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# Mindless Memorization Booster: A Method to Influence Memorization Power Using Attention Induction Phenomena Caused by Visual Interface Modulation and Its Application to Memorization Support for English Vocabulary Learning

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**Abstract:** Memorization is necessary for various fields, such as language learning in the field of education. While memorization learning is often tedious and demotivating due to requiring conscious effort, few support approaches improve memorization unconsciously with low conscious effort. In this study, we propose a method, Mindless Memorization Booster, which improves users' memorization unconsciously by visual stimuli of modulating the visual interface. This method is based on previous findings that the modulation of perceptual stimuli arouses attention/concentration. When the user looks at the memorization target, the proposed method presents a change in visual interface (e.g., changes in memorization target size, background color, and visual icon movement) to cause a psychological phenomenon of affecting the user's attention and concentration, aiming at enhancing the memorization unconsciously. A prototype system of the proposed method was implemented for an English vocabulary memorization learning application. The evaluation results showed that the user's memorization result was affected by the proposed method, and the speed of recall (i.e., outputs of the memorization word from the brain) increased by about 1 s per one memorization word without causing a negative affection on the number of correct answers for memorization. This result indicated the feasibility of the proposed method for memorization learning support. Our findings are helpful for designing visual information interfaces that consider the phenomena affecting the user's memorization and promote memorization learning unconsciously.

**Keywords:** memorization; English vocabulary memorization learning; cognitive biases; psychological effect; visual interface; human-computer interaction; nudge; design implications; information presentation

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## 1. Introduction

The memorizing in this paper refers to the cognitive work that inputs the target to the brain (hereafter referred to as "inscription") and the cognitive work that outputs the target from the brain (hereafter referred to as "recall"). Memorization is necessary for various fields (e.g., education, sports, work, and general life). One of the most important themes is the memorization of vocabulary, which is necessary for language learning in the field of education. This is because memorizing a variety of vocabulary in language learning is essential for the development of various abilities (e.g., the ability to listen, receive information, speak, write, read, and study) [1] and communication skills (e.g., thinking, feeling, and expression) [2]. Many methods using information devices have been proposed to support the memorization work of language learning by using various elements (e.g., gamification [3,4], memory theory [5,6], and others [7,8]).

Since memorization work is often difficult and demotivating (e.g., learning vocabulary often demotivates [5]), it is difficult to maintain attention and concentration during memorization learning at all times. Therefore, it would be helpful if computers could help enhance users' attention and concentration with less user's conscious effort during memorization learning. On the other hand, recent HCI and UBICOMP studies have shown that it is effective for enhancing mind and body functions by using approaches using unconscious phenomena (e.g., cognitive biases, psychological effects, and illusions) caused by information presentation systems [9]. For example, previous studies showed sensor feedback systems that manipulate the mind and body by using psychological phenomena caused by the perception of self biological information, such as myoelectric sensor feedback systems to manipulate user's physical load [10] and heart rate sensor feedback systems to enhance user's mental arithmetic function and mental anxiety [11–13]. Although the change of such mind and body functions with one's own is inherently difficult for humans and requires the user's conscious effort and high skill, the approach using such unconscious phenomenon has been shown to be effective for various mind and body manipulation (e.g., behavior [14–17], sensory [9,18], performance of mind and body [19,20]). It would be beneficial if such an approach using unconscious phenomena could be available for memorization learning.

The research questions in this study are as follows. "*RQ*: Is the user's memorization unconsciously affected by the unconscious arousal of attention/concentration caused by the modulation of perceptual stimuli of information devices? In addition, this phenomenon can be intentionally manipulated to support memorization learning." We focused on the phenomenon in which a person's attention/concentration is aroused unconsciously by changes in external information. For example, attention and concentration are aroused toward objects moving in the field of vision [21]. In addition, modulating the learning video sound enables the user's concentration unconsciously to enhance (i.e., return to the learning video) when the user's concentration on watching the learning video decreases [22]. Based on these previous examples, we hypothesized that the user's memorization learning is enhanced by the enhancement of attention/concentration caused by modulating the perceptual stimuli of the information interface. Although this verification is assumed to provide important implications to the design and the users of support systems involving memorization learning, few studies have focused on this test.

