Toward Large Scale Study using Smart Eyewear

Yuji Uema
JINS Inc.
Iidabashi Grand Bloom 30F
2-10-2 Fujimi Chiyoda-ku Tokyo
102-0071 Japan
yuji-uema@jins.com

Kazutaka Inoue
JINS Inc.
Iidabashi Grand Bloom 30F
2-10-2 Fujimi Chiyoda-ku Tokyo
102-0071 Japan
kazutaka-inoue@jins.com

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Abstract
The tracking of cognitive and physical activity using a wearable device is an emerging research field. While several studies have been performed on large-scale activity tracking using a watch-type wearable device, large-scale activity tracking using an eyewear-type wearable device remains a challenging area owing to the negative effect of such devices on a user's appearance. In this paper, we describe the initial result of a large-scale longitudinal study about the concentration level of users using an eyewear-type wearable device. Our approach is to use an eyewear-type wearable device and a predeveloped mobile application to collect data about eye blinks and head posture. The concentration level of users is estimated based on blink rate, blink strength, and head posture. We collected over 40,000 hours of data, and the result shows the change in concentration in a week and with time.

Author Keywords
Wearable device; Eyewear; Activity tracking; Eye Blink; Electrooculography

ACM Classification Keywords
H.5.3. Information interfaces and presentation (e.g., HCI): Group and Organization Interface

Figure 1: Hardware design of the JINS MEME device.

Introduction

Over the last few years, wearable sensors have become increasingly popular and they enable researchers to collect a significant amount of information. Particularly, several longitudinal studies have been carried out by taking advantage of the robustness and minimum interference of watch-type wearable devices. For example, Rachel et al. studied physical activity and sleep in a student population using 500 Fitbit Charge HR devices [1].

However, with respect to collecting data about everyday life, it remains challenging to gather data about eye movements using an eyewear-type wearable device. This could partly be because eyewear devices have an adverse effect on a user's appearance in most cases. Mary et al. conducted a large-scale survey and reported that applications of eyewear-type wearable devices are less than 3%, while those of watch-type devices are more than 30% [2]. This fact implies the difficulty of utilizing an eyewear-type wearable device. However, there is no doubt that acquiring information about the eye movements of users in their daily lives has high potential because there are numerous research results that connect eye movements and other parameters of users, such as attention, drowsiness, and cognitive activities. Therefore, in this work, we aim to conduct a feasibility study of large-scale longitudinal tracking of a user's activity using an eyewear device.

Eyewear device

To make a device as unobtrusive as possible, we have developed a state-of-the-art smart eyewear referred to as JINS MEME (Figure 1). JINS MEME is shaped like regular Wellington eyeglasses [3], and its weight is approximately 36 g with lenses, which is almost the same as that of metal frame eyeglasses. Figure 2 shows the details of the JINS MEME device. It consists of 3-point electrooculography sensors built in the nose pads (L-pad and R-pad in Figure 2) and bridge. The frame contains a 6-axis (accelerometer and gyroscope) sensor, a lithium-ion battery, and Bluetooth Low Energy. The battery life is 12 hours. A few studies have been performed using the JINS MEME glasses [4, 5]; however, to the best of our knowledge, a large-scale study still remains a challenging topic.

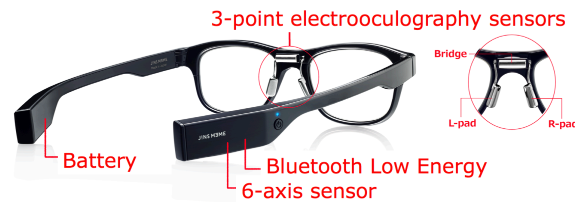

Figure 2: Structure of JINS MEME device.

Detection of eye movement and blinks

Eye movements, including blinks, are detected by the electrooculography sensor built in the nose pads and bridge of the eyewear, and they are calculated as follows [6]:

$$V_{vertical} = -(V_L + V_R)/2\,, \quad (1)$$

$$V_{horizontal} = V_L - V_R\,, \quad (2)$$

where $V_{vertical}$ is the up-down eye movement, $V_{horizontal}$ is the side-to-side eye movement, V_L is the potential between L-pad electrodes and the bridge (Figure 2), and V_R is the potential between R-pad electrodes and the bridge. Eye blinks appear as vertical eye movements. Kanoh [6] and Nathaniel [7] independently tested the blink detection accuracy of JINS MEME. Kanoh reported that the blink detection accuracy is

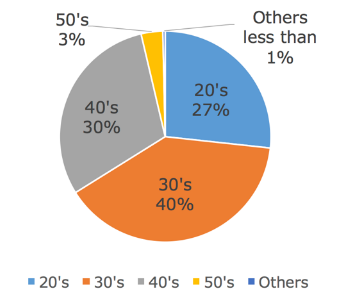

Figure 4: Age structure of users.

above 90% and Nathaniel reported that it is almost 98%. Using these results as reference, we developed a blink detection algorithm, which is available as an SDK [8]. In addition to blink detection, the parameters calculated using the 6-axis sensors are available on the SDK.

