# Evaluation of Information Presentation with Smartphone at History Museum by Eye Tracking

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**Abstract.** Our aim in this study was to evaluate the effect of information presented via smartphones on the behavior of visitors to a history museum and to propose appropriate website content for use with smartphones. We used eye-tracking data to analyze the behaviors of visitors. Of the 18 study participants, six were male and twelve were female. The participants wore head-mounted Eyemark Recorders (EMR-9, NAC Image Technology, Inc.) to view the exhibit. We recorded eye-tracking data for about an hour of the subjects' whole viewing time. The website content of the smartphones provided a series of four exhibit materials from which participants could obtain information. In the first part of the experiment, the participants viewed these four materials for about 10 min. Then, they viewed about a thousand exhibit materials at their own pace. The viewing times ranged from about 40 to 60 min. We analyzed the eye-tracking data from three perspectives: (1) object gaze time, (2) whether or not the participant was using the smartphone, and (3) the effect of the website content. There was no significant difference between the gaze times of exhibit materials and explanatory board with or without smartphone information presentation. This suggests the potential for smartphone information presentation in exhibits having a large amount of information to be presented as well as for exhibit materials such as those found in history museums. Based on our results, we see potential for increasing interest in material content by inducing visitors to view exhibit materials.

**Keywords:** QR code · NFC tag · History museum · Web content · Smartphone · Eye-tracking data · Behavior analysis of museum visitor

## 1 Introduction

With the ongoing development of information technology, museum exhibits now also feature displays of pictures and images on tablets or on museum materials and the presentation of interactive explanations by touch-screen technology [1]. In addition, some museums display exhibit descriptions on smartphones and at multifunctional terminals, using QR codes and IC tags as input [2]. Others utilize the latest information-expression technologies such as virtual reality, augmented reality, and projection mapping [3].


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We have found few studies in the literature that have evaluated how these technologies affect the behavior of museum visitors. To evaluate a museum's exhibit plan, museums have long conducted analyses of visitor behavior. The general method is to analyze observations of visitor behavior, the time spent viewing exhibits, and viewing flow lines [4, 5]. The results of these analyzes are useful for planning layouts of display shelves and materials in display cases. However, they are not suitable for detailed analyses regarding which material in an exhibit case is receiving the most attention, which materials are looked at for longer periods of time, and so on. For this type of detailed analysis, tracking the gazes of visitors can be useful [6].

In this research, we analyze the effectiveness of providing explanations of displayed materials on smartphones or multifunctional terminals in changing visitor behavior in history museums. The purpose of the evaluation is to determine whether the content of the displayed explanation affects the visitors' "observing exhibit materials" behavior. Based on the results, we determine whether it is possible to promote "viewing the exhibit" actions by providing exhibit explanations on smartphones or multifunctional terminals at historical museums. Furthermore, we consider the potential of content to effectively promote "viewing the exhibit." First, we measured the gaze time of visitors standing in front of exhibits. Then we determined whether and for how long they gazed at the "smartphone," "explanatory board with text information," and "exhibit materials."

## 2 Experiment Outline

Of the 18 participants in our study, six were male and twelve were female. The study target exhibit was a permanent exhibit of the Nagoya City Museum which houses roughly a thousand historical items.

As shown in Fig. 1(a), while viewing the exhibit, participants wore head-mounted Eye Mark Recorders (EMR-9, NAC Image Technology, Inc.). We recorded eye-tracking data for about an hour during the participants' entire viewing time.

**(a)** **(b)**

**Fig. 1.** Image of measurement

There were four exhibit materials for which participants could obtain information via the website content of their smartphones. In the first part of the experiment, the participants viewed these four materials for about 10 min. Afterwards, they viewed the entire exhibit at their own pace. The total participant viewing time was between 40 and 60 min. We described the experiment to the participants before they entered the exhibit and did not accompany the participants.