Therefore, aiming to verify the above-mentioned RQ, we propose a method, Mindless Memorization Booster, that unconsciously enhances the user's memorization learning by the stimulus of modulating the visual interface. When the user looks at the memorization target, the proposed method presents a change in visual interface (e.g., changes in memorization target size, background color, and visual icon movement) to cause a psychological phenomenon that affects the user's attention and concentration, aiming at enhancing the memorization unconsciously. This method is based on previous findings that the modulation of perceptual stimuli arouses attention/concentration. We set up a memorization learning scene for English vocabulary and implemented a prototype system of the proposed method. The evaluation results showed that the user's memorization result was affected by the proposed method, and the speed of recall (i.e., outputs of the memorization word from the brain) increased by about 1 s per one memorization word without decreasing the number of correct answers for memorization. This showed that the proposed method has the potential to support memorization learning.

The main contributions of this paper are as follows:

- We introduced a method that unconsciously enhances the user's memorization learning by inducing attention and concentration that are caused by the visual stimulus of modulating visual interfaces.
- We implemented a prototype system for supporting vocabulary learning.
- The results showed the feasibility of the proposed method and design implications of this study's findings for information presentation systems.

## 2. Related Research

### 2.1. Methods to Support Memorization of Language Learning

Memorization in language learning is one of the important topics. The memorization of various vocabularies in language learning is necessary to develop various abilities (e.g., the ability to listen, receive information, speak, write, read, and study) [1]. In addition, the memorization of various vocabularies is necessary for thinking, feeling, and expression during communication [2], and a vocabulary of about 7000 words is required for effective communication [23]. There is also a report that vocabulary has the strongest effect on reading comprehension [24].

Many methods using information devices for language learning support, such as vocabulary learning, have been proposed. One of the popular methods is motivation improvement support. Learning is often dull. Boredom and reduced motivation for learning are caused by boring training in vocabulary learning (e.g., vocabulary recitation) [5]. In the learning support method using gamification to improve motivation, user's learning motivation and active learning are increased by incorporating ingenuity into the in-game process (e.g., cooperation, communication, and social interaction between learner groups) [4,25,26]. Gamification has also been used for English vocabulary learning [27,28]. There is a method that uses gamification and appropriate difficulty setting to support continuous learning [3] and a method that uses gamification and automatic speech recognition technology to support learning for English pronunciation [29]. Learning support methods using such gamification are often conducted with mobile and ubiquitous computers [4,30]. In addition, other methods use the theory of memory. For the effective support of vocabulary memorization, there is a method of presenting appropriate English words according to the vocabulary ability and memory cycle of each learner [5], a method for providing optimal learning scenarios for individuals based on measuring cognitive abilities involved in human language processes [31], and a method that presents appropriate words based on the forgetting curve of Ebbinghaus [6]. Using the ubiquitous learning environment, there is a method for learning English words based on learner information (e.g., location information, learning time, individual English language ability, and leisure time) [7] and a method that provides a systematic vocabulary learning process [32]. In addition, various other support methods have been proposed. There is a method to provide vocabulary lessons using SMS [33] and a method that predicts the user's confidence and anxiety in learning to improve learning efficiency [34]. There is also a method that automatically hides English words in captions in order to maintain an appropriate cognitive load for using videos of learning English [8] and a method to learn multiple vocabularies using one piece of an image by generating automatic captions for photos [35]. In the study using augmented reality, there is a method using gamification elements with AR [36,37] and a method that uses AR as multimedia placed in the real environment [38], although these are not for vocabulary learning. Other mobile applications for vocabulary learning have been proposed, such as a method for college students [39] , a method that uses concept mapping visualization [40] , and a method supporting learners' self-regulated learning [41]. In addition, effective methods of vocabulary learning through listening to songs [42] and in virtual environments [43] have been investigated.

Such learning environments using information devices are often used as educational technologies (e.g., learning using mobile devices [44]). Then, many examples show that the use of information devices is effective for learning. For example, online vocabulary learning was more effective than traditional learning environments [45], the use of mobile applications was effective for users with low grades [46], and learning motivation was enhanced by providing a self-evaluation environment using information devices [47]. These studies indicate that the learning environment using information devices has already become common and will expand in the future.

On the other hand, although many methods have been proposed for memorization learning, such as vocabulary, there are few studies on approaches that utilize unconscious phenomena to induce attention and concentration caused by information devices in the same way as in our study. The results of our study are expected to provide new knowledge for the learning support system.

