Information Design for Purposeless Information Searching Based on Optimum Stimulation Level Theory

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Abstract. There are increasing opportunities to engage in purposeless information searching, such as browsing purposeful information. A growing focus is also promoting interest in products and services by utilizing these opportunities. Thus, rather than the efficiency of information searching, the new concept of the "continuousness" of information searching is expected for information design. It has been suggested that searching for information without a defined purpose or use is done based on intrinsic motivation (IM). The theory of optimum stimulation level (SL) gives a U-shaped relationship between IM and SL. On the basis of this theory, we hypothesized that the continuousness of information is enhanced in an environment in which the user can enjoy searching for information at the optimum level of stimulation. In this study, we attempt to specify the requirements for a method of information design based on the aforementioned hypothesis. We assess the effectiveness of the method with an experiment in which participants engage in information browsing. The SLs of the referred pieces of information are quantified on a scale from zero to one. After analyzing the relationship between the SL and the physiological and psychological responses of the participants, we clarify (i) the optimum SL, (ii) the SL that most effectively enhances the IM of the participants to search for information, and (iii) the SL between one piece of information and the next at which the IM of the participants is increased.

Keywords: Purposeless information searching · Intrinsic motivation
Physio-psychological analysis

1 Introduction

Nowadays, with the spread of mobile terminals, the reasons why people search for information have diversified. In terms of the clarity of purpose, information searching can be divided roughly into two patterns. One pattern is typified by an information search (IS) that is performed with a clear purpose, such as a route search or an accommodation reservation. We deem this to be an "objective" IS in which the motivation of the user is directed to the desired information. Therefore, when designing information on such sites for purposeless IS, the main focus is usually on IS efficiency. By contrast, we deem an IS performed without a clear purpose, such as simple browsing, to be a "non-objective" IS in which the motivation of the user is directed to

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the IS itself. In recent years, the expectation has been that a non-objective IS affords opportunities to promote the motivation to use products and services. Therefore, on such sites, rather than concentrating on IS efficiency, the importance from a new perspective of information design (ID) is to maintain IS sustainability, that is, to sustain the interests of users and to touch a lot of information.

As described above, in a non-objective IS, the motivation of the user is directed to the IS itself. In the field of psychology, such voluntary motivation in which the activity itself is the aim is called intrinsic motivation (IM) [1–7] to distinguish it from extrinsic motivation due to external factors such as compensation and punishment. In a non-objective IS, maintaining the user's IM at a high level is considered to be key in promoting IS sustainability.

One of the psychological theories related to the degree of IM is the theory of optimum stimulation level (OSL) [8–10] in which IM is viewed as having an inverted U-shaped relationship with stimulation level (SL). Replacing the novelty of information with its SL, if people touch too weak stimuli without novelty for themselves, they will be bored, but if they touch on themselves too novel stimuli, they become indifferent. However, there is an intermediate SL that induces IM, that is, the OSL. In a previous study [11], we considered familiar information as having too low an SL and unfamiliar information as having too high an SL. Furthermore, giving users information of differing SL revealed that IM increased the most in the group given information of intermediate SL.

In the present research, as a new ID targeting non-objective ISs, we applied OSL theory as a way to maintain user IM and promote IS sustainability. Specifically, in a non-objective IS, on the basis of the OSL theory, we hypothesized that it is highly likely that the user will stop the IS if she/he encounters information that is either too familiar or too unfamiliar. However, by continually encountering information whose SL for individual users is neither too low nor too high, high IM is maintained, and IS sustainability is promoted.

The purpose of this paper is to propose a method of ID aimed at maintaining user IM and promoting IS sustainability to give a new value to non-objective ISs. To do so, in the first experiment, we attempt to extract the ID requirements for promoting IS sustainability. Specifically, we used physiological psychology to investigate the effectiveness of giving information of how much range of SL to maintain user IM by analyzing the relationship between user IM and information SL in non-objective ISs. On the basis of this, we propose an ID that encourages IS sustainability, and in a second experiment, we verify the proposed ID.

2 Experiment

2.1 Method

In the first experiment, we observed and measured non-objective ISs by users. Our aim in doing so was to use physiological psychological indices to analyze the SL of the information being viewed and the extent of user IM at that time. Specifically, we had users engage in a non-objective IS, whereupon we analyzed the SL of the information

that they viewed as time series and used physiological psychological indices to evaluate the degree of user IM.

