Personalized Treasure Hunt Game for Proactive Museum Appreciation by Analyzing Guide App Operation Log

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Abstract. This paper proposes a method for enhancing museum visits by turning them into a personalized treasure hunt game. This approach uses gamification to augment visitor experiences, explicitly addressing the issue of retaining information during casual museum visits. This is achieved by creating quizzes customized to each visitor's interests and providing unique perspectives for appreciating exhibits. These quizzes, developed through analyzing museum guide logs and individual visitor preferences, encourage visitors to explore exhibits, thereby intensifying their engagement proactively. The game entails visitors identifying specific exhibits, guided by hints like images and maps, and inputting the exhibit IDs to win in-game rewards. Field studies employing actual data from the National Museum of Ethnology in Japan evaluated this approach's efficacy. Experimental results suggest that visitors are more likely to remember exhibit details connected to quiz answers, even two

weeks after their visit. Participants also enjoyed the impromptu exploration encouraged by the treasure hunt game.

Keywords: Gamification · Museum Guide · Personalization

1 Introduction

Visiting museums and viewing their exhibits is one of humankind's most critical intellectual activities. For example, many international travel tours include museum visits as part of the course to experience the region's culture. Many educational institutions also include museum studies as part of their curricula.

Despite visiting museums being recommended for learning purposes, not all visitors necessarily approach them with a clear objective. Specifically, visitors who arrive at museums for tours or extracurricular activities without particular motivation tend to wander through the venue passively, simply following the set route. Yenawine *et al.* [21] report a phenomenon where such passive museum experiences do not result in lasting knowledge or memories for the visitors.

In a case study, Housen *et al.* conducted tours with curatorial explanations at the Museum of Modern Art, New York, investigating visitor satisfaction and the knowledge that remained in memory. Their findings suggest that, while increasing the amount of information presented through additional explanations can raise satisfaction levels, it may not necessarily lead to knowledge acquisition if the experience remains passive.

Such phenomena, where passive observation does not lead to learning, have been pointed out in museum studies to emphasize the importance of active and autonomous experiences. For instance, Folk [6] argues that "Free Choice Learning" is crucial in museum learning contexts. The concept of Free Choice Learning posits that learners do not merely follow a predetermined route but learn by actively choosing what they are interested in.

For additional examples, Hein *et al.* [9] proposes a learning model based on Constructivism, stating that visitors build knowledge internally rather than through information from exhibits. Furthermore, Bain *et al.*, within the concept of "Object-Centered Learning," argues that there is greater value in personally interpreting exhibits and connecting them to daily life than merely looking at external knowledge presented through exhibits or explanatory text [13].

Indeed, an energetic and proactive appreciation is pivotal to ensuring that a museum experience is both meaningful and educational. However, catalyzing such autonomous engagement can often present a challenge. As such, numerous initiatives have been undertaken to facilitate proactive appreciation.

One traditional approach is the implementation of orienteering games, often embodied as stamp collecting, within the museum. In these games, museum curators prepare a list of selected exhibits. They then generate stamp sheets that provide hints about these exhibits and distribute them among the participants. Guided by these hints, participants then embark on an exploratory journey through the museum, seeking out the designated exhibits.

Fig. 1. Screenshots of the treasure hunt game in the museum (Some parts are overwritten for translation). Player finds four treasures (designated exhibits) to collect four stamps, aiming to complete with as few hints used as possible. The Quiz and Hint screen shows information about the treasure. Photos, exhibit locations, tags, and descriptions are displayed, but initially, they are blurred or hidden.

Such museum experiences utilizing orienteering aim to promote active observation by encouraging visitors to seek out items based on hints provided, turning the game into a springboard for autonomous engagement. Furthermore, curators often design much orienteering along a consistent theme.

In recent years, gamification that includes puzzle-solving has been increasingly adopted as an advanced mechanism to enhance museum experiences. For instance, institutions such as the Tokyo National Museum and the Louvre Museum offer game-like experiences. Participants of these games navigate through the museum while solving puzzles and searching for exhibits, utilizing tools like smartphones or puzzle sheets. Through these interactive game experiences, participants can develop an interest in and deepen their understanding of the exhibits.