### *2.2. Unconscious Phenomena Caused by Perceptual Stimuli*

Our proposed method uses visual stimuli that cause a change in the user's visual field. It is known that such changes in perceptual stimuli cause unconscious phenomena. Firstly, a person's attention/concentration is aroused due to changes in perceptual stimuli, such as the phenomenon in which attention and concentration are aroused toward objects moving in the field of vision and the phenomenon in which attention and concentration are aroused by something changing in visual or auditory information [21]. In addition, there is a method of changing the sound of the learning video when the user's attention is decreased to prevent the user's distracted behavior [22]. Secondly, there is a phenomenon in which the perceived elapsed time is changed due to changes in perceptual stimuli (e.g., amount and frequency of stimuli), which is called a fulfilled-duration illusion (FDI) [48]. For example, the perceived time becomes longer with more stimuli. This phenomenon is assumed to be due to a change in a person's attention or concentration. The fields of psychology reported that this phenomenon is caused by various perceptual stimuli (e.g., visual stimulus [49], auditory stimulus [50–52], and tactile stimulus [50]). In addition, many studies showed that these phenomena are intentionally caused by using stimuli of information devices, such as the visual stimulus (e.g., head-mounted display [53] and laptop display [54,55]), the auditory stimulus [18,56], and the tactile stimulus (e.g., wrist-worn devices [57]). Inspired by these previous studies, our study verifies the unconscious changes that occur in memorization tasks through phenomena caused by the change in perceptual stimuli on the information interfaces.

### *2.3. Information Interface Utilizing Unconscious Phenomena*

Our study supports memorization learning by manipulating unconscious phenomena caused by visual information interfaces. Like our study, many methods support users by using unconscious phenomena (e.g., illusions, psychological effects, and cognitive biases) caused by information devices. The necessity of studies investigating and manipulating such unconscious phenomena on information devices has been emphasized [9,58]. Such phenomena are difficult to prevent because they are assumed to be caused by an automatic mind of the dual-process theory [59,60] that causes unconscious, irrational, and subjective responses.

Several studies focused on attention and concentration. There is a method that enhances the user's attention toward learning videos by modulating the audio pitch of learning videos when the user's attention decreases [22]. Other examples are a work productivity log interface that highlights user's low productivity time [14], a clock that accelerates the passage of time [61], and timeline interface with various shapes showing the time remaining [62]. Several studies focused on the psychological effects caused by the perception of biometric sensor values. There us a method to present a different heart rate than the actual one to improve the user's cognitive performance and decrease the user's anxiety level [11–13] and a method that reduces physical and mental load by presenting false myoelectric sensor values that are larger or smaller than the actual measured values [10].

Studies on the psychological effects of facial expression perception include a method that induces positive emotions by presenting a pseudo-self-smile [63] and a method that improves the quality of collaborative work by modifying the other's facial expressions during video chatting [64]. Research on the psychological effects of voice include a method that changes the pitch of the self voice and others' voice to reduce the mental load in interpersonal situations [20].

Some studies focused on the psychological effects on motivation caused by perceiving competitive rivals. There is a step count log competition interface based on the psychology of competition (e.g., ranking that generates rivals who are close to the user's effort degree) [15] and a method that presents an environment to compete with ghosts having the user's future skill [65]. The psychological effects caused by the perception of other people's evaluations are also used to support dietary behavior change [66].

Some studies induced higher mental and physical performance in tense situations by a method that presents sound stimuli that are conditioned with the user's success experience based on Pavlov's classical conditioning [19] and a method that presents a pseudo-success experience in VR space [67]. Other examples include methods to control the amount of food consumed (e.g., change the size for meals [68] and change the appearance of the plate [9]) and a method to control the flow of tourists (e.g., route selection interface [69], ranking interface [17], and bus timetable interface to induce behavior to accept arriving early and waiting at the bus stop so as not to miss the bus [16]).

These previous studies showed that manipulating such phenomenon caused by information devices is effective for unconsciously changing the user's perception, mind and body, behaviors, etc. This study was inspired by these previous studies and also provides insights into the design of information interfaces that consider unconscious phenomena affecting user's memorization.

## 3. Proposed Method

This section describes the hypothesis of our study and the system to verify the hypothesis.

### *3.1. Hypothesis*

The research questions are described in Section 1. Figure 1 shows the flow of the phenomenon assumed in this study in the scene of vocabulary memorization of language learning.