Experimental Task. The task in this experiment was an IS using an experimental site that simulated a general site that users used for browsing. The presented information was taken from 24 categories covering hobbies and entertainment that are typical of people in their 20 s, these being the participants in this experiment. In addition, the experimental site consisted of four layers, and when a participant selected a category, it transited to the hierarchy of subcategory and reached the text information at the fourth hierarchy. Six types of text information were prepared for each meddle category. Each piece of text information consisted of around 1,000 characters.

Experimental Procedure. Our aim in the experiment was to observe the participants as they engaged in non-objective ISs, so we gave them the opportunity to browse while killing time without being conscious of the experiment. We first installed the measuring device and then asked the participants to wait in the resting state for 2 min. We then asked them to browse the site for 20 min while relaxing while we "prepared the experiment." We then asked them to wait again in the resting state for 2 min, whereupon we instructed them to search for particular keywords (e.g., "Ina Bauer") on the site. However, in this research, the latter IS was a dummy task and was not analyzed; it was the previous 20 min IS that we analyzed. After completing the experiment, we informed the participants of our actual intention with the experiment and asked them to complete a questionnaire.

Data, Participants, and Ethics. The first data set is the search log corresponding to the chronologically ordered information that the participants viewed. The second data set comprises subjective scores on the scale 0–100 for the degree of participant interest in each piece of information viewed. The third data set comprises the frequency of blinking, which is an index of interest and was measured using a digital video camera. The fourth data set comprises changes in cerebral blood volume (CBV), which is the Oxy-Hb concentration change in channel 16 of the prefrontal cortex (PFC) as measured by near-infrared spectroscopy. The data for subjective scores, blinking, and CBV changes were all standardized among the participants.

The participants were 15 students (11 men and 4 women) aged 20–25 who we instructed to refrain from caffeine and alcohol intake from the day before the experiments. Each participant gave written informed consent before the experiment.

Analysis Method. The SLs of the information that each participant viewed were quantified using the same method as in the aforementioned previous research. Specifically, prior to the experiment, we asked the participants to compare all pairs from the 24 categories in terms of "familiar" or "unfamiliar". On the basis of those data, each category was scaled by the modified Scheffe method and positioned on one dimension. Furthermore, to standardize the scale for all participants, the category with which a participant was most familiar was placed at zero, their least familiar category was placed at one, and each of the other categories was placed in the range 0–1 to quantify the SL of each category on a common scale for each participant. For example, the SLs of the information browsed by a particular (male) participant are shown in Fig. 1, and we draw the SL time series as the waveform shown therein.

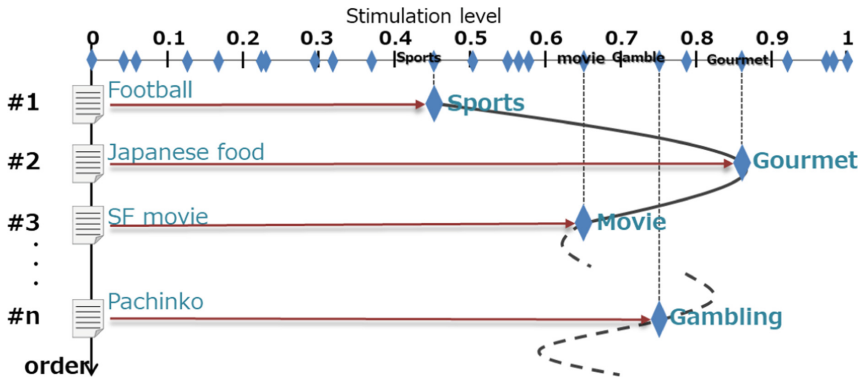

Fig. 1. Stimulus level (SL) of information browsed by a particular subject (time-series change)

2.2 Results

Characteristics of SL Time Series. As shown in Fig. 2, upon visualizing the SL time series of each participant (taking the SL on the horizontal axis and the order of the information viewed on the vertical axis), we see that each participant continued to search for information between a weak stimulus and a strong stimulus. Moreover, we found that the SL tended not to change suddenly between consecutive information browsings. From this, it seems that, in a non-objective IS, information is browsed while going back and forth with a certain SL as the boundary, and we reason that this SL is the OSL. Again, recalling the hypothesis of this research (namely that, in a non-objective IS, individual users are keen to access information whose SL to them is neither too low nor too high so that user IM is maintained and IS sustainability is promoted), we view this SL that is neither too low nor too high to be near the OSL.

