Applying Augmented Reality to Tourism Pamphlet and its Evaluation

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***Abstract*—Various studies have been undertaken to adapt Augmented Reality (AR) technology for use in real application. We see AR as being suitable for creating an enjoyable tourism pamphlet for users. In this study, we developed an AR tourism pamphlet and compared three types of different pamphlet (AR with map, AR-only and map-only). The results show that the combination of a map and AR performed better the traditional map pamphlet. By conducting an experiment where we measured the participants' brain activities, we confirmed that the burden on spatial cognizance and working memory, as well as throughout the rest of the brain, was reduced with the map-and-AR combination. We also confirmed that the combination drew interest far more than the map-only pamphlet. We believe this shows that the proposed pamphlet is overall a more natural form of information and, when compared with a traditional pamphlet, has the potential to be more enjoyable and less stressful for users.**

Keywords—Augmented Reality; Tourism; Pamphlet; Brain Activity; NIRStation

I. Introduction

A. Background

Augmented Reality (AR) technology has gained attention in recent years. AR is defined as an extended (or heightened) sense of realism. As its name implies, the technology is designed to extend (or intensify) the real world [1]. More specifically, it can show us a world containing a greater amount of content by layering digital information over the real world as seen through a computer or smartphone screen.

AR is divided into several categories [2]. First is marker-type AR, defined by a marker image that, when seen through the camera attached to a Personal Computer (PC) or similar device, interacts with the image to display digital data. In contrast, there is also marker-less-type AR, which detects specific shapes and colors in the camera image to display digital data without a marker. Both marker-type and marker-less-type AR use image recognition technology. There is also location-information-type AR, which uses the Global Positioning System (GPS) and sensors present in smartphones and similar devices to determine the specifics of the user's location in displaying digital information.

AR allows worlds that previously only existed in comics and animation to be actualized, a concept that excites us with its amusement and charm. Kobayashi [2] states that "Media like television, movies, comics and games are not used solely for the purposes of entertainment. Pleasure is, of course, a huge factor in these media, but it is possible to use that pleasure to our advantage to produce the experience of 'being educated while being entertained' (Edutainment) [3]. This point also applies to the new medium of AR." With this principle in mind, we conducted research with the expectation that the excitement experienced by users using AR would also be effective for a tourism pamphlet.

B. Past research

There have been various research works on the practical use of AR.

Kondo [4] states that one of the merits of composite reality (roughly equivalent to AR) is the ability to expand upon traditional teaching media such as textbooks. In addition, he developed three-dimensional computer graphics (3DCG) and audio explanations of the structure of the human brain. Materials useful for teaching mathematic spatial diagrams were developed and implemented in a high-school lesson. After the lesson, 70% of the students reported that it was easier to understand the content with the composite-reality technology.

Alzua-Sorzabal et al. [5] presented a usability study of a new prototype based on AR technologies. The observation-based study revealed the possibilities and limitations of the design of the prototype on the basis of the behavior of users. Most participants agreed that the approach of using AR technologies enhanced the interactive experience with tourist content. Moreover, they positively assessed the usefulness of the prototype as a tourist information point because of its ability to provide location-based content.

Teshima and Kosugi [6] reported tests using cartography teaching materials made by the researchers. The tests demonstrated that AR 3DCG displays were effective in cartography study. It was confirmed that AR teaching materials significantly raised test scores when it came to questions about target locations and names. The researchers reasoned that AR had a great effect on the learning of important components (i.e., the place and name memorization) of cartography.

Miyosawa et al. [7] states that AR is suitable for creating an enjoyable learning experience (i.e., edutainment) for students. They developed an AR application based on the same content as conventional printed teaching material in the field of foreign-language study. The learning efficacy of the two media was assessed by comparing the results of verification tests and monitoring brain activity during the learning process. There were no significant differences in test results between the two media. However, it was found that the subjects' brains were more active while studying the printed teaching materials than while studying the AR teaching materials. The researchers believed that this showed that the proposed method of study is overall a more natural one and, when compared with traditional methods of study, has the potential to be less stressful for students.

Despite the above studies, there has been insufficient research and discussion on the effectiveness of AR in other fields and on whether AR is suitable for highly specific fields.