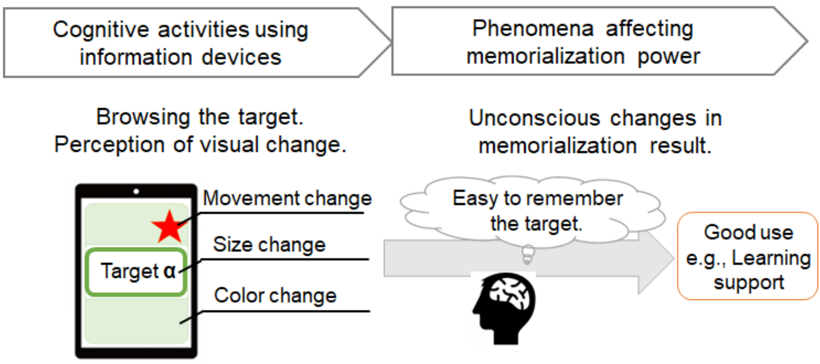


**Figure 1.** Hypothesis. Phenomenon of changes in memorization due to stimuli of modulating visual interface.

When the user looks at the memorization target, a visual stimulus (e.g., dynamic change of information in the visual field) is presented. This visual stimulus causes a psychological phenomenon that affects attention and concentration, resulting in an unconscious enhancement in memorization. This verification also leads to understanding whether the memorization is unconsciously affected unintentionally by the perceptual stimulus of the information device (e.g., the visual stimulus that enters the eye).

- (Case 1) This phenomenon does not exist. In this case, we can find that such a perceptual stimulus of the information device does not affect the memorization. We can also report that there is no concern that this phenomenon causes some bad situations for people.
- (Case 2) Although this phenomenon exists, it occurs with an unpredictable tendency. In this case, this phenomenon cannot be manipulated intentionally. For example, if a user's memorization randomly changes when a specific pattern of information is presented, it is not possible to manipulate this phenomenon. Therefore, it is necessary to discuss something to deal with such a problem (e.g., countermeasures, mechanisms, and user understanding).

- (Case 3) This phenomenon exists and occurs with a predictable tendency. In this case, this phenomenon can be intentionally used and suppressed. For example, if the user's memorization changes as predicted when a specific pattern of information is presented, this phenomenon can be intentionally manipulated. In this case, we can provide knowledge that is useful in designing information devices and applications that consider the phenomenon that affects the memorization.

### *3.2. Design of Mindless Memorization Booster*

This section describes a method for unconsciously improving the user's memorization learning by using the visual stimulus of the information screen. In this paper, we set up a scene to support memorization learning of English vocabulary. The reason for adopting this scene is that, as mentioned in Section 2, vocabulary learning on the screen of information devices is generally performed, and support for memorizing English vocabulary is an important topic in education.

#### Information Screen and Visual Stimulus

As shown in Figure 2A, the information screen consists of three components: memorization target, background, and visual icon. This information screen imitates a general vocabulary learning application screen and includes components that can exist in most information screens.

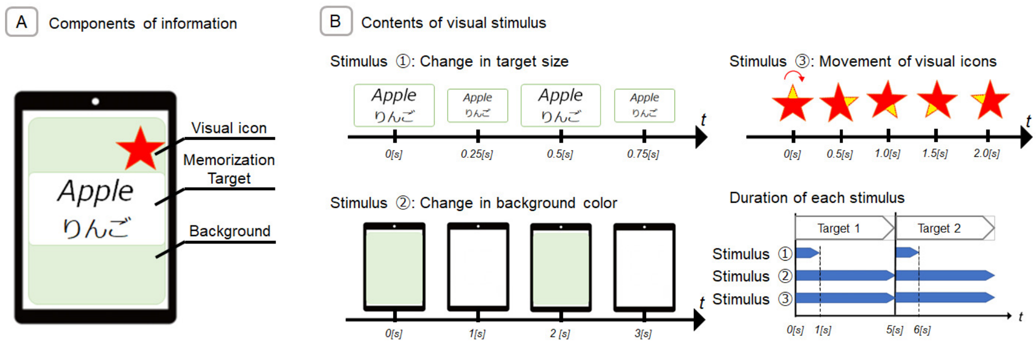


**Figure 2.** (**A**) Information screen design. (**B**) visual stimulus content.

The visual stimulus was designed to cause visual changes. The contents of the visual stimulus were three types shown in Figure 2B. The detailed explanations are as follows.

(1) Stimulus 1. Size change of memorization target: This stimulus is a change in the size of the memorization target that the user watches. The size of the memorization target in the center of the screen becomes smaller and larger repeatedly. The settings in the implementation are as follows. The size of the memorization target becomes smaller by 33% and returns to the original size. This change occurs twice in 1.0 s. Since it becomes difficult to read the memorization target if the size of the memorization target is constantly changed during all time, the duration of this change is set to the first 1 s of 5 s. This 5 s is the display time of one memorization target in our system.

