Evaluation of Deep Flow in Psychology During Reading Using a Life-Log Device

Ryota SHIMIZU* and Hisaya TANAKA *
* Kogakuin University, 2665-1 Nakano-cho, Hachioji-shi, Tokyo 192-0015, Japan
j117148@ns.kogakuin.ac.jp hisaya@cc.kogakuin.ac.jp

Abstract: With the current spread of the Internet, information is being collected in various ways, such as watching videos. However, the basis of information collection is reading sentences, with books as typical media. Books comprise both print books and e-books, but many people find that paper-based books are easier to read than e-books. Therefore, a commonly used learning method is reading print books. However, reading on paper is easily affected by the reader’s situation, such as the surrounding brightness, environmental sound, and posture. Although there are many environmental factors, in this experiment, we focused on the environmental lighting. The purpose of this study is to determine an environment where one can concentrate on reading. For that purpose, we evaluate and determine the flow, which is the feeling of being immersed, via the number of blinks, head movement, and subjective information. It was found that local lighting results in greater head acceleration and angular velocity values, but the number of pages to be read is greater and the reading experience time is shorter. Therefore, although the experiment was limited to five subjects, it can be said that an environment is more suitable for reading when local lighting is used.

Keywords: Flow, Paper books, Lighting environment, Head movement, Time perception

1. INTRODUCTION

Reading print books is a learning method used by many people, both young and old. Children read picture books, and across 9 years of school as compulsory education, learning activities will be conducted in textbooks. After compulsory education, many people continue to higher education or become employed, but there are many opportunities to read additional materials, such as specialized books and business documents, afterwards. A questionnaire conducted by Akahori et al. showed that more than 90% of people read paper books more easily than e-books of specialized texts or general reading materials [1].

However, reading is easily affected by the surrounding environment. For example, a reader who can hear a TV in the background may think about the sound if it is interesting, even while reading.

Therefore, in this experiment, we evaluate and compare the flow determined from the measured data when a person reads in different environments, focusing on the environment at the time of reading.

The definition of flow is the sense when a person is immersed in an act and a state of deep immersion, in which distractions are not a problem, or a state in which the experience itself is so enjoyable that one expends much time and effort [2]. By comparing flow across environments, we can determine which environment is suitable for reading.

As an environment, Sakagami et al. investigated the relation between lighting conditions and the subject's concentration level [3]. For this experiment, we used this document as a reference and established general lighting and local lighting as environments for reading.

The purpose of this study is to compare flow based on physical and subjective information obtained during reading and to consider an environment in which one can concentrate well on reading.

2. METHODS

2.1 Measuring device

In this study, JINS MEME ES_R is used to measure flow-related data. According to the specifications published by the manufacturer, Jins Co., Ltd., electrooculography (EOG) sensor information, acceleration (ACC) sensor information, and gyro sensor information can be acquired for full mode (sampling frequency: 100 Hz), and Bluetooth is adopted for wireless data communication.
2.2 Measurement of blind rate

As shown in Figure 1, the eye potential sensor has three electrodes. As a result, the difference between the bridge electrode and the L-pad, and R-pad electrodes can be output as $V_L$ and $V_R$, respectively. EOG_H and EOG_V are the horizontal and vertical movements of the eye, and are calculated by equations (1) and (2), respectively. In this experiment, the data are measured by observing blinking via EOG_V. Therefore, the main EOG information used is EOG_V, which is within the measurement range from $-1500$ to $1500 \mu V$. The number of blinks was counted from the EOG_V waveform and converted into a frequency (blinks/min).

![Figure 1: JINS MEME ES_R EOG sensor](image)

2.3 Acceleration and gyro sensor information

It is possible to measure head movement from the acceleration sensor and the gyro sensor of JINSMEMEES_R. In this experiment, we compare the standard deviations of acceleration and angular velocity.

The acceleration of JINS MEME ES_R is the X axis on the left and right, the Y axis on the front and back, and the Z axis on the top and bottom, and each movement distance is quantified. Therefore, the standard deviation (S.D.) of acceleration can compare the head movements of each subject. Figure 5 shows the result of the S.D. of the acceleration data measured during reading for 30 min. The parameter G is gravitational acceleration.

The angular velocity represents the amount of rotation on the X, Y, and Z axes. In rotation, the X, Y, and Z axes are called the roll, pitch, and yaw, respectively. Angular velocity is the amount of rotation on each of the axes. Therefore, by calculating each S.D., we can compare the number of head movements with their speed. The unit dps represents degrees per second; for an object that rotates once per second, the angular velocity is 360 dps. Figure 6 shows the result of the S.D. of the angular velocity data measured during 30 min of reading. Figure 2 shows the acceleration and angular velocity of JINS MEME ES_R.