C. *Objective of the Paper*

A standard tourism pamphlet is an item that contains pictures and information regarding sightseeing locations. In this paper, we conduct a subjective evaluation via a questionnaire about a tour pamphlet that employs AR, in terms of the information obtained about sightseeing locations, and perform a test to observe any trends in brain activity. From these test results, we determine the compatibility of AR with tourism pamphlets.

D. *Composition of the Paper*

The first section covers the background to the present study, existing challenges, past research, and the objective of the paper. The second section introduces the thought put into developing the AR tourism pamphlet, and the pamphlet's contents. The third section discusses the two tests conducted using the materials prepared in the second section, and the questionnaire results. The fourth section covers in further detail the results of each test performed in the third section. In the fifth section, we analyze the results obtained in the previous section. The sixth and final section presents our conclusion and discusses future research.

II. THE TOURISM PAMPHLET

A. *Development environment*

1) ARToolKit

ARToolKit [8] is a C/C++ programming language library that allows support of marker-style AR applications. Originally, the process of detecting a marker in the captured image and acquiring data about the position and orientation required a fair amount of technical knowledge, but ARToolKit turns that data into a simple black box around a marker. Its primary feature is to obtain the image from the camera, detect the marker through pattern recognition, calculate the position of the marker in three-dimensional (3D) space, and display the composite 3DCG as shown in Fig. 1, allowing us to create an application where the printed marker is read through a webcam and then overlaid with 3DCG. We were able to use markers and 3DCG that we had prepared. For this study, we created a tourism pamphlet using ARToolKit.

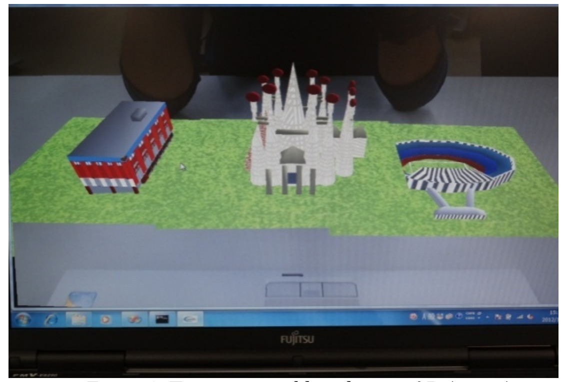

Figure 1. Tourism pamphlet adopting AR (image)

2) Metasequoia

Metasequoia [9] provides configuration materials for modeling and mapping. It is modeling software that allows 3D objects to be compiled in polygonal units. In our research, we used the free version of Metasequoia to create five 3DCG models, as seen in Fig. 2.

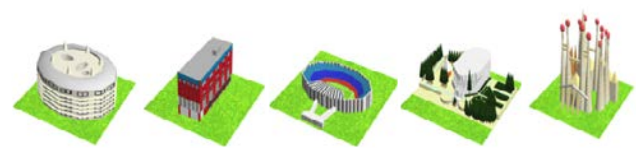

Figure 2. 3DCG objects created in Metasequoia

B. *Applying AR*

In our research, we developed a pamphlet that put AR to practical use. By paying attention to the pictures of sightseeing locations on the map and replacing the pictures with 3DCG, we expect that it is possible to better capture the viewer's interest.

C. *Developed Tourism Pamphlet*

We produced three different tourism pamphlets. Figure 3a shows the tourism pamphlet with map and AR, which provides information about sightseeing locations in Rome, Italy. Figure 3b shows the map-only tourism pamphlet, which provides information about sightseeing locations in Barcelona, Spain. Figure 3c shows the AR-only tourism pamphlet, which also provides information on attractions in Rome, Italy.

Figure 3. Pamphlets with a) map and AR, b) map only, and c) AR only

The AR-with-map and AR-only pamphlets display the prepared 3DCG over the marker on the PC screen when the marker is viewed through a webcam connected to a PC. The map-only pamphlet specifies the sightseeing location on the map with a picture alongside.

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Figure 4. Examples of the included information sheets.

The pamphlets introduced in Fig. 3 include information sheet on each location, as shown in Fig. 4.

III. EXPERIMENTS

We performed two experiments. Section 3.1 outlines the questionnaire for the first experiment using the pamphlet and information sheets. Section 3.2 details the second experiment in which brain activity was measured while the participants were given the pamphlets and informational sheets. Experiments 1 and 2 were carried out at the same time and for the same participants.

