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Abstract	Augmented reality (AR) has become extremely advanced, and AR is now applied in many fields, including advertising. However, it is still unclear whether AR technology is effective in advertising, especially in relation to customers' memories of products. Here, we investigate whether AR enhanced the memory of objects more than a movie or photo did. We conducted a psychological experiment in which participants viewed objects with AR, a movie, or a photo. Then, the participants judged their impressions of the presented objects. Finally, the participants took a memory test about the presented objects. The results showed that the memory performance related to the objects when using AR was significantly lower than the performance when using movies or photos. This result suggests that learning via AR impairs visual memory. This characteristic of AR should be considered when using AR, especially in applied fields.
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Learning via Augmented Reality Inhibits Visual Memory

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Augmented reality (AR) has become extremely advanced, and AR is now applied in many fields, including advertising. However, it is still unclear whether AR technology is effective in advertising, especially in relation to customers' memories of products. Here, we investigate whether AR enhanced the memory of objects more than a movie or photo did. We conducted a psychological experiment in which participants viewed objects with AR, a movie, or a photo. Then, the participants judged their impressions of the presented objects. Finally, the participants took a memory test about the presented objects. The results showed that the memory performance related to the objects when using AR was significantly lower than the performance when using movies or photos. This result suggests that learning via AR impairs visual memory. This characteristic of AR should be considered when using AR, especially in applied fields.

Introduction

Recently, augmented reality (AR) technology has become extremely advanced, and AR is now used in applied fields, such as advertising. In the advertising field, it is preferred that a product is well remembered by customers in order to enhance their purchase (e.g., Strong, 1925). Therefore, methods to enhance customers' memories of products have

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been investigated.

In cognitive psychology, there is the well-known *picture superiority effect* in which a picture is better memorized than a word (Paivio & Csapo, 1973). Based on this effect, pictures or photos are used to enhance customers' memories of products in advertisements (Sugitani, 2006). For example, catalog books are one of the materials developed based on this theory. In addition, if advertisers are trying to give as much information as they can to customers, they often use a movie rather than a photo. TV commercials and movies on web sites are examples of such attempts.

Following this line of study, AR is expected to enhance a customer's memory of a product more than a movie or photo. In AR content, the user controls how the objects are manipulated based on what s/he wants to see. Active viewing, in which a user can control an object as s/he wants, enhances the user's visual memory of the object more than passive viewing (e.g., Herman & Siegel, 1978; Larish & Andersen, 1995). Hence, AR should enhance the memory of products in advertisements. In addition, AR is able to provide information that a user wants to obtain. For example, when a user wants to know a specific detail about an object, s/he can look at that detail by manipulating the object in AR as long as s/he wants. This seems to be an efficient way to provide the information that users want to know because the information that a user does not want to know is not given. Therefore, this may lead to an increase in the amount of information actually presented to a customer. Moreover, AR provides better concentration for learning content (Bodekær et al., 2016), and better concentration enhances memory (e.g., Doerksen, Shimamura, 2000). For these reasons, AR is expected to be a better tool for advertising products when compared to movies and photos.

While the expectation to use AR is growing in the advertisement field, the assumptions of its usefulness have not yet been clear. Therefore, this assumption that AR enhances users' memories of objects is assessed in this study. In the current study, an object was presented using a photo,

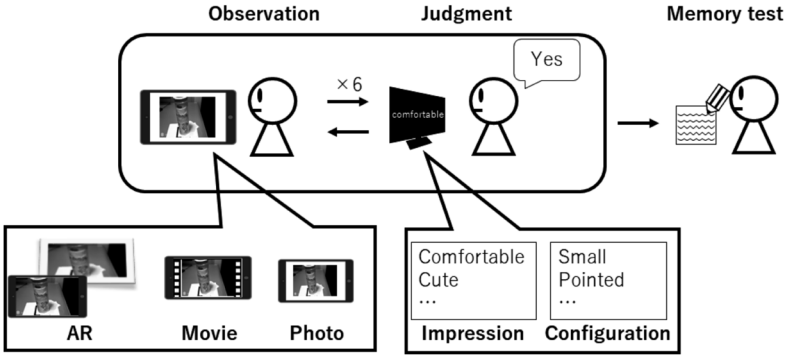

Fig. 1　Experimental Design

movie or AR (Fig. 1). Then, participants judged their impressions and configurations about the object. It has been reported that the memory required when one judges one's impression of an object is different from that when one judges one's configuration of it (Wells & Hryciw, 1984). Furthermore, both impressions of and knowledge about products (e.g., configuration) affect purchasing behaviors (Petty & Cacioppo, 1986). Therefore, two types of sentences, that is, about impressions and configurations, were prepared to assess the impact of the different types of memory in this study. Finally, the participants took a memory test. If AR enhances the user's memory of objects, the performance in the memory test for objects presented with AR should be better than the performance for objects presented with a movie or photo.