![Figure 2: Direction of acceleration and angular velocity of JINS MEME ES_R](image)

3. EXPERIMENT

3.1 Environment

In this experiment, reading was carried out in two states: general lighting and local lighting. Figures 3 and 4 show the general lighting and local lighting in photos taken from the subject’s left. Fluorescent lamps were used for general lighting and a desk lamp was used for local lighting. Both had the same illuminance on the surface of the desk, 500 lx. The peripheral illuminance was 200–250 lx and 10–40 lx for general and local lighting, respectively.

![Figure 3: General lighting](image) ![Figure 4: Local lighting](image)

3.2 Experimental equipment

- JINSMEME ES_R (sampling frequency: 100 Hz)
- ES_R development kit
- ES_R dedicated receiver (dongle)
- Laptop computer (Panasonic CF-NX2, Windows 10 Pro, Intel Core i5, RAM 4.00 GB)
- Desk lamp

3.3 Experimental subjects

The subjects were 5 males with a mean age of 22.8 years. In addition, the subjects had good eyesight for reading. All subjects agreed to informed consent prior to participating in the experiment.

3.4 Experimental task

We asked the subjects to read different novels by the same author for 30 minutes at a time in general and local
Then, we had the subjects complete the tests and questionnaires to determine their reading comprehension. The books used are Keisuke Matsukawa’s “KASHI KARI” (page 321) and “Mickey Mouse’s Melancholy” (page 276). Because the numbers of rows and columns per page were the same, the difference in the number of characters to read was small.

The questionnaire, discomfort (with a device), and tiredness were scored out of 5 points. The evaluation of the book was scored out of 10 points, which comprises enjoyment of the book and desire to continue reading.

3.5 Experimental procedure

In this experiment, we asked the subjects to answer the questionnaire before the experiment. On the day of the experiment, the procedure and precautions were explained, and the subjects were allowed to acclimate to the environment in a resting state for 5 min. Then, the subjects first read with general lighting for 30 min, after which, the subjects stopped reading and were asked to fill out a reading test and questionnaire. After a 10-min break, the task was repeated with local lighting. After the experiment, we also asked oral questions.

This experiment was carried out according to “Psychological Biometrics for New Interface Development 2019-A-17.”

4. RESULT

JINS MEME was used to measure three characteristics: blinking, head movement, and subjective experience.

Subject 3 blinked 19 times/min with general lighting and 23 times/min with local lighting. It was impossible to count the other subjects’ blinks, due to the lack of EOG_V data.

Figures 5 and 6 show the head movement results in terms of measured acceleration and angular velocity, respectively. The characteristics of each subject's head movements are compared in the figures using the mean of the X, Y, and Z axes. Figure 7 shows the mean comprehension evaluation of the five subjects, which compares the results of the questionnaire in the two environments. Specifically, we compare the intensive evaluation, discomfort, tiredness, and evaluation of the books.

Figure 8 shows each subject’s perceived time spent reading, as well as the mean subjective time. The red line represents the actual reading time of 30 min. In addition, the mean number of pages read under general and local lighting was 43.0 and 47.6 pages, respectively.
5. DISCUSSION

From the results in Figures 5 and 6, the values of acceleration and angular velocity were greater under local lighting. Morishima et al. demonstrated that increased workload causes tunnel vision [4]. In addition, Ogawa et al. suggested that eye movements accompanied by head movements increase as a result of tunnel vision [5]. Therefore, it is considered that the subject was concentrating on reading with local lighting, which increased the workload and increased head movement.

The results of the ECG_V data showed that subject 3 blinked more frequently with local lighting. Although only data from subject 3 was recorded, we consider increased blinking and head movement to correspond to increased concentration.

It can be seen from Figure 7 that the book read with general lighting was evaluated higher than that read with local lighting. However, the number of pages read was less for general lighting than for local lighting. Therefore, the increase in number of pages read under local lighting is considered to be due to the environment, not enjoyment of the content.

Figure 8 shows how long the subject felt the reading experience was. As a result, although the actual reading time was 30 min, the subjects felt that the reading time was approximately 29 min (mean) with general lighting. In contrast, the subjective reading time was approximately 20 min (mean) with local lighting. Subject 1 did not feel this perceived time reduction. However, overall, reading under local lighting tends to feel faster than that under general lighting.

6. CONCLUSION

In this experiment, subjects read under general and local lighting, and we performed psychobiological measurements of flow to determine which environment is more conducive to concentration on reading. It was found that the head acceleration and angular velocity were greater in the local lighting, the number of pages read was greater, and the time spent reading felt shorter. Therefore, we consider local lighting more conducive to the flow state than general lighting. In other words, it was possible to measure the reading environment in terms of psychological flow. Therefore, although this study was limited to five subjects, it can be said that an environment is more suitable for reading when local lighting is used.

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