A. *Experiment 1: Questionnaire Results*

1) Experiment Objective

From the questionnaire results, we can examine whether the map with AR better conveys information and captures the interest of travelers than the traditional map-only pamphlet and AR-only pamphlet. The questionnaire results are used as indicators of the overall evaluation and points of possible improvement.

2) Participants

Nineteen students (20 to 24 years old) from the Tokyo University of Science, Suwa, participated in the experiment.

3) Materials

The materials used in the experiment were

a) the three tourism pamphlets (the AR+map tourism pamphlet, the map-only pamphlet, and the AR-only pamphlet),

b) the three information sheets (information corresponding to each of the three pamphlets),

c) a laptop equipped with a webcam, and

d) the questionnaire.

4) Experimental Method

Each participant took information from each pamphlet for 1 minute (i.e., a total of 3 minutes for the three pamphlets). The order of the pamphlets was changed for each participant to prevent any bias due to the order of presentation. The participants then filled out a questionnaire. We ran a training session for participants not familiar with AR.

5) Questionnaire Results

Four evaluation options were provided: “strongly agree”, “agree”, “disagree”, and “strongly disagree”. We chose four options to prevent a neutral answer. With each option respectively counting as four, three, two or one point, we used PASW Statistic (SPSS) to perform a statistical analysis. The significant variance using this software is below 5%.

Significant variations in results among pamphlets were found for the statements “It was easy to connect the name with the location”, “I was interested in the location”, “I want to visit the location”, and “I want to use the pamphlet again”.

The statements for the various pamphlets were compared using the Bonferroni method. This paper discusses only the significant variations that were observed.

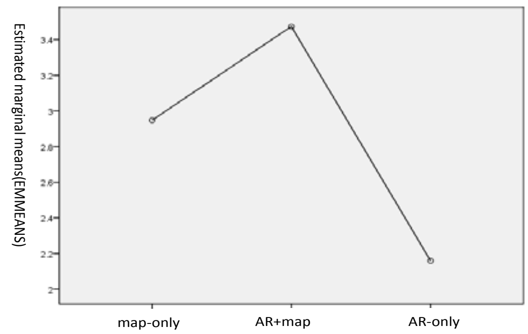

Figure 5. Was it easy to connect the name with the location?

For the statement regarding how easy it was to connect the name with the location, we observed significant variance between map-only and AR-only pamphlets and between AR+map and AR-only pamphlets. Figure 5 shows that the average ratings descended from best to worst in the order AR+map > map-only > AR-only. We can conclude from these results that the AR+map pamphlet was best able to connect the name with the location.

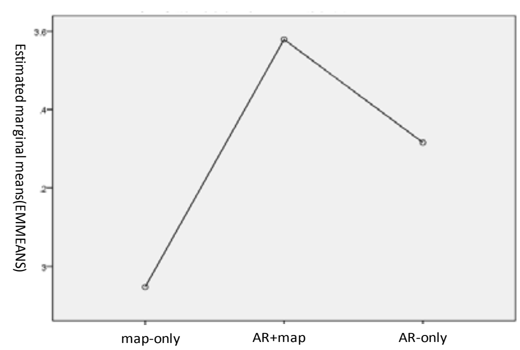

Figure 6. Were you interested in the location?

For the statement regarding interest about a location, we observed significant variance between map-only and AR+map pamphlets. Figure 6 shows that the average ratings descended from best to worst in the order AR+map > AR-only > map-only. We can conclude from these results that the AR+map pamphlet elicited the most interest in the participants.

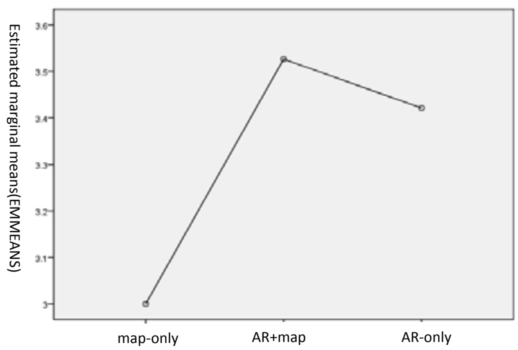

Figure 7. Did you want to visit the location?

For the statement regarding the participant's desire to visit a location, we observed significant variance between map-only and AR+map pamphlets. Figure 7 shows that the average ratings descended from best to worst in the order AR+map > AR-only > map-only. We can conclude from these results that the AR+map pamphlet elicited the most desire to visit a location.