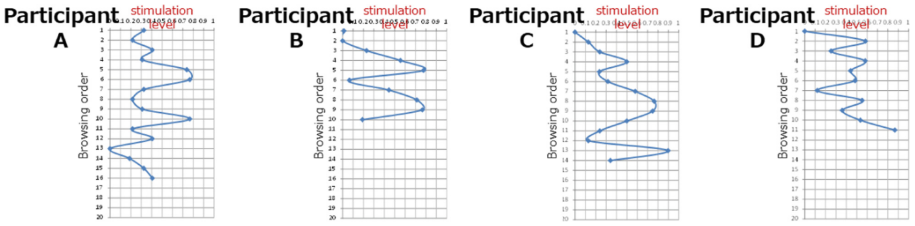

Fig. 2. Characteristics of changes in SL time series

Therefore, to embody the ID requirement of promoting IS sustainability, we first clarified quantitatively the OSL that was common to all participants and further examined the appropriate SL difference between consecutive information browsings.

Quantitative Identification of OSL. Therefore, taking the SL on the horizontal axis and the order of the viewed information on the vertical axis, we considered that the OSL is present in more than the local minimum value of the wave and less than the local maximum value, and we analyzed its existence probability using the following algorithm. Specifically, first, in the maximum value appearing at the *i*-th information browsing, we defined a section where the maximum value or less as one, and a section where the maximum value or more as zero. Similarly, in the minimum value appearing at the *j*-th time, we defined a section where the local minimum value or less as zero, and a section where the local minimum value or more as one. In this way, we evaluated as zero or one whether the OSL exists on every SL and accumulated it for all participants. Finally, by dividing the accumulated value by the total number of occurrences of the local maximum value and the local minimum value, we obtained the OSL existence probability (see Fig. 3).

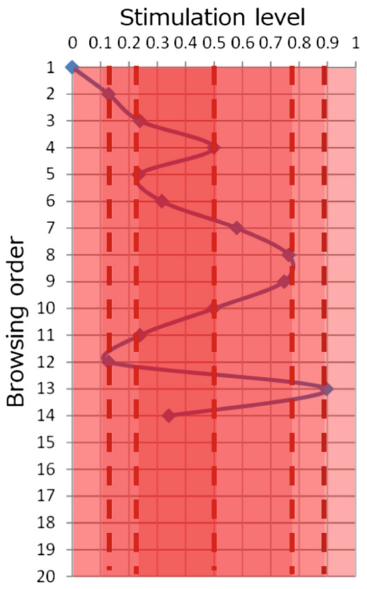

Fig. 3. Quantitative identification of optimum stimulation level (OSL)

From the analysis, we see that taking the SL on the horizontal axis and the OSL existence probability on the vertical axis presents the relationship between SL and OSL existence probability as an inverted "U". Therefore, for the sake of clarity, we grouped the SLs into five sections according to OSL existence probability and then examined the relationship between SL and IM from the physio-psychological reaction to viewing information in each section (see Fig. 4).

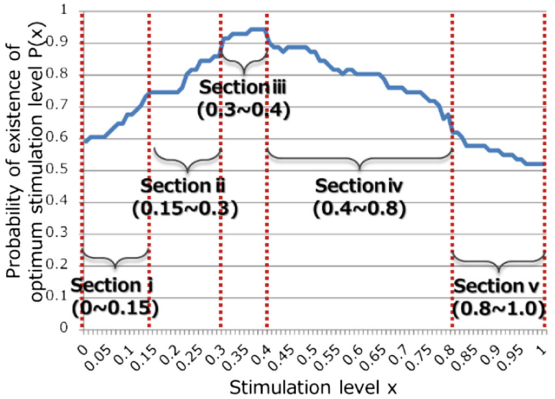

Fig. 4. OSL existence probability

Relationship Between SL and IM. Figure 5 shows the results of the subjective scores. Averaging the degree of interest in each section showed that the interest in Sect. 3 was the highest.