Estimation of concentration levels

Using the JINS MEME SDK[8], we developed an application referred to as "Office" to estimate the concentration levels of users. Based on the knowledge obtained in a preliminary experiment, we consider the following three key parameters regarding concentration: (1) blink rate, (2) blink strength, and (3) head posture. Blink rate is a well-known parameter used to measure concentration levels [9]. Several studies have concluded that the numbers of blinks decreases as the amount of required concentration increases. Blink strength is the peak-to-peak value of the blink signal of an electrooculogram. We use the time variation in blink strength to estimate the concentration level. We use head posture as a key parameter because through a preliminary test, we found that when we focus on something deeply, our head posture is stable and close to straight. Blink rate, blink strength, and head posture can be calculated using the JINS MEME SDK [8]. Figure 3 shows the interface of the developed application. The application calculates concentration levels on a scale of hundred. We tuned the parameters of the algorithm and defined a concentration level above 80 as "deep concentration".

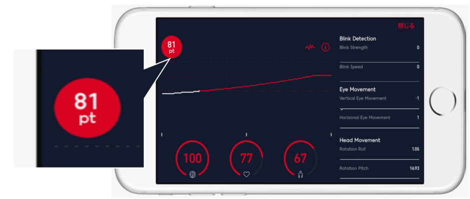

Figure 3: Interface of application showing a concentration value of 81, which is a state of deep concentration, at the top left.

Collecting data using JINS MEME

We collected data using our application. Users were asked to agree to a privacy policy regarding the collection of data. As the purpose of this study is to explore the potential of a large-scale longitudinal study using an eyewear device, we did not impose any additional conditions on users. Users were only asked to input some information when they used the application for the first time. Then, they were able to use JINS MEME and the Office application anytime in their daily lives. The period of data collection was from October 2016 to April 2017. The measured values for each user were sent to and stored on a server.

Initial result

In the first period of data collection, the total amount of available data was 43,874 hours. Most of the users were in their 20's, 30's, and 40's, as shown in Figure 4. Other ages, which consisted less than 1% of the users, included 10's, 60's, and unknown ages (the case where a user did not input age information at the initial setup). In this initial analysis, we aimed to find a trend in the data. Figure 5 shows the ratio of the "deep concentration" period in a week. Figure 6 shows the change in the deep concentration ratio in 24 hours.

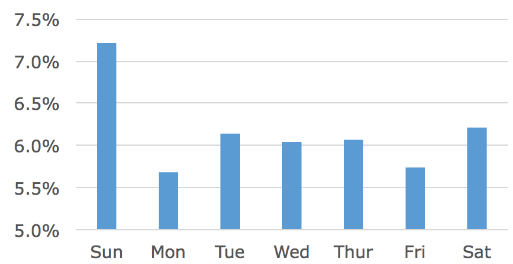

Figure 5: Ratio of deep concentration in a week.

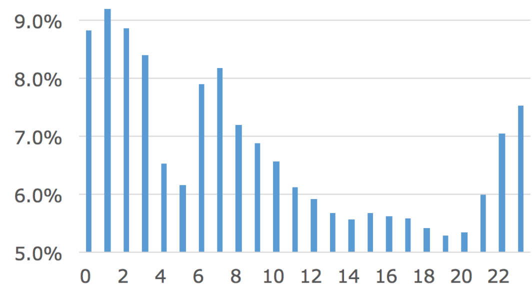

Figure 6: Change in ratio of deep concentration in 24 hours.

Discussion

We obtained a trend that users concentrate more on weekends and during nighttime, including early mornings. This result agrees well with our prediction. As our application was developed with the objective of measuring the concentration of users who focused on a single task, concentration level decreased during daytime and weekdays owing to interruption by other people and objects. Furthermore, it is empirically said that several people are more productive at night or in early morning. Our initial results support this empirical principle.

Acknowledgement

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