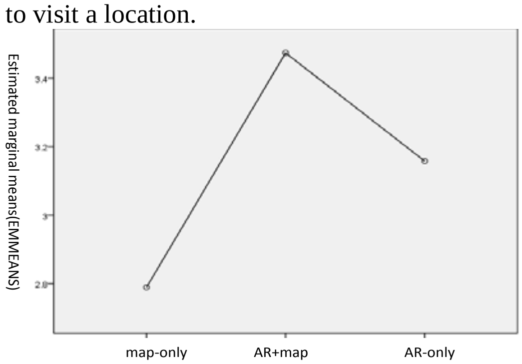

Figure 8. Do you want to use the pamphlet again?

For the statement regarding the participant's desire to use the pamphlet again, we observed significant variance between map-only and AR+map pamphlets. Figure 8 shows the average ratings descended from best to worst in the order AR+map > AR-only > map-only. We can conclude from these results that, of the three pamphlets, participants most wanted to use the AR+map pamphlet again.

By condensing these statements, we can argue several points.

(1) The statements "It was easy to connect the name with the location" and "The information about the tourist locations was easy to understand" were categorized as statements measuring ease of comprehension. In that category, the order of results was AR+map > map-only > AR-only. There is a high probability that the AR-only pamphlet received low valuations because participants were unfamiliar with managing the markers. We also postulate that the AR+map pamphlet was the most intuitive scheme in allowing participants to understand the location. We can conclude that the AR+map pamphlet was easiest to understand.

(2) The statements "I was interested in the location", "I want to visit the location" and "I want to use the pamphlet again" were classified as statements measuring interest. In that category, the order of results was AR+map > AR-only > map-only. We can conclude that the map-only pamphlet was insufficient for capturing the participants' interest as both AR+map and AR-only pamphlets received higher valuations.

B. *Experiment 2: Measuring Brain Activity*

1) Experiment Objective

By measuring the brain activity of participants as they take information from the AR+map, map-only and AR-only tourism pamphlets, we can investigate which parts of the brain are most active. We can also confirm which pamphlet was easiest to use through differences in brain activity of participants between each pamphlet.

2) Participants

We conducted the experiment with 19 students from the Tokyo University of Science, Suwa.

3) Materials

The materials used in the experiment were

a) the three tourism pamphlets (AR+map tourism pamphlet, the map-only pamphlet, and the AR-only pamphlet),

b) the three information sheets (information corresponding to each of the three pamphlets),

c) a laptop equipped with a webcam, and

d) a brain-activity measuring device (NIRStation, a multichannel near-infrared spectroscopy brain-activity measuring device).

As shown in Fig. 9, NIRStation measures changes in blood volume in the surface area of the cerebrum using optic fibers at the scalp to emit near-infrared light. Blood volume (oxyhemoglobin, oxy-Hb) is increased to send more oxygen to active parts of the brain. Near-infrared light enters 25–30 mm below the scalp and travels along the cerebral cortex and decays during a cycle of diffusion and absorption before returning in part to the scalp. From the light absorption levels and light path length in the oxy-Hb, we can detect changes in blood volume (indicating activity). As the equipment is non-invasive and unrestrictive for the wearer, it is possible to use the equipment in long and repeated measurements.

4) f-NIRStation Setup

As seen in Figs. 9 and 10, using the summits of the triangles formed by the eye sockets and auricles, the headgear follows the latitudes provided by the 10-20 system for brain activity between the 6ch and 11ch of the left brain, and between the 29ch and 34ch of the right brain, allowing for measurement of each channel. The number of channels in f-NIRStation was set to 44.

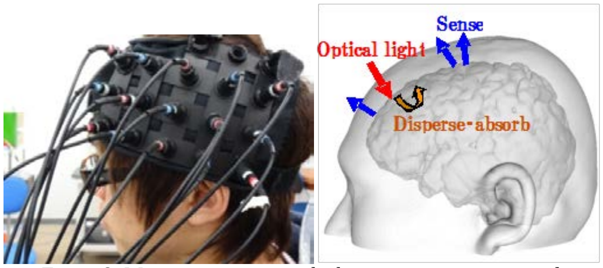

Figure 9. Measurements using the brain activity measuring device (NIRStation).