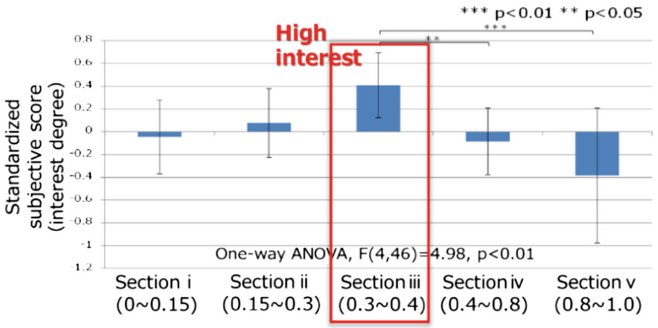

Fig. 5. Subjective scores

Figure 6 shows the blinking frequency. It is known that blinking frequency increases with SL. We investigated the increase (i.e., the average difference from the resting state) in blinking frequency while browsing information at each SL and found again that the interest in Sect. 3 was the highest.

Figure 7 shows the changes in CBV. The PFC is divided into several regions of which we focused on the dorsolateral PFC (DLPFC) that is involved in motivation and the medial PFC (mPFC) that is involved in spontaneity. By examining increases and decreases in Oxy-Hb concentration (average difference from resting state) that indicated activation of the DLPFC and mPFC while viewing information in each SL section, we found that spontaneity and motivation were highest in Sect. 3.

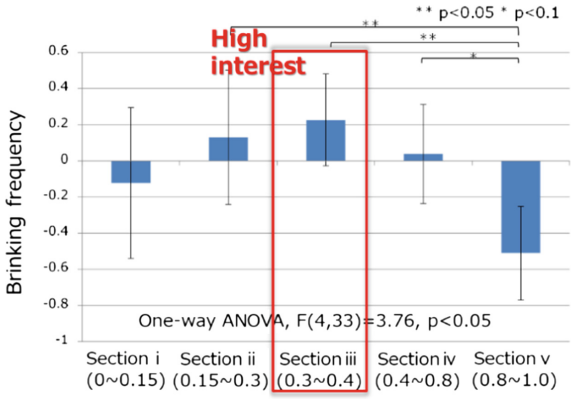

Fig. 6. Blinking frequency

Summarizing the results of the physio-psychological reactions suggests that IM would likely be highest when the information of Sect. 3 were viewed. From this, we

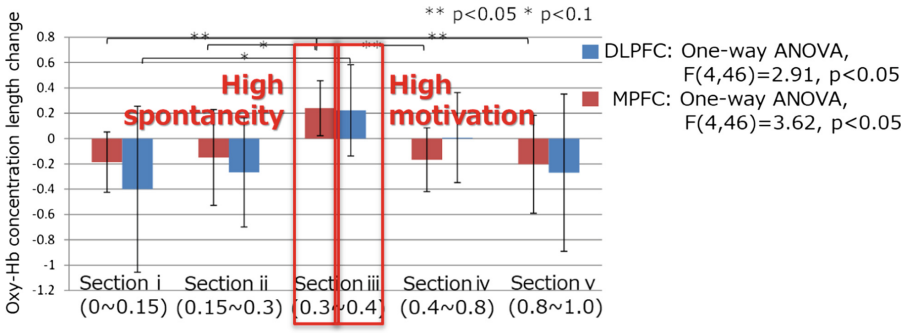

Fig. 7. Changes in cerebral blood volume (CBV)

consider the OSL common to all participants to be 0.3–0.4. Moreover, we found IM to be relatively high in the sections with SLs of 0.15–0.8. From the above, by designing the information such that the IS that goes back and forth within the SL range of 0.15–0.8 focusing on the OSL 0.3–0.4 is performed, it seems that user IM could be high and maintained at the level. This is the first requirement of ID for IS sustainability.

Quantitative Identification of Appropriate SL Difference. Another feature of the typical SL time series was that the SL tended not to change abruptly between consecutive information browsings. Therefore, we examined the appropriate SL difference between consecutive information browsings. Specifically, to identify the appropriate SL differences when the SL either increased or decreased, we analyzed the correlation between SL difference between information $n - 1$ and n and the IM intensity while browsing information n.