(2) Stimulus 2. Background color change: This stimulus is a change in the color of the screen background. The background color changes repeatedly between red and white. The settings in the implementation are as follows. The background color changes from red to white in 0.5 s and changes from white to red in 0.5 s. The rate of this change was taken into consideration to prevent photosensitive epilepsy. This change occurs all the time during a memorization target is displayed. Thus, this stimulus occurs for 5 s, which is the display time of one memorization target in our system.

(3) Stimulus 3. Changes in visual icon movement: This stimulus is a change in the movement of the visual icon on the screen. The visual icon rotates at a fixed position. The settings in the implementation are as follows. The visual icon is star-shaped and rotates 360

degrees to the right once in 2.5 s. This change occurs all the time during a memorization target as the same as Stimulus 2.

The reasons for designing these visual stimuli to cause visual changes are as follows. The first reason is that changes in perceptual stimuli cause psychological phenomena related to attention/concentration [21,22] and perceived elapsed time [48,49]. We hypothesized that these phenomena induce cognitive and psychological states that enhance the memorization. The second reason is that it is assumed that different cognitive and psychological functions are affected through changes in another cognitive and psychological functions. One of the previous studies showed that the cognitive work of calculation is enhanced through the change of mental anxiety caused by a psychological phenomenon caused by a heartbeat sensor information presentation system. The third reason is that it is desirable that the proposed method to be verified this time can be applied universally on many information screens. The three elements adopted in this study can exist on any information screen.

### 3.3. Implementation

The memorization learning application consisted of two screens of a memory phase screen and an answer phase screen. Each was as follows.

Memory phase screen: The design and implementation of the memory phase screen is shown in Figure 3A. In Figure 3A of implementation, (1) is the target English words to be memorized and the corresponding Japanese, (2) is a visual icon, and (3) is a background. The reason for adopting Japanese is that this evaluation experiment was conducted with native speakers of Japanese. The display time for one memorization target was 5 s, and the screen for the memorization target changed automatically for every 5 s. This is because it was necessary for the evaluation experiment to set the viewing time of all memorization targets as the same time.

Answer phase screen: The design and implementation of the answer phase screen is shown in Figure 3B. After using the memory phase screen, this screen was used to answer. In Figure 3B of implementation, (1) is a memorization target with English words and (2) is the choice of the answer in four choices consisting of Japanese corresponding to the English word. After answering, the next button at the bottom of the screen is clicked to move to the next answer for the next English word. Since there is no time limit on the answer screen, users press the next button at any time.

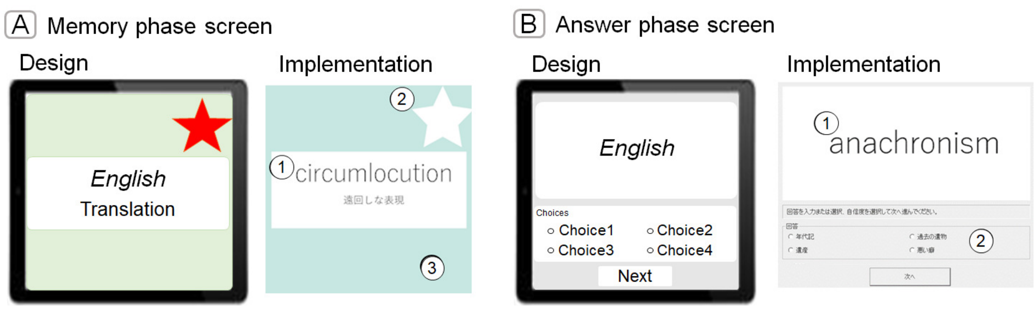


**Figure 3.** Memorization support application screen. (**A**) Memory phase screen. (**B**) Answer phase screen.

(Other) The order of execution of the memorization target on the memory phase screen and the answer phase screen is the same as shown in Figure 4.

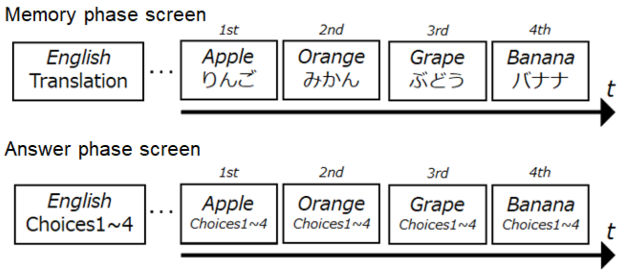


**Figure 4.** The order of the memorization target in each phase.

### *3.4. Indicator Related to the Efficiency of Memorization Learning*

In this study, we defined two important indicators for improving the efficiency of memorization learning: correct answer rate and answer speed. These mean the cognitive work that inputs the object to the brain (inscription) and the cognitive work that outputs the object from the brain (recall), which are components of the memorization.

