Relation between Location of Information Displayed by Augmented Reality and User's Memorization

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ABSTRACT

This study aims to investigate the effectiveness of Augmented Reality (AR) on user's memory skills when it is used as an information display method. By definition, AR is a technology which displays virtual images on the real world. These computer generated images naturally contain location information on the real world. It is also known that humans can easily memorize and remember information if this information is retained along with some locations on the real world. Thus, we hypothesize that displaying annotations by using AR may have better effects on the user's memory skill, if they are associated with the location of the target object on the real world rather than when connected with an unrelated location. A user study was conducted with 30 participants in order to verify our hypothesis. As a result, a significant difference was found between the situation when information was associated with the location of the target object on the real world and when it was connected with an unrelated location. In this paper, we present the test results and explain the verification based on the results.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation(e.g., HCI)**]: Multimedia Information Systems Artificial, augmented and virtual realities

; H.1.2 [**Models and Principles**]: User/Machine Systems Human factors

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General Terms

Human factors

Keywords

augmented reality, memorization, user study

1. INTRODUCTION

Augmented Reality (AR) systems present information by overlaying it on user's real world view. One of the most important merits of using AR is to display information as virtual images associated with specific location on the real world. A large body of literature exists that describe studies for measuring usefulness of AR for user activities support.

The usefulness derived from this feature include that AR systems can assist users effectively to understand the size, location and rotation of the object in the real world. Henderson et al. [1] described an AR system to support military mechanics conducting routine maintenance tasks by enhancing localization with overlaid labels and context-setting 2D and 3D graphics. Reitmayr et al. [2] described an AR system that dynamically creates CG annotation to support users to recognize locations of objects. Chastine et al. [3] presented the effectiveness of virtual pointer in collaborative augmented reality. These studies have attached a high value on user's visibility, but a considerable amount of uncertainty still exist as to other fields.

In this paper, we evaluate effectiveness of AR related to the user's memory skill. 'Memorization' means the action that is done to retain information in the user's brain after looking at objects (information). Computer generated images by AR naturally contain location information on the real world. It is also known that humans can easily memorize and remember information if this information is retained along with some locations on the real world [4]. Thus, we hypothesized that displaying annotations by using AR may have better effects on the user's memory skill, if they are associated with the location of the target object on the real world rather than when connected with an unrelated location. There are a number of systems which use AR as the display method of annotation associated with specific location to do 'context-sensitive help' in tasks like machine maintenance, object assembly and so on. Most of these supports are intended to be used by users doing unfamiliar tasks. Users can complete these tasks if AR support system can be used at all times. However, it should be desirable that users completely memorize and understand all tasks in the process. If the effectiveness of AR on user's memory skill can be proven, we could argue that these AR support systems are effective for displaying information as well as memorizing tasks and information related to them. In this paper, we present the results of the user study for evaluating effectiveness of AR information display methods on user's memory skill when they look at the differently displayed information.

2. RELATED WORK

Human memory process consists of three main phases. The phase when human tries to encode and memorize information is called 'Memorizing'. The phase when human retains information she or he memorized is called 'Retention' and the phase when human tries to bring back information she or he retains is called 'Recall'.

The feature of human memory that information associated with specific location is easily memorized, is well known. The main reason is that when humans perceive their surroundings by using vision and memorize specific objects in that specific surrounding, the surroundings of that object would also work as a clue when trying to recall the objects later on. When humans try to memorize an object, images of the surroundings are also unconsciously memorized. If its effect is strong enough, this memory is retained not as a semantic memory but as an episodic memory. Semantic memory refers to the memory of meanings, understandings, and other concept-based knowledge unrelated to specific experiences. Episodic memory is the memory of events (times, places, associated emotions, and other contextual knowledge) that can be explicitly stated. Episodic memory is known as the memory that can be more easily memorized and recalled than a semantic memory, which is one of the main reason of the fact that information associated with specific location is easily memorized. The usefulness of this feature can be proven by fact that 'the method of loci' is widely used as a memorization technique [5].