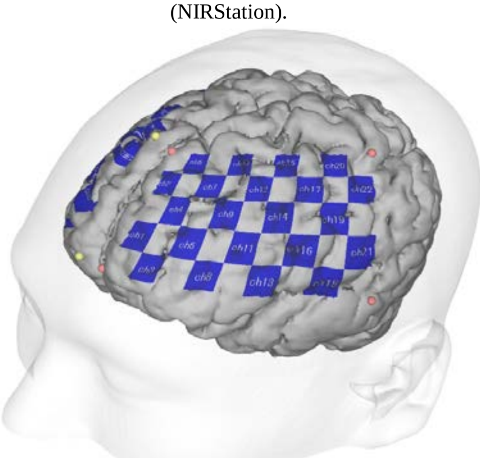

Figure 10. Corresponding brain position and channel numbers

5) Experimental Method

Brain activity was measured in the participants as they reviewed information in the tourism pamphlet for a duration of 1 minute. Before receiving the information, we established a 20-second rest (no action or thinking) period. This allowed us to determine the difference between the brain's activity during the rest period and during the task. The participants were given each pamphlet for 1 minute. The order of the pamphlets was changed for each participant to prevent order bias.

6) Process

Each participant was provided with a chart describing the process and a laptop with a Web camera for use with the AR+map pamphlet and AR-only pamphlet, with the AR application already prepared. For the map-only pamphlet, they were provided with only the pamphlet and the accompanying information sheet. Of the five sightseeing locations provided on each pamphlet, the participants were asked to select three. We had them repeat this three times for a total of nine places. We also provided information sheets about these locations.

IV. Brain Activity Measurement Results

A. Statistical Analysis of Brain Activity Measurement Results (Average Values)

With f-NIRStation, it is possible to output the brain activity values during rest compared with the values during the task as a t-statistic. Using these t-statistics, we can perform a statistical analysis using PASW Statistic. The percentage of significant variations is within 5%. The Bonferroni method was used simultaneously for multiple comparisons.

f-NIRStation outputs data for one experiment in 44 channels for each activity. Since the experiment was performed three times, there are three instances of data for all 44 channels for each participant. Using PASW Statistic, we were able to obtain the average value of all channels of brain activity for each of the map-only, AR-only and AR+map pamphlets and search for any significant variations between the three.

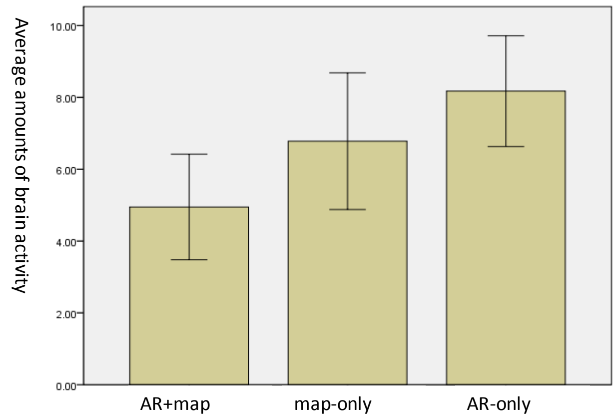

Figure 11. Differences in average brain activity between pamphlet types.

As a result, we were able to confirm significant variations between the types of pamphlet. The bar graph in Fig. 11 shows the average amounts of brain activity. The figure shows that there is significant variation in brain activity for the AR+map and AR-only pamphlets. The descending order of average brain activity is AR-only > map-only > AR+map.

When using the AR-only pamphlet, the brain activity increased. As there was no map, we conjecture that participants were required to carefully read the information sheets and to pay close attention to the sightseeing location. We can conclude that for purposes of stimulating the brain, the AR-only pamphlet is most suitable.

There was little brain activity for the AR+map pamphlet. We postulate that this is because the pamphlet can be reviewed in a passive manner. When one is passively performing an action, brain activity is less than that when one is actively performing an action. As the AR will display the sightseeing location in 3DCG, it seems that one can comprehend the pamphlet without reading the additional information. We can conclude that for the purposes of not over-stimulating the brain, the AR+map pamphlet is most suitable.

B. Considerations Regarding Brain Activity Measurement

Figure 12 displays the parts of the brain assigned to the channels of f-NIRStation, the brain activity measurement device used.