Experiment

Participants

Fifteen participants were recruited for this study (average＝20.7, *SD*＝1.4).

Stimulus

Six objects (clock, bag, drinking flask, tumbler, and keyboard) were

prepared for this study. Forty photos were taken of each object from 360° directions. Then, 3D objects were created from the photos using ReCap® (Autodesk). The 3D objects were presented in an AR application constructed by Unity® and Vuforia®. The AR application was run on an 8-inch tablet. For each 3D object, a movie was recorded in which the object was presented from 360° using the AR application. In addition, nine photos were prepared for each object. These photos were screenshots from the movie. The nine photos were taken from nine different angles for each object.

Procedure

All participants were engaged in both an impression task and a configuration task. The order of the impression task and the configuration task was counterbalanced between subjects. In both tasks, there were three conditions: the AR condition, movie condition, and photo condition. The order of the conditions was also counterbalanced between subjects.

In the impression and configuration tasks, participants were asked to judge whether the presented sentence applied to the presented object (two-alternative forced choice) by pressing a button after observing the objects for 1 minute. In the impression task, the presented sentences were about the participant's impression of the objects, whereas in the configuration task, the sentences were about the configuration or details of the objects. In the AR condition, the objects were presented via an AR application. Participants were able to manipulate the objects to observe them from any angle they wanted. In the movie condition, the objects were presented through the movie that was recorded in the AR condition conducted by another participant. In the photo condition, the objects were presented using the nine photos. In all conditions, the objects were presented for 1 minute. Different objects were presented for each condition. Therefore, three objects were presented for each task, and the total number of the presented objects for each participant was six. The combination of the object and the condition were counterbalanced.

After the impression and configuration tasks, participants engaged in a memory test. In the memory test, descriptions of the previously presented objects were provided to the participants. The participants judged whether the sentence about the objects that they had observed before was correct. Two sentences were prepared for each object; therefore, percipients answered twelve questions. Finally, participants were thanked and debriefed.

Results

Memory test

The number of participants with 0, 1, and 2 correct answers was counted and analyzed (Fig. 2). A chi-squared test was conducted for the rate of the number of correct answers. For the impression task, there was a marginally comparable rate of the number of correct answers among the groups [$\chi^2(2, N=15)=4.77$, $p<.10$, Cramer's $V=0.33$]. The proportion of participants in the AR condition giving two correct answers was significantly lower than that in the movie and photo conditions. For the configuration task, there was no comparable rate for the number of correct answers among the groups [$\chi^2(2, N=15)=4.19$, *n.s.*, Cramer's $V=0.22$].

Response time in the impression and configuration tasks

The response time for judgment in the impression and configuration tasks was calculated (Fig. 3). A one-way analysis of variance (ANOVA) was conducted on the response time using observation condition (AR, movie, and photo) as the within-subject factor for each task. For the impression task, there was a marginal main effect of observation condition ($F(2, 28)=2.50$, $p<.10$). There was a significant difference between the movie and photo conditions. For the configuration task, there was no main effect found ($F(2, 28)=0.29$, *n.s.*).

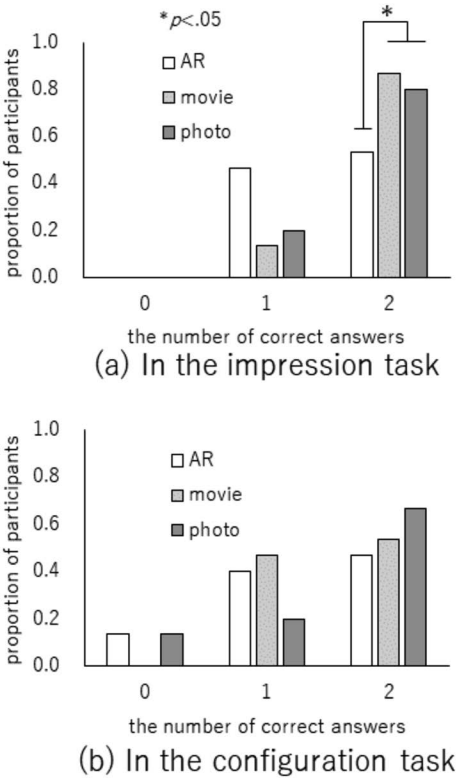

Fig. 2 The proportion of the number of participants in the memory test.