In Fig. 8, the SL difference between information $n - 1$ and n is recorded on the horizontal axis, and the subjective score at information browsing n is recoded on the vertical axis. Here for the sake of clarity, we divide the SL difference into three groups

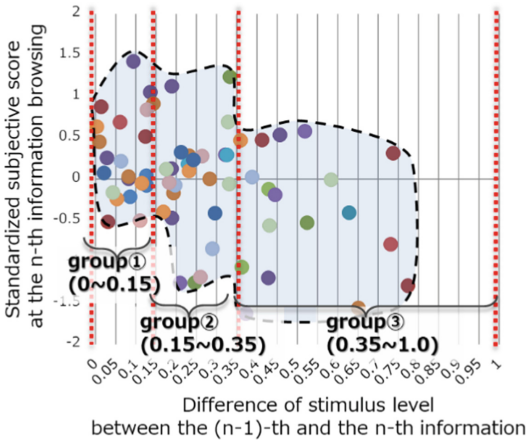

Fig. 8. Relationship between stimulation level (SL) difference from information $n - 1$ to n in the direction of increasing interest and the subjective score for browsing information n

and examine the relationship between SL difference and IM from that between the physio-psychological reaction to viewing information n and the SL difference in each group.

Figure 9(a) shows the subjective scores, Fig. 9(b) shows the blinking frequency as an indicator of interest, and Fig. 9(c) shows the CBV changes as an indicator of motivation and spontaneity. These results show that participant interest and spontaneity to information browsing were highest for category 1. This result suggests that IM is highest when the SL difference between consecutive browsing information is between zero and 0.15 in the increasing direction.

Similarly, we also examined the transition in the decreasing direction. From the distribution of subjective scores, we analyzed the SL differences by classifying them into four, as shown in Fig. 10, for the sake of clarity. The subjective scores and CBV changes suggest that IM is highest when the SL difference between consecutive browsing information is between −0.35 and −0.5 in the decreasing direction (see Fig. 11(a), (b) and (c).

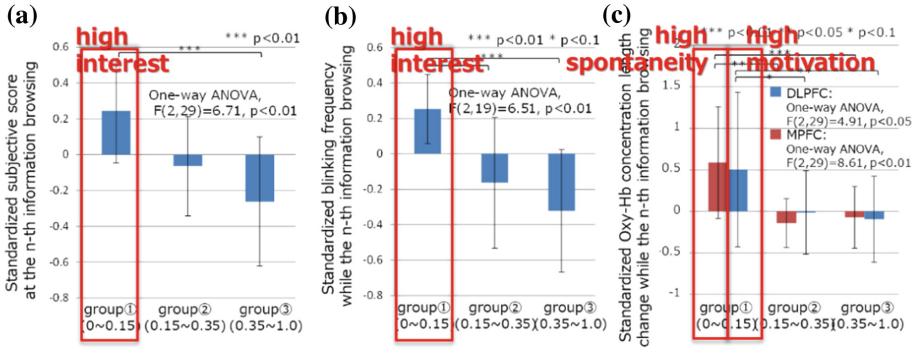

Fig. 9. (a) Subjective score for information browsing n. (b) Blinking frequency for information browsing n. (c) CBV change for information browsing n

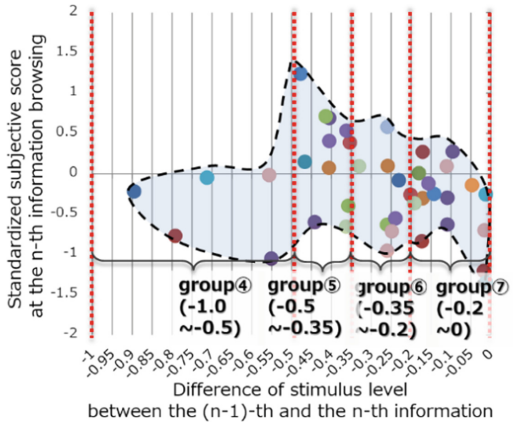

Fig. 10. Relationship between SL difference from information $n-1$ to n in the direction of decreasing interest and the subjective score for browsing information n

Requirements of ID to Promote IS Sustainability. To summarize the ID requirements obtained from the experiment, with the most familiar category for each user being zero and the least familiar category being one, we find an OSL of 0.3–0.4. Furthermore, if the SL is 0.15–0.8 with a focus on that, the IM is maintained at a relatively high level. This is the first requirement.

In addition, the desired SL difference is between zero and 0.15 in the increasing direction (i.e., when transitioning to a less familiar category information) and between −0.5 and −0.35 in the decreasing direction (i.e., when transitioning to a more familiar category information). This is the second requirement.