The EMR-9 device records the direction of the participant's head with a view camera, and uses an eyeball camera to record the eye position indicating where the participant is looking in the field of view, known as the eye mark. By superimposing the eye mark on the visual-field video, we can analyze the participant's line of sight. In this experiment, the view camera used a lens viewing angle of 62° and detected the eye mark with its binocular eyeball camera.

## 2.1 Measurement of Gaze at Exhibit While Utilizing Smartphone Information Presentation

We selected the content of four exhibit materials to be presented on smartphones and prepared one web page for each of the four exhibit materials. These four materials had a common "animal" theme. The selection of a common theme made it is easier to compare and draw interest to the exhibit materials. Figure 2 shows a view of the layout of these materials.

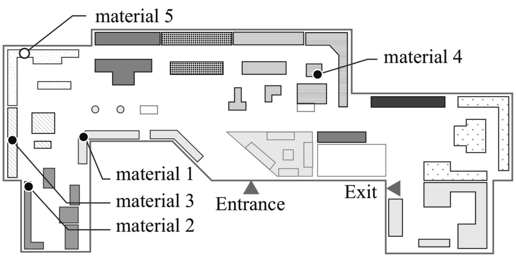


**Fig. 2.** Schematic map of the target museum and layout of materials 1 to 5.

We prepared two types of Web contents. The first one was "to show gaze points and induce positive viewing of the exhibit." The other was "to show only objective information such as attributes and eras, and positive viewing of the exhibit is not induced." The contents for materials 1 and 4 had the former characteristics and the contents for materials 2 and 3 had the latter characteristics.

Web content can acquire URLs from QR codes and NFC tags. We set the QR code and NFC tag on the reading table, as shown in Fig. 1(b), and located it near the exhibit materials.

The participant was instructed to view these four materials in the order of 1 to 4 while referring to information on the smartphone. In addition to the materials targeted by the Web content, the participant was free to read exhibit materials in the vicinity and any related explanatory panels.

### 2.2 Measurement of Gaze During Normal Viewing

After measuring participant gaze while they were using the smartphone, we measured the freely viewed gazes of participants throughout the whole exhibit. The 18 participants viewed the exhibit in about 40 to 60 min at their own paces.

For the time analysis, our target was material 5 (Fig. 2), for which it was easy to determine the participant's gaze because there was sufficient distance from the surrounding material.

## 3 Analysis Method

Of the 18 measurement data, 8 data included one male and seven females with high eye mark detection accuracy were selected and analyzed. Gaze time series was detected by the d-factory, which is the software for image processing of eye tracking movie. The statistical parameter calculated from the gaze time series were analyzed. Furthermore, participants' behavior analysis was performed using view camera image, while recorded the video camera wearing the participant.

### 3.1 Gaze Time Calculation Method

Here, we define "gaze time" as the "duration of the state of gazing to obtain detailed information." We describe the judgment criteria for this state in Sect. 3.2 below. In d-Factory videos, eye marks are superimposed on the visual-field video recorded by the EMP-9. While watching the video, we tag gaze items such as "sp (to indicate smartphone)" in every 2/60 sec frame and thereby generate a gazing time series.

### 3.2 Criteria for Judging the Gazing State to Obtain Detailed Information

We know that there are two search states in the gazing process, known as "diffusion search" and "specific search" [7]. In this analysis, we paid particular attention to the "state in which detailed information is obtained," which corresponds to "specific search."

When utilizing gaze detection, to identify the materials and interests toward which the participants direct their searches, we used a method for detecting the gazing and fixation points based on the characteristics of the eye movements [8].

Based on these characteristic eye movements, we acquired visual information from the point on which the line of sight rested.

Therefore, to detect "the state of obtaining detailed information," we must discriminate between the eye movement fixations.

To define the range of eye movement fixations, we use the two elements of time and distance. As a feature of the duration of eye fixation during the specific search activity of painting appreciation, the retention of a participant's gaze is reported to most often tend to have an eye fixation duration of 300 ms [7].