Discussion

The aim of this study was to assess whether the visual memory of an object presented by AR is enhanced when compared to the visual the memory of an object presented by a movie or photo. We found three important results.

First, it was not found that the performance of the memory test in the AR condition was superior to the performances in the movie or photo conditions. In fact, for the impression task, the proportion of par-

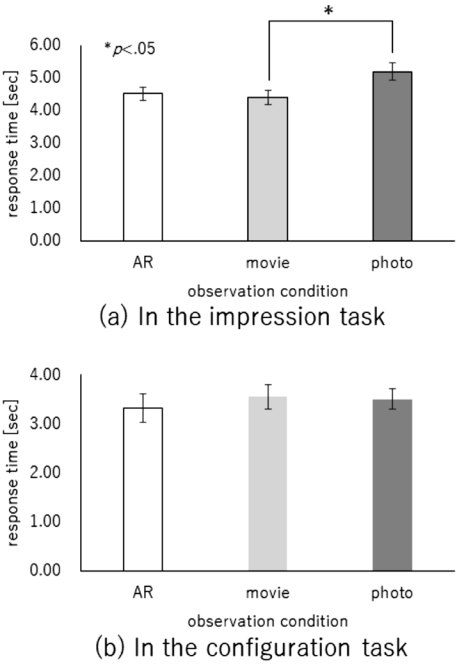

Fig. 3 The average response time in the impression and configuration tasks.

ticipants giving two correct answers (all answers were correct) in the AR condition was significantly lower than the same proportion in both the movie and the photo conditions. This result indicates that learning with AR impairs the user's object memory when compared to learning with movies or photos, especially when the impression of the object is recalled and judged. The movie presented in the movie condition was the exact same as the movie presented in the AR condition because the movie was recorded from the AR condition. Nonetheless, there was a significant difference between the AR condition and the movie condition. The experience in AR itself might require cognitive resources, and the resources assigned to the memorization of the objects might be reduced. The reduction of the cognitive resources assigned to memorization might induce the decrement of the performance of the memory test in

the AR condition. Hine and Tasaki (2019) showed that memory performance with active viewing in virtual reality (VR) harmed the memory of paintings compared to memory performance with passive viewing in VR. They argued that active viewing requires cognitive resources, and as a result, memory performance is decreased. In addition, Makransky et al. (2019) conducted an EEG experiment and found that VR experience required more cognitive resources than the experience of watching TV. AR, like VR, might be required for cognitive resources, and this might not be suitable for remembering objects.

Second, while there was a reduction in memory performance for the impression task with AR, there was no reduction for the configuration task with AR. In the current experiment, when the participants answered the question for the impression task, they might have integrated information about the object rather than paying attention to specific information because the presented sentences were impressions (Hine & Itoh, 2014). On the other hand, the participants might have paid attention to specific information for the configuration task because answering the question required them to recall details about the objects. This difference might have induced the differences in the results of the memory test. If so, AR might be disadvantaged for integrating information. When AR is used for advertisements, it should be used for remembering configurations of or details about products rather than for forming impressions.

Third, the response time in the movie condition was significantly faster than that in the photo condition for the impression task. This means that the participants judged their impressions of the object with the movie more quickly than with the photo. Regardless of the use of the movie or the photo, human constructs a 3D object via perception processing form 2D images (e.g., Marr, 1982). In this process, the movie might facilitate the construction of a 3D object. In particular, when the users judged their impressions of the objects, the constructed 3D object might have helped their judgment, and their response times were shorter than that in the photo condition. In further studies, the difference in

the impacts of movies and photos should be systematically investigated.

Recently, AR technology has become expected to be a new tool for leaning in applied fields such as advertising. AR is attractive, and this engages users' concentration on the object. The current study reveals that AR impaired participants' memories of the objects. To use AR technology more efficiently, the particular characteristics of AR should be considered, especially when AR is used in applied fields.

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