenty three participants. Thus, we find that the temperature of the nose seems a reliable physiological metric to measure engagement through the involuntary physiological reactions of mental workload.

(5) Long Term Tracking Study
Publication pending, we are able to distinguish reading activities and will look into other cognitive tasks also regarding the quality of the tasks.

５．主な発表論文等
（研究代表者、研究分担者及び連携研究者には下線）

〔雑誌論文〕（2）（計２件）(refereed reading)

① Kai Kunze: Eyewear computers for human-computer interaction. Interactions 23(3): 70-73 (2016) DOI: 10.1145/2912886

② Oliver Amft, Florian Wahl, Shoya Ishimaru, Kai Kunze: Making Regular Eyeglasses Smart. IEEE Pervasive Computing 14(3): 32-43 (2015) DOI: 10.1109/MPRV.2015.60

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① Susana Sanchez, Tilman Dingler, Heng Gu, Kai Kunze: Embodied Reading: A Multisensory Experience. CHI Extended Abstracts 2016: 1459-1466. 7 May 2016. San Jose, US.

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〔図書〕（計１件）

①Book Chapter in Assistive Augmentation: Augmented Narrative. Susanna Sanchez, Kai Kunze. Pages 76 -96 (350) Springer Publishing. To be published 2016.

６．研究組織

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