In this analysis, we defined the staying times of eye marks of 300 ms or more as "fixations in eye movement." In addition, to obtain detailed and clear information, we recorded participants visually examining many images from which we judged their states of gazing, and found the variations of their lines of sight to be within about $80 \times 80$ [pixel] on field images of $640 \times 480$ [pixel]. Hence, when this condition was satisfied, we defined "fixations in eye movement" to have occurred. When tagging gazed items, we used a visual observer to judge whether this occurred within about $80 \times 80$ [pixel] or less.

However, in this experiment, there were three gaze items categorized as "the state of obtaining detailed information." In Sect. 3.3, we describe our judgment criteria for "the state of obtaining detailed information".

### 3.3 Gaze Items

Figure 3 indicates a typical participant's gaze behavior, including "gazing at smartphone (sp)," "getting information from explanatory board with text information (read)," "gazing at the exhibit materials (material)," "movement of line of sight (jump)," "search for gaze target (search)," and so on. Of these, "sp," "read," and "material" are gazing objects categorized as states of obtaining detailed information.

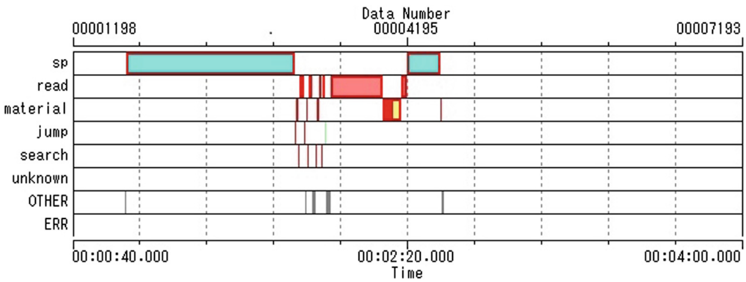


**Fig. 3.** Pattern diagram of viewing exhibit

The gaze item "sp" indicates the state of gazing at the smartphone, when the eye mark has remained there for more than 300 ms. "Read" indicates the state in which information is obtained from an explanation board on which there is text information, when the "lateral direction movement" of the eye mark follows a character from left to right for more than 300 ms. "Material" indicates the state of gazing at the exhibit materials when the line of sight remains within the range of $80 \times 80$ [pixel] at the exhibit material or its vicinity and the dwell time is 300 ms or more.

### 3.4 Regarding the Analysis of Participant's Behavior

The web page content for materials 1 and 4 have the characteristic "show gaze points and induce positive viewing of the exhibit." The web page content of materials 2 and 3 have the characteristic "show only objective information such as attributes and eras and no positive viewing of the exhibit is induced." Specifically, the content for material 1 states that "there is a dog's bone near the chest of the skeleton" and reference 4 states that "it is for warming the hand and there is a hole at the back." We conducted a behavior analysis in response to this material 1 text using the index "Were there any participant behaviors of gazing at the chest part of the human bones?"

With respect to material 4, we performed a behavior analysis with the index "Were there gazing behaviors from other than the front, such as going around and behind the material or looking into the back of the material?"

## 4 Results

We analyzed eye-tracking data from three perspectives: (1) object gaze time, (2) whether or not the smartphone was used, and (3) the effect of the website content.

### 4.1 Results Regarding the Proportions of Gaze Times of "Sp," "Read," "Material" of Entire Gaze Time When Viewing Exhibit with Reference to a Smartphone

From Fig. 4, we can see that for cases where participants viewed exhibits while referring to a smartphone, the proportion of time spent looking at the smartphones was the greatest at around 70%. In addition, the average percentage of gaze time for the state in which participants obtained information from the explanation board with text information was 14%, and the average of the gaze time for the state of gazing at the exhibit materials was about 14%, which is almost the same rate.