Sections 1 through 14 in Fig. 12 correspond to the following areas of the brain: ①left dorsolateral prefrontal cortex, ②left inferior frontal gyrus, ③left angular gyrus, ④ left superior frontal gyrus, ⑤left frontotemporal region, ⑥ left superior parietal lobule, ⑦left motor cortex, ⑧right dorsolateral prefrontal cortex, ⑨right inferior frontal gyrus, ⑩right angular gyrus,⑪right superior frontal gyrus, ⑫right frontotemporal region, ⑬right superior parietal lobule, ⑭ right motor cortex.

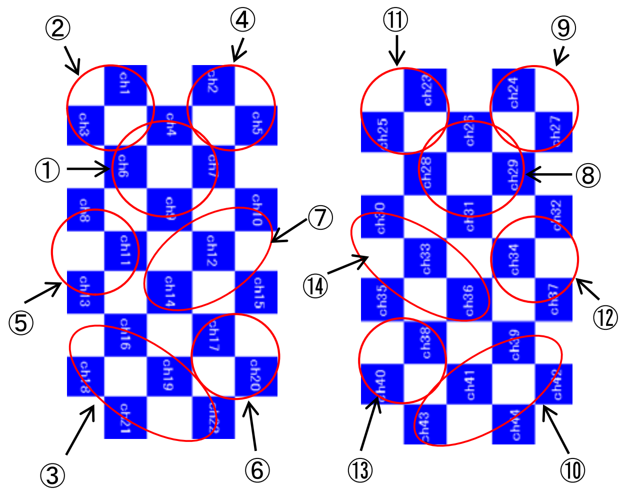

Figure 12. f-NIRStation's channels in relation to portions of the brain

Parts in which significant variance was observed are aggregated in Fig. 13. From left to right, each bar graph represents the results for the AR+map, map-only, and AR-only pamphlets. The bars display activity during the task as being in the plus-end, and at rest as being in the minus-end. The plus-ends of the graphs are proportionate to the amount of brain activity, while the minus-end is inversely proportionate.

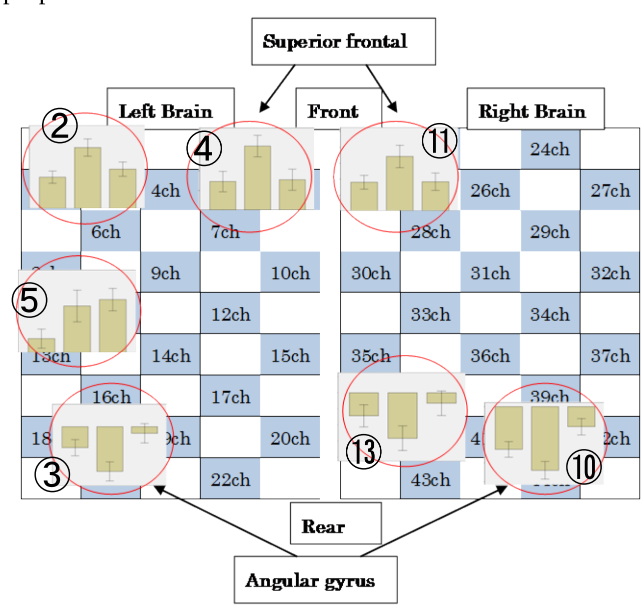

Figure 13. Areas in which significant variation was observed

As seen by looking at each part in Fig. 13, significant variances were detected in ⑩ the right angular gyrus, ⑬the right superior parietal lobule, ⑪ the right superior frontal gyrus, ③ the left angular gyrus, ② the left inferior frontal gyrus, ④ the left superior frontal gyrus, and ⑤ the left frontotemporal region; however, after employing the Bonferroni method, we discovered there were no significant variations between types of pamphlet in the right superior frontal gyrus.

1) The angular gyrus (③ and ⑩) is the parts of the brain responsible for language processing, particularly for figurative expressions and conjecturing [10]. When the parts of the brain are categorized, they are often grouped with the visual cortex. As seen in Fig. 13, the order of amount of activity descends in the order AR-only > AR with map > map-only. We postulate that with the AR-only pamphlet, the participants were able to confirm the contents of the information sheets using the 3DCG. Additionally, the AR allowed the participants to see the tourist locations before their own eyes and move around them freely. We believe it is possible that the AR gives the sensation that they are in fact in the place, rather than just viewing 3DCG on a screen. We believe it is for these reasons that the brain was more active for the AR-only pamphlet.