While these game-based experiences can stimulate proactive appreciation, they also entail substantial costs for creation. In the case of orienteering, experts need to identify exhibits that align with a particular concept and decide which exhibits the participants should visit. Similarly, for puzzle games, specialists in riddles or quizzes must design the game according to the exhibits they want to showcase and the messages they want to convey. As a result, it is challenging to offer multiple orientation or puzzle games simultaneously within a single museum.

Consider an individual visiting a museum, without pre-established interests, as part of a school activity. They may opt for a museum guide device's orienteering function, potentially gaining knowledge about the rally's themes and featured exhibits. However, this knowledge might not align with their personal interests, reducing the chance of it being used in the future. Engaging with a topic related to their interests makes them more likely to recall the related exhibit, indicating effective knowledge acquisition from the visit.

In this study, we propose a method that dynamically generates a personalized treasure hunt game by analyzing the behavior logs of a museum guide device. Figure 1 shows an example of an actual gameplay screen. A stamp card screen appears when a player launches the game feature on the museum guide. Players hunt for four exhibits to collect four stamps. After tapping the button under the first stamp field, a quiz screen is generated dynamically by analyzing the visitor's operation log. The quiz screen includes a request for the treasure, *i.e.*, exhibit to be found, as well as hints in the form of images, maps, tags, and descriptions, which are initially obscured. Hidden hints can be revealed in a step-by-step manner. The player can get a stamp when they find the correct exhibit and inputs its ID. If incorrect, two hints are revealed. The player aims to collect all four stamps with as few hints as possible.

The main novelty of our method is its ability to be personalized by connecting the game with the museum guide. Visitors at the museum often use the guide app to read detailed information about exhibits or to check the location of their favorite exhibits. These actions are reflected in the operation logs, strongly indicating their interests. It encompasses not only an individual's conscious interests but also latent interests and unconscious actions. Our method analyzes these logs and extracts common tags from the exhibits they viewed frequently. Then, while retaining these tags, they seek out an unseen exhibit as "treasure".

We implemented a prototype of a treasure hunt game that can actually be used at a museum and conducted a subject experiment on-site. We evaluated how the game experience was perceived and analyzed whether the exhibits they found were remembered two weeks later. During this process, we altered part of the generated quizzes for experimental purposes, allowing us to verify the effects of personalization and the impact of raising awareness of one's interests.

2 Related Work

This study aims to enhance museum experiences through personalized treasure hunts. This section introduces prior research on learning support through treasure hunts, gamification in museums, and personalization, and discusses the positioning and novelty of our study.

2.1 Treasure Hunt Game in Education

Treasure hunt games have been used since ancient times for education, mainly for young children. In recent years, research has been progressing on computer applications to facilitate the educational benefits of these games. For instance, Farella *et al.* [7] argue for the effectiveness of treasure hunt games on mobile devices when the game design is conducted by teachers themselves. Kohen-Vacs *et al.* [11] have enabled a digital-supported treasure hunt game outside the school using the location information of mobile devices.

Relevant to our research, Ng *et al.* [12] have realized a treasure hunt game using mobile devices in museums. Their study reports that gamification increases

the learning effect compared to traditional guides. Ceipidor *et al.* [2] have also realized a treasure hunt game in museums using QR codes. Cesário [3] propose advanced gamification at the maritime museum that fits the museum's theme.

The novelty of our work lies in its ability to personalize the treasure hunt by integrating it with a museum guide. The museum guide is well-suited to estimating the user's latent interests from queries input by the user and the exhibits they viewed in detail. Additionally, although not utilized in this experiment, unconscious actions derived from scroll and acceleration sensors and the exhibits viewed from beacons or location information can also be detected. Using these to provide tailored treasure hunts must help individuals' learning.

2.2 Gamification in Museum

Gamification in museums has long been a focus of attention, especially research on mobile device learning support. Yatani *et al.* [20] propose learning with PDAs in museums. In their study, the device is intended to help multiple people solve questions collaboratively to better understand the exhibit content. Ueda *et al.* [18] also propose a system that encourages independent appreciation of each exhibit by generating a three-choice quiz for each museum exhibit. Our research similarly aims to aid learning in museums through gamification. To this end, the technical challenge in this study is to make such gamification dynamically generable and tailored to the individual.