In the field of cognitive science, this feature is verified by the user study called 'object in place'. In 'object in place' test, the user is instructed to look at a test image which contains complicated surrounding and some objects and to memorize it. After that, the user is instructed to look at two answer images which contain a specific object from the test image, and to choose which image contains the same object. Comparing between the answer images with surrounding image and without (only an object), Hollingworth showed that participants could choose images more accurately when they see the answer image with the same surrounding as the test image [6]. It has also been confirmed that when a test is conducted where the user is instructed to look at different images with meaningless symbols in them as background and to search for a specific symbol from the images, user's response become faster if the same background is used [7]. This is not a memory test, however, as it's similar to 'object in place' in terms of using the fact that users unconsciously memorize background, which works as a clue to recall the memory.

If this feature would be applied to AR, we can assume that when the objects (information) are displayed on specific locations which contain some background images for users to see, they might recall the objects previously displayed by only seeing that same background. However no one has assessed that how effective changing display method is on the users' memory skill when AR system displays information near the object on the real world and users are instructed to see it. In this paper, our aim is to evaluate how effective changing of display methods is on the users' memory skill when users are imposed the task to memorize information displayed by AR.

3. USER STUDY

We present a user study to evaluate the effectiveness changing display method on users' memory skill. As mentioned above, one of the most important features of AR is that this technology can overlay a virtual object like 3D-CG model, on the real world three-dimensionally. Thus it would be desirable to conduct user studies in a 3D-experimental environment. However, in a 3D-experimental environment, view management problems would be much more complicated. We assumed it would be too difficult to only evaluate the effectiveness of different display methods. In order to simplify the situation, we limited the target of displayed information to a paper on the desk and conducted the user study in that situation for barometer of evaluating these effects.

3.1 Overview of System

Figure 1 shows the overview of the system for the user study.

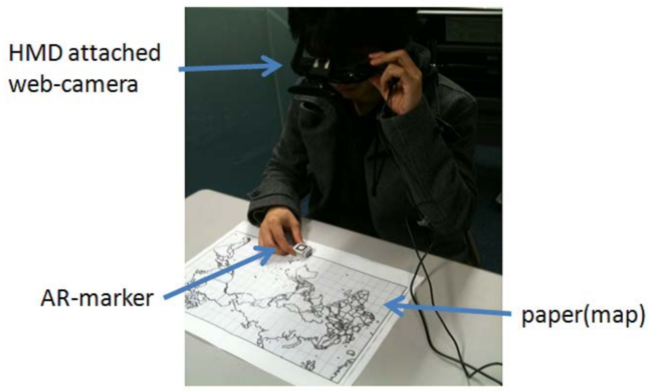


Figure 1: Overview of the system

The device for the user consisted of a Head Mounted Display (HMD, Video-See-Through type) equipped with a single web-camera. HMD provided 640×480 images at 30 frames per second and 32ĄŃ-field of view. Users wore the HMD and all of the information was displayed on that by using augmented reality. To conduct the user study, we created a system that displays specific information associated with each location when users do the following simple operation in each of the locations of the paper. A3 sized (297 mm×420 mm) map was used as the target on which information was put. Since feature points of the paper were extracted and learned in advance [8], it enabled the position and location recognition from the web-camera to the paper by capturing any part of the paper. In this user study, the users were frequently assumed to do the operations on top of the paper, part of the paper was assumed to become frequently occluded from the web-camera attached to the HMD. A prior learning method could maintain robust tracking in a similar situation, so it was decided to be used in this experiment. In the pilot study, five users used the system with this prior learning method and all commented that there is no tracking loss and they could concentrate on the tasks of the study.

CG points were displayed to 10 locations randomly chosen on the paper. When users put an AR marker (20 mm×20 mm) near the location of each CG point, information (symbol image) was displayed on the specific location for 7 seconds. Figure 2 shows view for user. User was instructed to memorize the symbol image itself and the location of the CG point associated with it while the symbol image was displayed. When each point was selected once by users, the color of that point was changed from blue to yellow. With it, the user could distinguish CG points which had not been selected yet from CG points which already had selected.