A detailed explanation of the correct answer rate and answer speed is as follows. (1) Correct answer rate: This indicator is the rate of successful memorization of memorization targets (i.e., inscription). The value of this indicator increases with memorizing more targets. For example, if there are five targets to memorize, the correct answer rate becomes 60% by memorizing three targets. (2) Answer speed: This indicator is the speed from watching the memorization target to answering (i.e., recalling). This can be said to be the degree of ease in recalling the target to be memorized. The value of this indicator increases with faster answering of the meaning of the presented English word. Recall speed is an indicator related to learning efficiency. For example, when the recall speed slows down by from 0.5 to 1 s per one English word, it decreases the learning efficiency. The effect of recall speed on learning efficiency increases as the number of memorization targets increases with each passing day and year. In addition, the delay of recall speed causes trouble in situations where it is important to recall momentarily (e.g., conversation scenes and reading comprehension scenes).

This paper verifies whether these indicators change due to the stimulation of the proposed method. From the viewpoint of improving learning efficiency, at least one of these must become better. In addition, neither of them should become worse. Even if the correct answer rate improves, it cannot be said that the learning efficiency has improved if the answer speed slows down. Moreover, even if the answer speed is improved, it cannot be said that the learning efficiency is improved if the correct answer rate is reduced.

## 4. Evaluation

We evaluated the effect of the proposed method on memorization learning. A total of 20 subjects participated in this evaluation. They were an average age of 22.5, 16 males and 4 females, and Japanese university students in the Faculty of Information Engineering consisting of 16 fourth-year undergraduate students and 4 first-year master's students. Their first language was Japanese, their level of English was sufficient to pass the general Japanese university entrance examinations, and none of them had mastered English at a native level.

### *4.1. Conditions for Stimulus Presentation Rate*

Three conditions were prepared in which the presentation ratio of the stimulus was changed for the memorization targets. This was for verifying how much stimulus should be presented to have an effect. The outline is shown in Figure 5. The first was a non-stimulation condition in which all memorization targets were presented without the stimulus. This is a control condition. The second was a semi-stimulation condition, in which 50% of all memorization targets were presented with the stimulus. The stimulus enters the memorization target with even numbers (i.e., 2nd, 4th, and 6th). The third was a full-stimulation condition, in which all memorization targets were presented with the stimulus.

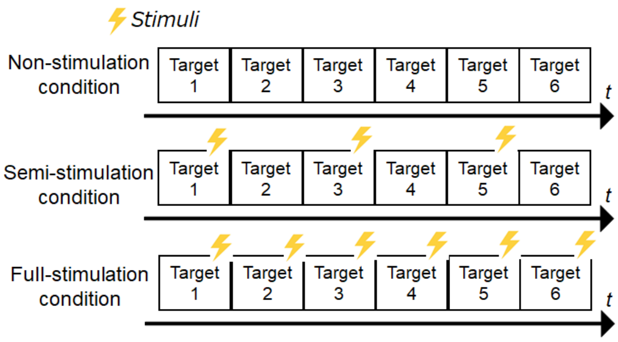


**Figure 5.** Conditions for stimulus presentation rate.

### *4.2. Experimental Tasks and Procedures*

One cycle of the experimental task consisted of two phases. The detailed explanation is as follows. (1) Memory phase. Subjects browse the memorization target using the memory phase screen. There were eight targets to memorize. Each memorization target was automatically changed every 5 s to make the viewing time of all targets the same. (2) Answer phase. Subjects answer the memorization target using the answer phase screen with four choices for every English word.

This one cycle was performed for each condition of the non-stimulation condition, the semi-stimulation condition, and the full-stimulation condition. The combination of the memorization targets and the stimulus was randomized for each subject. The execution order of each condition for stimulus presentation rate was randomized for each subject. There is a 3-minute break in each cycle. Although there were eight targets to memorize, the 1st and 8th memorization targets were omitted from the aggregated results because they were considered to be easy to memorize in terms of the beginning and the end. Thus, subjects answered six memorization targets in the answer phase.