In recent years, with the development of mobile technology, research on gamification using Augmented Reality (AR) has also been active [4] [5]. Methods for estimating visitor location and enabling interaction with exhibits using Wi-Fi, beacons, infrared communication, *etc.* are also being investigated [15]. As an example of research that combines location information within a museum with gamification, Rubino *et al.* [16] propose a viewing method based on storytelling.

The guide app used in our research also can estimate location using beacons and read text using a camera, but at this time, it is not being utilized for games. Based on these studies, enabling richer input and output based on location could improve the gaming experience and make learning more meaningful.

2.3 Personalization of Museum Experience

Personalizing museum experiences and promoting individualized learning have been actively pursued in recent years. Wang *et al.* [19]propose a project that allows visitors to design their own viewing plans at the museum by connecting the local museum to the web. In their project, visitors can examine exhibits on a web application in advance, input exhibits of interest, and navigate a course tailored to them on a PDA.

Shoji *et al.* [17] propose a method of personalizing not the museum experience itself, but its souvenirs, to help secure personal memories when reviewing them later. In their research, they analyze the logs of museum guide devices, estimate the exhibits the visitor may have been interested in, and print them on postcards.

As a study that personalizes the way each exhibit is viewed, Keil *et al.* [10] propose a method of displaying exhibits of interest in various ways using AR technology. By pointing a tablet device at the exhibit, additional explanations are added, or a synthesized narrative video is played. In the context of personalizing museum experiences, Pujol *et al.* [14] have researched personalized storytelling in various museums. Our study applies such personalization in conjunction with gamification. The goal is not just to show a simple route, but to actively encourage searching, to firmly anchor personal interests in memory.

In research related to this study, Camps-Ortueta *et al.* [1] propose a method of making games enjoyable by personalizing the gaming experience itself. Their research also discusses that educational games are fundamentally dull and the fun found in regular games is limited during learning sessions. In our study, only the exhibits targeted in the game are subject to personalization. Still, in the future, the number of stamps collected, game rules, and difficulty levels should also be personalized.

3 Personalized Treasure Hunt Game Generation

This section explains the mechanism of the application for supporting users' proactive museum appreciation. As our method is closely linked to the actual guide terminal, we use the implemented prototype as an example in the explanation. Our application operates on an iPad and can search and view detailed information for over 4,000 exhibits in a the National Museum of Ethnology, Japan.

3.1 System Overview

This section describes an outline and overall picture of the system. This application consists of front-end and back-end components. The front end aids viewing exhibits by facilitating search and presenting detailed information. During this, the user's activity logs are collected. On the server side, the received logs are analyzed, and quizzes personalized to each individual are generated. The front end is implemented as an iOS app in Swift. The back end is implemented in Python, and the screens are displayed using Vue.js, a JavaScript framework.

The "Recommended Exhibits" screen is initially presented when launching the guide app, where various exhibits are randomly arranged. From this list view, which also includes search results, users often tap on various exhibits to view their detailed information. The application continually logs the extent to which the detail screens of each exhibit are viewed.

Next, when "Treasure Hunt Game" is selected from the main menu, the built-in browser within iOS is launched. The operation logs are sent to the server, where they are analyzed, and a quiz tailored to the user is generated. When the user starts the game, a stamp sheet without any stamps is displayed. On this screen, users can view the game instructions. By pressing the "Question 1"