2) Significant variation was only detected in the right of the superior parietal lobules (⑬). The parietal lobe is the part of the brain responsible for somatic sensations related to spatial reasoning. The right parietal lobe is concerned with input. As seen in Fig. 13, the order of amount of activity in the right parietal lobe descends in the order AR-only > AR with map > map-only. This part of the brain inputs information related to deciphering the spatial image and location of the 3DCG from the AR-only pamphlet (the image appears in front of the eyes rather than one simply on top of a map). We postulate that the brain activity was low for the map-only pamphlet as one only had to read the information sheets, which required little input from the parietal lobe.

3) The left and right superior frontal gyrus (④ and ⑪) is part of the working memory [11] that deals with spatial cognizance and allows us to concentrate. As seen in Fig. 13, the order of the amount of activity in the superior frontal gyrus descends in the order map-only > AR-only > AR and map. As activity in this area was greatest for the map-only pamphlet, more concentration was required to closely read the supplied material as there was no 3DCG. We postulate that for that reason, the map-only pamphlet made the working memory more active.

4) Significant activity was detected only in the left frontotemporal region (⑤). The temporal lobe is responsible for understanding spoken language and grasping meaning and form. As seen in Fig. 13, the amount of activity descends in the order AR-only > map-only > AR and map, with the AR-only pamphlet inducing the most activity. We

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can postulate that by looking at computer graphics, our brain works harder at perceiving the form of an object. We believe that the activity was lowest for the AR+map pamphlet as the meaning and form of objects was easier to perceive and required less reasoning.

V. OVERALL CONSIDERATIONS

The objectives of this paper were to use AR with a map created by the researchers to examine any effect on interest of the observers in the field of tourism, to examine the compatibility of AR with tourism pamphlets, and to consider the effectiveness of AR with a typical tourism pamphlet.

We first performed an experiment using a questionnaire to obtain subjective opinions on the information received about sightseeing locations. It was found that ease of comprehension (based on differences in averages) descended in the order AR+map > map-only > AR-only. It is highly probable that the AR-only pamphlet had the lowest valuation because participants were unfamiliar with how to manipulate the pamphlet. It is believed that with the AR+map pamphlet, the locations of the sightseeing locations were conveyed in an intuitive manner. As such, the AR+map pamphlet was easiest to understand.

The interest in the locations (based on differences in averages) was found to descend in the order AR+map > AR-only > map-only. The map-only pamphlet failed in capturing interest when compared with the two pamphlets implementing AR.

We conducted another experiment to observe trends in brain activity and monitor any differences between the types of pamphlet. From the results, we can form the following conclusions for the combination of the map and AR.

1) In terms of spatial cognizance, combining AR with the map induced significantly less brain activity than using AR alone. We believe that this reduces stress on the brain.

2) In terms of working memory and grasping the significance/form of objects, a combination of AR and the map induced less brain activity than just one or the other alone.

3) The overall brain activity descended in the order AR-only > map-only > AR+map; this trend of brain activity applied to the whole brain.

From the above points, we see that the AR+map pamphlet created the least stress in inputting the significance and form of objects into the working memory, leading us to believe that the combination of AR and a map (when used to convey location information) is effective not just when applied to tour pamphlets.

VI. SUMMARY AND FUTURE PROSPECTS

We were able to grasp the features specific to each type of tourism pamphlet: one with a standard map, one with AR only, and one combining the map with AR.

We demonstrated that there was predominance particularly in the combination of the map and AR over the traditional map pamphlet. By conducting an experiment where we measured the participants' brain activities, we confirmed that the burden on spatial cognizance and working memory, and throughout the rest of the brain, was reduced with the map and AR combination. Additionally, we confirmed that the combination drew far more interest than the map-only pamphlet.

In previous practical studies of AR in foreign-language studies, the results for AR studies were much the same, demonstrating that AR allows for study with reduced stress. In our research, though we were able to demonstrate that combining map information and AR increased interest and reduced stress, there was much that we were unable to confirm, such as how long the information lasts in the mid-range memory.

We are also interested in the differences between AR devices, for example a PC, Smartphone and head mount display. The effectiveness of AR may depend on the device type. We are thus planning to conduct more studies in this realm of research.

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