We prepared the English words for memorization that were not taught at the subject's university, such as circumlocution, anachronism, connoisseur, anthropocentricity, jurisprudence, ophthalmologist, schizophrenia, and plenipotentiary. Synonyms were prepared for the dummy answer choices. For example, psychiatrist, pediatrician, and physician were dummy answer choices for ophthalmologist, which was the correct answer. There were two evaluation indications: the correct answer rate and the answer speed described in Section 3. The correct answer rate was the correct rate for the four-choice answers for every word. The answer speed was the speed until the next button to open the next page was pressed after the answer was inputted.

### *4.3. Results And Discussion*

Analysis of variance (ANOVA) and multiple comparison tests using LSD method was performed. The result of the answer speed is shown in Figure 6. Regarding the answer speed, the result of the analysis of variance was significant ($p < 0.05$). There was a significant difference between the full-stimulation condition and the non-stimulation condition ($p < 0.05$). The answer speed was faster in the full-stimulation condition compared to the non-stimulation condition. In addition, there was a significant difference between the semi-stimulation condition and the non-stimulation condition ($p < 0.05$). The answer speed was faster in the semi-stimulation condition compared to the non-stimulation condition. The result of the number of correct answers is shown in Figure 6. There is no significant difference among conditions.

The results show that the presentation of the stimulus affected the memorization task. The answer speed was significantly higher in the conditions with the stimulus than in the condition without the stimulus. This means that the ease of recall was enhanced (i.e., the time to output an answer was shortened). In addition, there was no significant difference in the correct answer rate between the conditions, which means that the phenomenon of misunderstanding (i.e., error) of memorization did not occur due to the presentation of the stimulus. These results indicate that the proposed method caused an unconscious change in the memorization task to support memorization learning. Regarding three conditions, the answer speed was significantly improved with the full-stimulation condition and the semi-stimulation condition. Therefore, if the ratio of stimulus presentation is about 50% or more, the same effect as this experiment seems to be produced. Since the answer speed increased and the correct answer did not increase, the proposed method does not have an adverse effect that increases the incorrect answer.

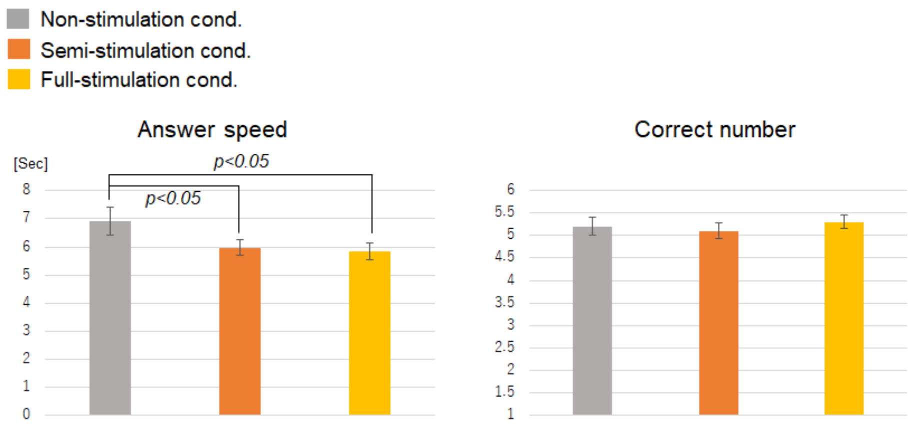


**Figure 6.** The average score of answer speed and correct number for each condition.

The reasons for the increased answer speed can be interpreted as follows. Firstly, there is a possibility that the proposed method aroused subjects' attention and concentration. Previous studies showed the phenomenon in which a person's attention/concentration is aroused unconsciously by changes and modulation in external information [21,22] as described in Section 1. In light of these previous findings, it can be interpreted that viewing a screen with the stimuli of modulation, rather than a monotonous screen with no stimuli, unconsciously aroused or maintained attention and concentration, resulting in an unconscious enhancement in commitment to the memorization task and stronger memorization. Secondly, there is a possibility that the proposed method induced the subjects to look at the memorization target carefully. Previous studies showed the phenomenon in which difficult-to-read fonts are more likely to be remembered [70], and this phenomenon can be interpreted that the ease of memorization can change by a mechanism that encourages the subject to look at the memorization object carefully and subconsciously. In light of these previous findings, modulating the visual screen may have worked well as such a mechanism.

## 5. General Discussion

Case 3 in Section 3 was accepted. The result of our study indicated that the visual stimuli of modulating the visual interface unconsciously affect a user's memorization task. Phenomena could occur in a predictable trend and could be manipulated intentionally. This result indicated the following two possibilities that contain implications for the design and use of information devices capable of presenting visual stimuli.