From the above, it is conceivable that, by presenting the above requirements to a site that is the target of non-objective ISs, the user IM could be maintained and the IS persistence could be promoted.

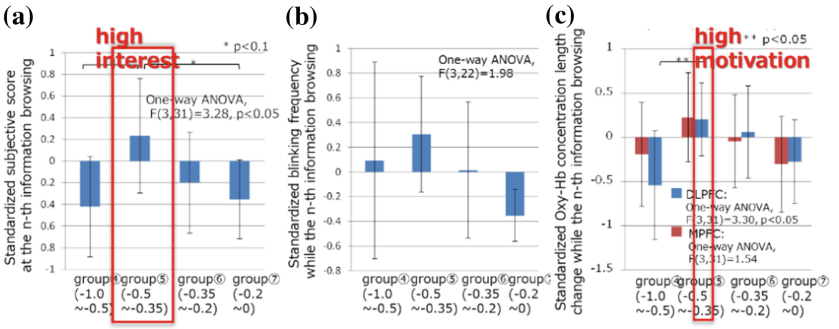

Fig. 11. (a) Subjective score for information browsing *n*. (b) Blinking frequency for information browsing *n*. (c) CBV changes for information browsing *n*

3 Verification of Effectiveness of the Proposed Information Design

3.1 Experiment to Verify the First Requirement

Method. In the verification experiment, we verified whether IS persistence is promoted by maintaining user IM by embodying the ID requirements clarified from the experiment that was discussed in the chapter 2 on the site.

The experimental method is as follows. The participants were asked to view as much information as they wanted without restrictions on either the time or the number of views. On the experimental site, the information displayed at time *n* was gathered automatically from the information prepared in advance for each category based on the SL data of each participant. For example, when transitioning from zero to 0.15 within the SL range of 0.15–0.8 from information $n - 1$ to information *n*, the categories included in the range were selected randomly, and furthermore, a random piece of information included in the category was displayed.

The participants were asked to wait at the rest for 2 min after attaching the measuring device before carrying out the above tasks. During each task, blinks and CBV changes were measured. The participants were then asked to describe their introspection with a free sentence.

The subjects were 10 students (7 men and 3 women) aged 21–25. Two experimental conditions were prepared: one in which it was possible to view information in the whole SL range without applying the first requirement and another one in which it was possible to view information in the SL range of 0.15–0.8 by applying the first requirement. The SL difference between browsing information $n - 1$ and n was set randomly in both conditions. To eliminate the influence of ordering, the experimental order was controlled.

Results. We examined the following two indices of IS sustainability. Figure 12(a) shows the average number of pages that changed. It is understood that, when the first requirement was applied, the number of pages increased significantly compared to when it was not applied. Also, Fig. 12(b) shows the average number of free sentences. It can be seen that the number of free sentences is roughly proportional to the number of transitioned pages. This suggests that, in the case of an SL of 0.15–0.8 when the first requirement was applied, it was not that the number of pages was increased by successively shifting the page for reasons such as boredom but that the IS continued because of voluntary interest.

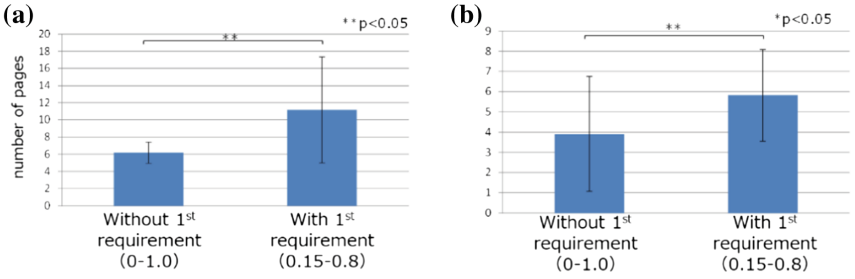

Fig. 12. (a) Average number of pages. (b) Average number of free sentences

Next, the results for the physiological index of endogenous motivation were analyzed. Analysis of blinks (Fig. 13(a)) as an index of interest showed that interest increased when applying the first requirement. Furthermore, analysis of CBV changes (Fig. 13(b)) as an indicator of motivation and spontaneity showed no statistical difference, but the average value was higher when the first requirement was applied. These results suggest that, when the first requirement is applied, the IM is higher than when it is not applied.