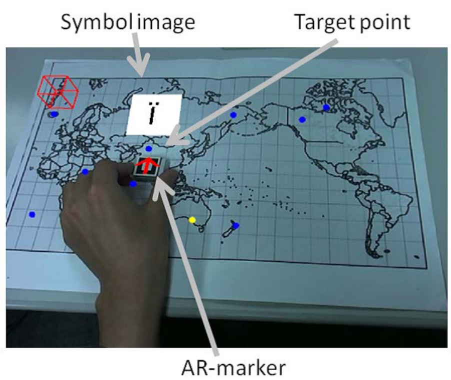


Figure 2: View for user

This system enabled displaying of information with three type of methods. We evaluated how they affected user's memory skills when these changing display methods. Various parameters of the study were refined during pilot user study with five users, as reported above.

3.2 Participants

We had a total of 35 participants in the study, 21 to 35 years old (average 24.3), 31 males and 4 females. All participants had regular memory skill. 18 reported they had the experience of using similar AR annotation systems and 17 reported they had no previous experience.

The research was piloted with five participants and was later conducted using 30 participants.

3.3 Conditions

Information Display Method

Displaying Information (Symbol Image) in the system was conducted by the following three types display methods.

Type 1: The information is displayed near the location of each CG point on the paper.
In this display method, the symbol images are displayed near the location of each associated CG point on the paper. This display method takes advantage of the AR feature which can associate information to a specific location on the real world.

Type 2: The information is displayed at random locations on the paper.
In this display method, the symbol images are displayed on locations randomly chosen from 50 locations which decided in advance without relation to locations of CG points. If the display locations chosen randomly were too near to the selected CG points (this threshold value was set 120 mm from the result of the pilot user study), reselecting the location was conducted to distinguish between Type 2 and Type 1 methods. It was not intended that users had to take time to look for the location on which symbol images were displayed each time. Thus CG lines connecting the symbol image and each CG point was also drawn to convey the position of each symbol image for the user as soon as possible.

Type 3: The information is displayed at the same location on the 2D display.
In this display method, AR is not used as the technology overlaying information on the real world. All symbol images are displayed at the same location on the 2D display without relation to each location of CG point.

Figure 3 shows these display methods. The difference in appearance of each display method is very little, as seen in Figure 3. Information presented to users was of course identical. In this user study, these three display methods were compared to evaluate the effectiveness of associating information to some locations on the real world on the user's memory skill.

Information Display Target

In this user study, the following two types of A3 maps were used as information display targets.

Type A: Normal World Map.

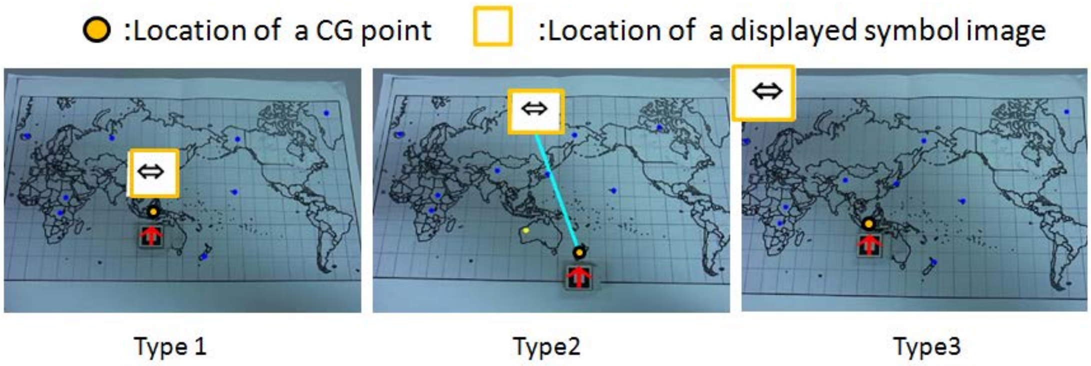
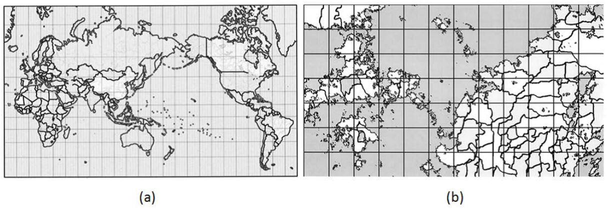


Figure 3: Display method

Type B: Map of Non-Existing Location.