### *5.1. Approach That Uses Psychological Phenomena Caused by Information Devices for Enhancing Memorization Task*

The result of our study indicates that unconscious phenomena caused by the visual stimulus of modulating visual interface can be utilized as an approach to unconsciously enhance the cognitive work required for memorization tasks. It is difficult for almost all people to change their memorization ability through their conscious effort. However, such changes were caused unconsciously by using our method. It is also worth noting that the phenomena caused by our method occurred instantaneously and did not require any additional user preparation and user effort. Technology that can manipulate this phenomenon is assumed to be used to support activities containing memorization tasks. The implemented system in this paper can be used to support the memorization of vocabulary for language learning. The proposed method can also be available for different learning contents (e.g., mathematics, chemistry, and society) other than language learning. Other than for learning purposes, it is possible to support the comfort of life by enhancing the memorization in daily life. Examples other than for learning purposes include information on the person who communicated, daily fun events, and places where things are placed. The findings of our study can be helpful for the development of technologies that cause the change in the user's memorization for a good purpose.

### 5.2. Dark Side of Using Psychological Phenomena Affecting User's Memorization

This paper showed that the user's memorization is unconsciously affected by the perceptual stimulus from the information screen. The phenomenon of enhancing the memorization (i.e., easier to memory and recall) has no disadvantage to the user from the viewpoint of learning support. However, this phenomenon can also lead to the problematic induction of mind and thought. For example, if people become able to easily and unconsciously memorize or recall a particular product and person (e.g., a celebrity, politician, or partner on a romance matching site), there is a possibility that people unconsciously select a particular product and person in the context of important choices. In fact, one example of the availability heuristic of cognitive bias shows that people's judgment is affected by objects that are easily recalled. Such unconscious affections may occur accidentally (i.e., unexpectedly). Moreover, it may be caused intentionally (i.e., as expected) due to someone's malicious intent so as to benefit a particular country, organization, or individual. It is also assumed that the effects on the memorization in this study may occur with stimuli other than visual stimuli (e.g., auditory and tactile stimuli). Therefore, it is necessary to design and use the computer system as considering the possibility that the memorization is affected by stimuli. The following is an example of a countermeasure to check and prevent adverse effects on users. Users should understand and manage the changes that occur to them when they use the system. The system should check if groups of people using a particular system tend to memorize or select specific objects. The system should have a simple mechanism for testing and grasping such a user's change, and the simple mechanism should be used before using the system or at regular intervals (e.g., several months).

### 5.3. Limitations and Future Work

(1) Verification of phenomena caused by stimuli of different perceptual channels: We will verify whether the same phenomenon occurs with stimuli of different perceptual channels. Although this study used visual stimuli, similar phenomena may be caused by using stimuli of other perceptual channels, such as auditory and tactile ones. If a similar phenomenon can be manipulated in different perceptual channels, it is convenient because an appropriate perceptual channel can be used in a situation, where it is difficult to use a certain perceptual channel. (2) Verification for various subjects: This paper has a limitation to make the result generalization because the number of subjects was limited and the subjects were young university students. Therefore, we will verify various and many people to generalize our findings to wider attributes of people. On the other hand, we consider that our experiment also obtained the necessary verification results to understand and discuss our focused effect since the previous study [9,71] focusing on psychological phenomena of information presentation systems showed the necessary verification results with about 10 people. (3) Verification of activities to which the proposed method can be applied: we will verify whether the proposed method can be applied to the memorization of various learning domains and the memorization tasks of daily activities.

## 6. Conclusions

This paper proposed a method, "Mindless Memorization Booster", that unconsciously enhances the user's memorization learning by the visual stimulus of modulating visual interfaces. The proposed method presents a change in visual interface (e.g., changes in memorization target size, background color, and visual icon movement) to cause a psychological phenomenon that affects the user's attention and concentration, aiming at enhancing the memorization unconsciously. We set up a memorization learning scene for English vocabulary and implemented a prototype system of the proposed method. The evaluation results showed that the user's memorization result was affected by modulating visual interfaces and the speed of recall (i.e., outputs of the memorization word from the brain) increased by about 1 s per one memorization word without decreasing the number of correct answers for memorization. This indicated the feasibility of the proposed method to support memorization learning. We also discussed the possibility that the phenomena in this study can be used for good purposes or for bad purposes. Our findings are helpful for the development of visual information interfaces that consider the phenomena affecting the user's memorization.

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