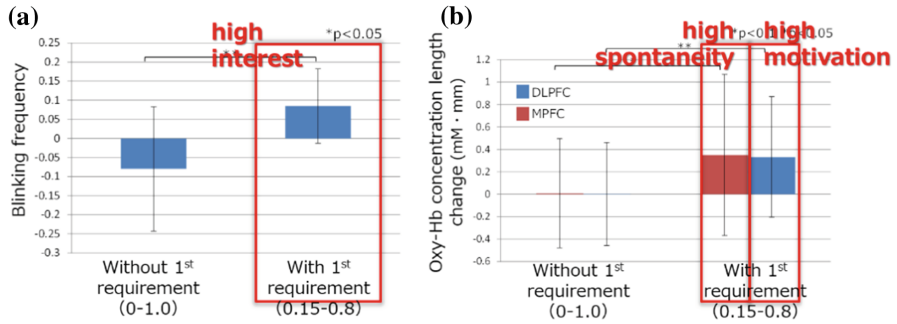

Fig. 13. (a) Blinking frequency. (b) CBV changes

3.2 Experiment to Verify the Second Requirement

Method. The participants in the experiment to verify the second requirement were the same as those in the experiment to verify the first requirement. There were two experimental conditions, namely, one applying only the first requirement and another one applying the optimum SL difference, that is, applying both the first and second requirements. All of the other experimental methods were the same as those in the experiment to verify the first requirement.

Results. We focused on the following two results as indices of IS sustainability. There were no statistically significant differences in the number of pages that transited (Fig. 14(a)) and the number of free sentences (Fig. 14(b)), but the average value suggests that the IS would last longer.

Next, we focused on the results for the IM index. Analysis of blinks (Fig. 15(a)) as indicators of interest showed no significant difference, but comparing the average values suggests that IM would increase when applying the first and second requirements compared to applying only the first requirement. Furthermore, analysis of CBV changes reveals statistically significant differences (Fig. 15(b)), suggesting the possibility of markedly increasing IM by applying the first and second requirements.

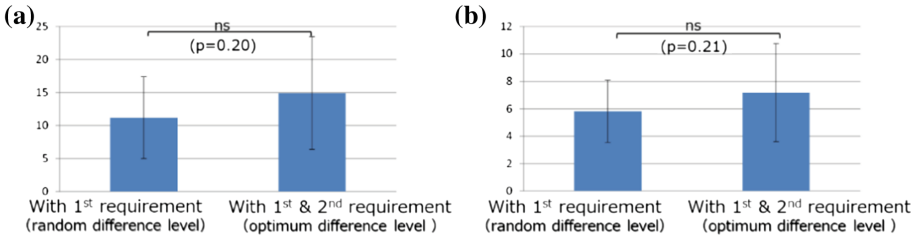

Fig. 14. (a) Average number of pages. (b) Average number of free sentences

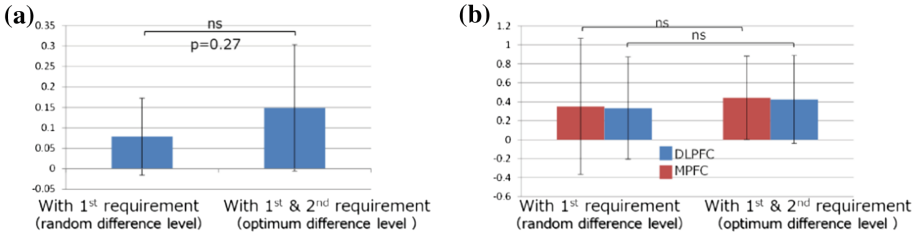

Fig. 15. (a) Blinking frequency. (b) CBV changes

4 Conclusion

In this research, we applied OSL theory as a way to maintain user IM and to promote IS sustainability in the ID for a non-objective IS. As a result, from the physio-psychological approach, it was found that, by designing the first and second requirements obtained from the experiment on the site, IM is maintained and the IS is sustained. As an application of this research to an actual situation, by acquiring personal characteristics such as the degree of user familiarity with various categories and providing a browsing environment in compliance with the requirements of the above ID, it seems possible to make an IS based on IM sustainably. This will lead to the creation of new opportunities to allow users to acquire information on products and services.

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