(a)Type A: Normal World Map
(b)Type B: Map of Non-Existing Location

Figure 4: 2 Types of Maps as Information Display Targets

Figure 4 shows these maps. When information is displayed on the normal world map, we can assume two types of memorization methods as follows. In the first method, the user regards the world map as a 2D square and takes advantage of the relative positions of each CG point as well as where the CG points are located on the square. The second method is where the user takes advantage of his or her previous knowledge about countries on the world map. While second method might be effective, it was assumed to cause un-uniformity of results since each users' previous knowledge about the world map is not constant. Additionally, to obtain the pure effectiveness of associating dimensional positions of information with each location on the real world, a target map that the user could not memorize by using the second method, was necessary. Therefore a map of a non-existing location was also used. This user study evaluated the effectiveness of using different display targets on user's memory skill.

3.4 Experimental Design

We used a mixing-subjects design with two single independent variables (display methods and display targets). Display methods (Type 1, 2 and 3) were arranged in a within-subjects design and display targets (Type A and B) were arranged in a inter-subjects design. We recorded the accuracy rate and the answering time in each test. In addition, participants were instructed to evaluate the degree of memorization difficulty by keeping a score. The order of the display methods was completely balanced for all possible orderings, with each possible ordering traversed to remove the order effect. 15 participants were instructed to use Type A map and other were instructed to use Type B map.

Our hypotheses about the study's outcome were as follows. Since Type 1 displays symbol images near the location associated with each CG point, it was assumed users could memorize them as a 'single location-based image' including the background map image. We assumed that user can easily memorize and recall information in particular about the its location with the Type 1. Therefore we hypothesized H1 and H2.

H 1. In the test of symbol images, user will memorize information more accurately with display method Type 1 than Type 2 and 3.

H 2. In the test of locations of symbol images, user will memorize information much more accurately with display method Type 1 than Type 2 and 3.

Since the information was displayed at random locations on the paper with the Type 2 method, compared to other types where user could understand the location of displayed information in advance, more response time was assumed to be necessary to recall information. Therefore we hypothesized H3.

H 3. In the answering time of test, user will need more time with display method Type 2 than Type 1 and 3.

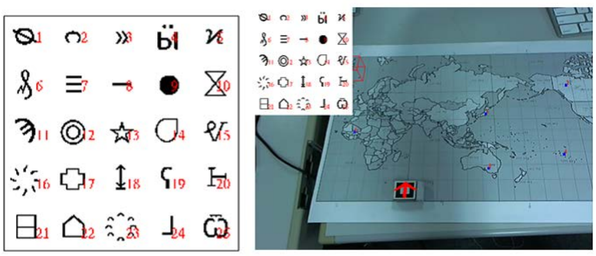
We assumed that while Type A would have positive effects on the memorization since users could take advantage of their previous knowledge of the world map with Type A (e.g. country names), this effectiveness would be weaker than the effectiveness of changing display method.

Thus we hypothesized H4.

H 4. User will memorize slightly more accurately and answer slightly more fast with display target Type A than Type B.

3.5 Experimental Procedure

At the beginning of the user study session, the study administrator explained how to use the system, experimental procedure and how to response in the test sessions to the participant. The administrator was careful to only explain the individual features about each display method and not to recommended any particular strategy. Next, the user was given the HMD and a three minute training session to get accustomed to the interface. When the administrator determined that the participant was familiar enough with the system, he or she was instructed to remove the HMD and take a break to concentrate on the experimental subjects. After this introduction part, the memorization test session started. 10 CG points were displayed on 10 locations of an A3 sized map of the real world. When the user put the AR marker near each of the CG points, the symbol images associated with each CG point in advance, were displayed. After a certain period of time, symbol images disappeared. During the displaying of symbol images, the user tried to memorize each symbol image and the location of the CG points associated with them as correctly as possible. In this study, the administrator did not give any instructions on how to memorize to the participant, instead leaving each participant to find their own way of memorization. After the memorization session, users were instructed to remove the HMD and wait for 30 seconds for the short-term memory of the session to fade a bit.