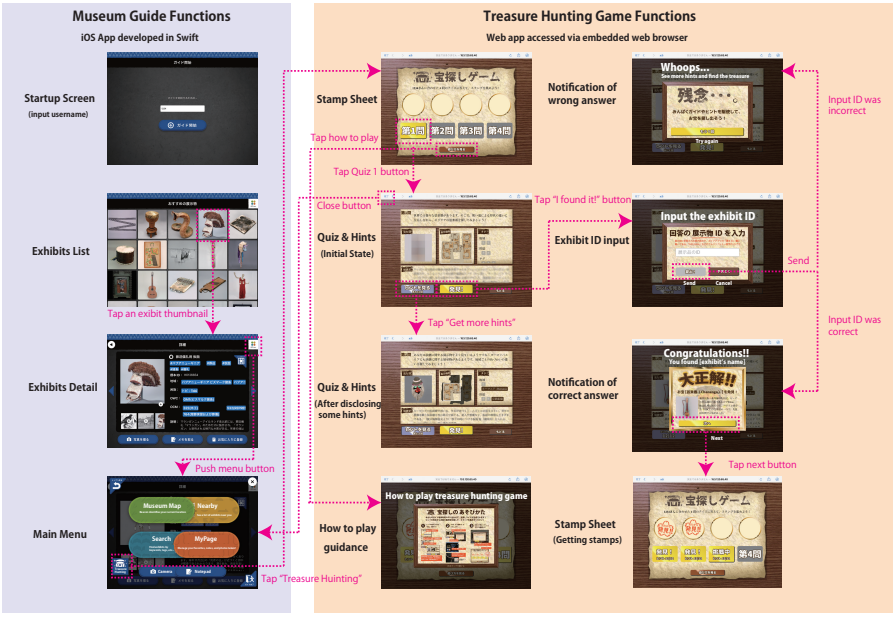

Fig. 2. Screen transition of actual gameplay on the app. Player access both the guide screen and game screen to find exhibits in the museum. They can get a stamp when they input the correct exhibit.

button under the stamp, users can navigate to the detail screen of the treasure hunt target.

The detail screen displays instructions and four hints about the treasure the user should find. The instruction includes personal interests and viewpoints. For example, "You were paying close attention to pots. While noticing the different materials used in different regions, please find the following pot in the Africa area."

The hints are a photo, a map, tags, and a description. Initially, these hints are blurred and hard to see (top image in Figure 3). The photo is pixelated and low resolution. The map is not narrowed down, so the search range covers the entire museum. No tags are displayed. The description is also blurred and unreadable.

By tapping the "Get More Hints" button, users can gradually reduce the blur on any hints, as shown in Figure 3. Each hint can be clarified in four stages, and since there are four items, users can get hints up to 12 times in total. When the hint button is pressed, the image's resolution gradually improves, and in the end, the original resolution of the exhibition image can be seen. The map also gradually narrows the search range, eventually narrowing to about 10 meters. The number of tags gradually increases. The text gradually becomes readable as the blur is removed word by word.

Fig. 3. Screenshots of hints to be disclosed in stages. Each time a player presses the "Get More Hints" button, photo, map, tags, and description are displayed more clearly, step by step. The player can press the button 12 times.

Table 1. Questionnair results on usability. The average score of eight participants (from 1 to 5), and the standard deviation of each participant's score.

Evaluation	AVG	SD
Amusingness	4.3	0.5
Usability	3.1	1.3
Design	3.9	0.7
Serendipity	3.9	1.0
Interests Expended	3.8	0.5
Fit Interests	3.9	0.7
Difficulty	3.4	1.4
Cost	3.5	0.9
Quality of Hints	2.6	1.1
Photo Usefulness	4.4	0.6
Map Usefulness	2.5	2.0
Tag Usefulness	4.1	0.7
Description Usefulness	3.5	0.9

Table 2. The number of players who remembered the treasure exhibits two weeks later (out of 8). Each player solved one question from each of the four types of quizzes. They were asked about recall, recognition, and whether they liked the quiz.

method	# Recall	# Recognition	# Favorite
Quality Only	8	7	4
Quality+ViewPoint	7	8	1
Interest Only	7	7	2
Interest+WiewPoint	5	6	1
Average	6.75	7.00	-

Using these gradually revealed hints as clues, the player searches for exhibits on the guide or on-site at the museum. Pressing the "I Found it!" button at the bottom of the treasure hunt target's detail screen displays a dialog where they can input the exhibit ID. The exhibit ID is a unique 8-letter string given to each exhibit, composed of a Roman character and seven digits, such as "H0123456". This ID can be seen on-site exhibit signage and on the exhibit detail screen within the guide app.

If the player inputs the correct ID, they can view detailed information about that exhibit and receive a stamp on their sheet as a reward. At this point, the number of times the player presses the "Get More Hints" button before finding the treasure is recorded. If an incorrect ID is entered, two levels of hints are forcibly disclosed. Players need to find the treasure with as few mistakes and as few hints as possible.

3.2 Estimate Player's Interest from Operating Log

The system generates a personalized quiz when a player opens a new Quiz and Hints screen for the first time. The system estimates their interests from the uploaded log. It counts the tags on the exhibits they have viewed in detail.

An individual's interests are expressed as a set of multiple tags. For example, pairs like "Art, Dance" or several tags like "Hunting, Religion, Ceremony, Wooden Products" represent individual interests. These combinations of tags are scored based on their count and how many times they appear in the log. The system treats several top tag sets as the player's interests.