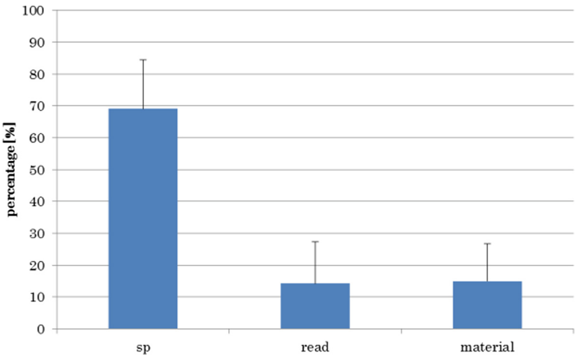


**Fig. 4.** Percentages of gaze times of "sp", "read", and "material" with respect to the entire gaze time for materials 1 to 4.

### 4.2 Comparisons of Whether or not Smartphones Were Used

Figure 5 shows a graph comparing the absolute gaze times of "read" and "material" with and without the use of a smartphone. We analyzed the difference between them

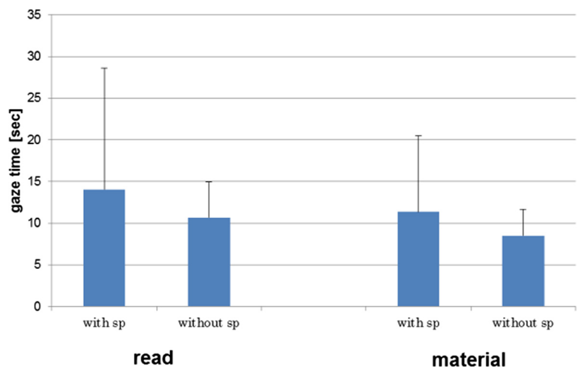


**Fig. 5.** Gaze time durations of "read" and "material" when using and not using smartphone

and the results indicate that the difference was not at a 5% significance level. As such, we found there to be no potential for participants not to see materials due to their viewing information while referring to a smartphone. Also, even when presenting information via a smartphone, we found panels and captions to be viewed as much as when participants had not referred to smartphones.

When comparing the gaze times spent when using and not using a smartphone, the average time when used was about 80 sec and when not used was about 20 sec. The difference between these average values is at the 5% significance level. Therefore, we can conclude that referring to smartphones while viewing exhibits provides opportunities for visitors to stop in front of exhibit materials and spend time looking at them.

### 4.3 Effect of Web Content on Participant's Behavior

In our behavior analysis for material 1, we used the index "Were there participant gazing behaviors at the chest part of the human bones?" In that of material 4, we used the index "Were there gazing behaviors other than at the front, such as going around and behind the material or looking into the back of the material?"

The behavioral analysis results for both materials 1 and 4 confirmed the presence of the above behaviors for more than half the participants. As such, we can confirm that information presented by the smartphone led to active appreciation behavior by the participants.

## 5 Conclusions

In this experiment, we found the gaze time of "sp" to constitute the longest proportion of the gaze time with respect to information presentation by smartphones when viewing the exhibit. On the other hand, there was no significant difference between the gaze times of "material" and "read" with or without smartphone information presentation. This suggests the potential for smartphone information presentation in exhibits having a large amount of information to be presented as well as for exhibit materials such as those found in history museums. Enabling the selective acquisition of information that cannot be conveyed by panels and captions utilizing terminals only, such as by smartphones, does not influence gaze behaviors toward exhibit materials and text information. Enhancement of the exhibit by promoting active information acquisition by interactive content-utilizing terminals such as smartphones can leading to increased learning. Furthermore, utilizing the learned information to induce viewing of actual exhibit materials can facilitate the appreciation of the museum experience. Although the subject of the experiment was a history museum, we believe that this result can be applied to science and natural history museums with similar characteristics that have visitor learning as a goal. However, other considerations arise with exhibits such as those in art museums that do not require a lot of information presentation in order to appreciate their worth.

In future work, we will increase the accuracy of the detection of participant interest. In this analysis, we used as criteria the judgment of participant time and distance. We did not consider the possibility that a participant may not be interested but simply gazing at a random single point. As such, when judging participant gaze, we must consider not only the time but also the eye fixation frequency and the pupillary response to improve the detection accuracy of participant interest.

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