(a) (b)

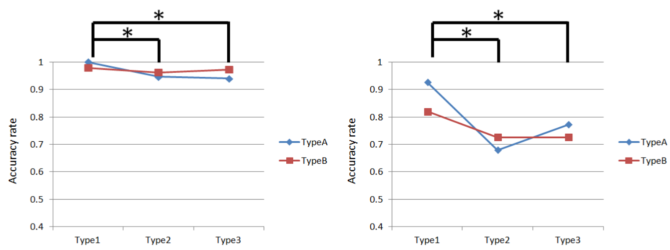
(a)Symbol Image Test chart (b)View of Location Test

Figure 5: View of two type test

After the short clearing session, the user was instructed to look at 25 numbered symbol image chart displayed on a PC monitor and was asked to answer which 10 images they had memorized (This was the 'Symbol Image Test'). Next, the user looked at the same 25 numbered symbol image chart, the 10 numbered CG points and the tests' map image displayed on the PC monitor and was instructed to associate each symbol image with each CG point in the correct order (This was the 'Location Test'). Figure 5 shows the views of the two test sessions for the participants. After each test, the user filled out a brief questionnaire asking about their memorizing methods and ease of memorization. These procedures were repeated for all of the three different display methods. As mentioned earlier, the order of the display methods was changed for each participant. After the last display method was completed, the participant was asked to fill out a questionnaire asking which display method would be the best and participate in a brief interview about their impressions on the user study.

4. RESULTS

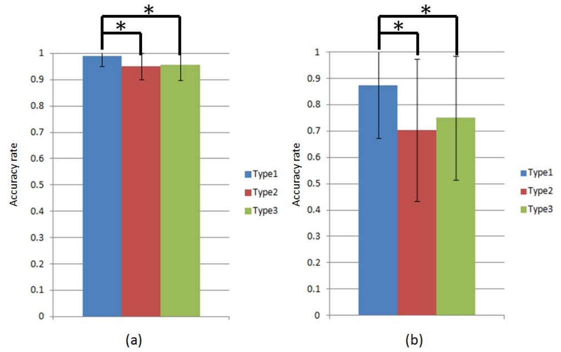
We did not find any significant difference in learning or in display order effects, which implies that the training session was adequate. Figure 6 shows the accuracy rate of test answers in each condition (each display method and target). Figure 6(a) shows the accuracy rate of users' answer in the Symbol Image Test and Figure 6(b) shows the accuracy rate of user's answer in the Location Test. With a ANOVA, we found significant effect between display methods on the accuracy rate of the answer in the Symbol Image Test ($F(2,56)=4.97$, $p<0.5$). Figure 7 shows the accuracy rate of the test answer in each display method. Using LSD method, it was found that users memorized symbol images more accurately with Type 1 than Type 2 and 3. With a ANOVA, we found significant effect between display methods on the accuracy rate of the answer in the Location Test ($F(2,56)=6.05$, $p<0.1$). Using LSD method, it was found that users memorized the locations significantly more accurately with Type 1 than Type 2 and 3. Thus hypothesis H1 and H2 were confirmed.



(a)The accuracy rate of the Symbol Image Test
(b)The accuracy rate of the Location Test

Figure 6: Accuracy rate comparison of all situations (three display methods and two display targets)

Figure 8 shows the answering time of the tests in each condition (each display method and display target). Answering time means the time that it took to complete all answers since the test session was started in each test. Figure 8(a) shows the answering time of the Symbol Image Test and Figure 8(b) shows the answering time of the Location Test. With a ANOVA, there was no significant effect between display methods on the answering time of the Symbol Image Test. With a ANOVA, we found a significant inclination between display methods on the answering time of the Location Test ($F(2,56)=2.58$, $p<.10$). Figure 9 shows the answering time of the tests in each display method. Using LSD method, it was found that user needed more time answering with Type 2 than Type 1. However the answering time had a large variance between individual users, so the result of

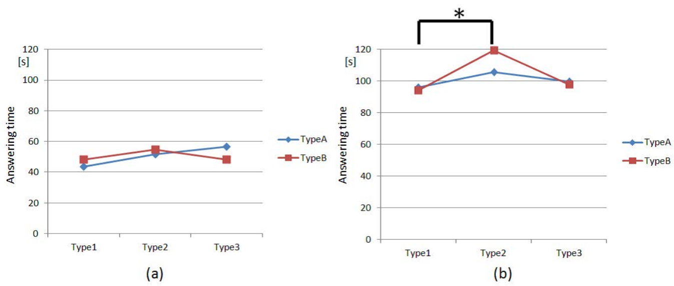


(a)The accuracy rate of the Symbol Image Test
(b)The accuracy rate of the Location Test

Figure 7: Accuracy rate comparison of the three display methods

ANOVA showed significant inclination only. Thus H3 could not be confirmed despite slightly shorter answering time in Location Tests with Type 1 than Type 2.

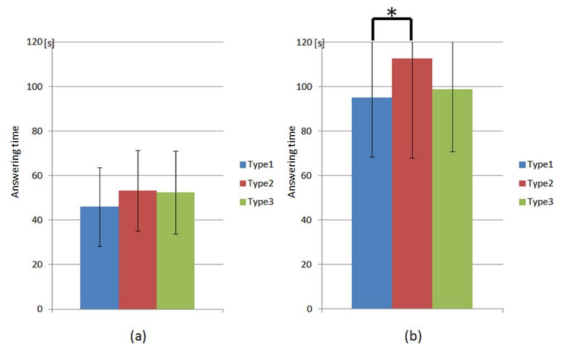
In addition, since we did not find any significant differences between the two target map results, hypothesis H4 was rejected.



(a)The answering time of the Symbol Image Test
(b)The answering time of the Location Test

Figure 8: Answering time comparison of all situations (three display methods and two display targets)

Figure 10 shows the scores for ease of memorization between each display method and target that users were instructed to rank (with easy=7, difficult=1). Figure 11 shows the division of scores which users ranked for each display method. Table 1 shows in which display method the users thought they got the best score (multiple answers allowed).



(a)The answering time of the Symbol Image Test
(b)The answering time of the Location Test

Figure 9: Answering time comparison of the three display methods

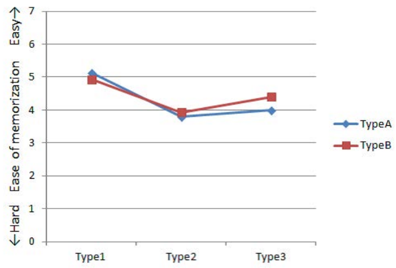


Figure 10: User responses from post-study questionnaire. Each score shows ease of memorization for each display method.

5. DISCUSSION

First, we discuss the hypothesis H4 in relevance to the display target. While we assumed that users could memorize information more accurately and recall faster with Type A than Type B due to their previous knowledge of the map (e.g. country names), there was no difference between two results. In the post-study questionnaire, only three participants used this previous knowledge. Since participants were not instructed on how to memorize information, memorization using previous knowledge should be considered not useful. Thus we can conclude that this factor did not affect the memorization results on the users' unconscious level at least.

Next, we discuss the hypothesis H1 in relevance to the display method. Since the Symbol Image Test was the test where participants freely chose 10 images which they memorized from 25 images, this test was similar to the recognition memory test where participants were instructed to answer whether they know specific objects or not [9]. This test was easier than other tests, so the results of each test in all display methods were very accurate and we found only slight difference with Type 1 and 2, and also between Type 1 and 3. In the post-study interview, many users confirmed their preference to Type 1 method with the following comment: "I could easily concentrate on the memorization task because

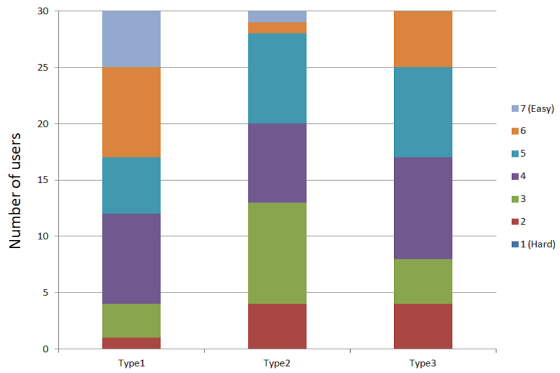


Figure 11: Number of each score which users ranked for each display method

Table 1: User responses from post-study questionnaire. "In which display method did you think you got the best score?" (multiple answers allowed)

	Type 1	Type 2	Type 3
number of users	20	8	10

I did not need to shift my attention away from the location of where the AR marker was already." Therefore, it can be considered that in the memorization task associating location of information with the target object in the real would be useful, because this would save the users' the trouble of shifting their focus away from the object to be memorized.

We discuss the hypothesis H2 in relevance to the display method. In the Location Test, answering order was randomly set and the accuracy rates of this test were much lower than in the Symbol Image Test. Type 1 method achieved a much better score in the accuracy rate than other display methods. In the post-study questionnaire, memorization method mainly seemed to consist of two types. One method was as follows. First, participants decided a starting point from the 10 CG points and the created a path for memorizing the other 10 symbol images associated with each CG point. After that, they memorized each symbol image using this predetermined path. When they tried to recall this information, they usually recalled each symbol images starting from the first one until they got to the requested symbol. The other memorization method was in which participants visualized a square of space in their mind and allocated each symbol image to each location of that square. In addition, some participants commented that they used both methods combined. With all memorization methods, the display method that showed information near the location of CG points, like in Type 1, achieved better scores than other display methods that showed information further away. As mentioned above, displayed information near the specific locations like Type 1 saved users' the trouble of shifting their attention. In addition to that, because users could memorize their target CG points and the symbol images as one, the accompanying background map image could be the clue which reminded the users of the symbol images as mentioned in section 2. This is a possible explanation for why Type 1 achieved the best score.

In the post-study questionnaires and interviews, many of the participants commented that they especially had difficulties memorizing the locations with Type 2. The reason for this might be that users had to have an 'extra step' to recognize where to next shift their focus from their current location, as they could not know the location of the next symbol image in advance. This makes us believe that displaying information on unrelated locations partly disturbs users' memorization task.

Next, we discuss the hypothesis H3 in relevance to the display methods. We could not find any significant differences in terms of answering time in the Symbol Image Test, but we found a significant inclination between Type A and Type B in terms of answering time in the Location Test. We did not explain that the answering time was also measured and the participants were not instructed to answer as soon as possible. Thus, how the users answered varied greatly and variance of the answering time was large within subjects. Therefore, while we can not conclude there is a significant difference among each of the display methods in terms of answering time, the general concept of displaying information near the target location in the real world might cut down the answering time in comparison with displaying information on an unrelated location, if we take into account above issue and instruct users on how to answer.

A well known fact is that while humans can answer whether he or she knows the object or not, much more time is needed to answer its related factors, which caused the large difference in answering time between the Symbol Image Test and the Location Test [9].

Finally, in the results of the questionnaire about which method was the best for the participants, many users ranked Type 2 lower than Type 1 and 3 (see Figure 11): "The display feature of Type 1 had more positive effects on the memorization of the locations than I expected". Very few users commented on being distracted by the display feature of Type 1: "because symbol images were displayed near each of the CG points in Type 1, I could not see the part of the background map during displaying of symbol information". As a whole, however, the results indicated that the users could memorize information most easily with Type 1.

As a result, we can conclude that displaying information associated with locations of specific objects can increase the amount of information which users can memorize at a certain period of time. For that, we indicate the following conclusion. When a location on which information has to be associated, is important, displaying information associated to that specific location on the real world by AR is useful in terms of memorizing it.

6. CONCLUSION

In this study, we hypothesized that displaying annotations by using AR may have better effects on the users' memory skills when it is associated with the location of the target object on the real world rather than when it is connected with an unrelated location and evaluated the hypothesis by conducting a user study. In the results, we could confirm that it is useful to display annotations (information) associated with specific locations by using AR when users tried to recall information previously displayed by looking at the location on which the information was displayed. We feel the results presented in this study are an important first step in understanding how systems using AR can affect user's memory skill.

However, since the system used in this user study was a simplified system compared to actually used systems to support user's task by AR, verification of the hypothesis was not adequate. Memorized information was restricted to meaningless images independent from each other in this study. The targets on which information was displayed on were restricted on locations on the target 2D paper. We plan to address these limitations in the future work and conduct a user study that supports users' memorization with AR when they are instructed to memorize a sequence of tasks as similar to real human tasks.

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