3.3 Ranking Treasure Candidates by Generating Quizzes with Templates

Next, the system seeks out exhibits that align with the player's estimated interests, and that the player has not yet seen, to present them as treasures. The system extracts all exhibits tagged with the tag sets of the player's interests. The system removes exhibits from the extracted ones the player has seen before, and those displayed physically close to those already seen. This encourages the player to walk around and see more related exhibits while searching.

These exhibits are candidates for treasures, and the system generates multiple quizzes using templates. Depending on the metadata and type of exhibit, some templates may be applicable while others may not. Therefore, we prepared multiple quiz templates in advance and manually scored them for quiz-like characteristics. Then, the system applies the templates for all treasure candidates and presents the quiz with the highest score.

Our prepared templates are basically in the form of "Let's look for [treasure category] in the [display area]". To this template, we add a part that expresses interest, such as "It seems you are interested in [one interest tag]," and a feature that provides a viewpoint, such as "Let's search while paying attention to [viewpoint name]".

In the ethnographic museum we used for this case, each exhibit is tagged with multiple OCM (Outline of Cultural Materials) tags, which indicate what the exhibit has been used for, and OWC (Outline of World Cultures) tags, which indicate where the exhibit has been used. These tags are valuable resources for generating personalized quizzes and providing hints to guide the players' treasure hunt.

Only certain tags can be used as [treasure category] or [interest]. For example, tags that indicate a type, such as "534: MUSICAL INSTRUMENTS", can be used, but abstract tags like "805: ORDERING OF TIME" are unsuitable for quizzes. Therefore, we manually prepared templates for each tag that is easy to search for as a noun. Moreover, for abstract tags that appear frequently, we have prepared a template for each tag, like "Let's look for exhibits related to [abstract topic]".

Similarly, the template corresponding to the viewpoint differs depending on the tag. For example, drawing attention to "differences in color by region" When

drawing attention to "differences in shape by use", the target exhibit can only be a tool, and only if their usages are different. To address such situations, we prepared many templates for specific combinations of OCM included in a candidate's interest tags and OCM. For instance, if the interested OCM is 222, 223, 224, or 227, and the OCM of the treasure starts with 28, a template that creates a quiz sentence focusing on "differences in materials by use" can be applied.

Such a rule and the combination of actual sentence patterns are generally considered more specific when there are fewer applicable candidates for the template. Therefore, scores were manually assigned to the templates in order of strict conditions. The system applies the templates to the candidates, and selects the candidate that fits the template with the highest score as the treasure for the player to seek.

3.4 Design to Facilitate Gamification

We've designed and improved the reward system to make this treasure hunt game enjoyable. Firstly, we have designed the game interface, using the metaphor of treasure hunt and stamp collecting. In line with the theme of the treasure hunt, we gave it a look of a parchment on a wooden desk. Additionally, we have added a metallic texture to each component.

Next, we designed the gaming experience always to display progress and stages. Generally, in gamification, it is said to be crucial for the progress and achievements to be visualized [8]. Therefore, we adopted a format in which hints for the quiz are gradually disclosed. A stamp is collected on the sheet when the player finishes a quiz. This way, they can check how far their learning has progressed.

In addition, stamps served not merely as a visualization of progress, but also as rewards that users were delighted to obtain. The appearance of the stamps resembles the stamp traditionally used in Japan on high-scoring test papers (*i.e.*, ). Furthermore, the design of the stamps became increasingly elaborate as users accumulated more of them. The screen effects at the moment of stamp acquisition were also striking, with a glowing ring pressing the stamp and a shaking screen effect.

Moreover, we provided a clear objective for the game. By specifying the number of hints used and ensuring hints are forcibly disclosed upon failure, we created gameplay aimed at completing the game with as few hints as possible. To facilitate this, the system recorded the number of hints disclosed so far in completing the treasure hunt, allowing for future review. This process may allow for more vital impressions of exhibits by recognizing failures that caused additional hint disclosure. It is also likely to stimulate the incentive for revisits by inciting an ambition to attempt the game with fewer disclosed hints in subsequent attempts.

4 Evaluation

A prototype system was implemented and field-tested in an actual museum to verify the efficacy of the proposed application. This experiment was conducted on-site at an actual museum, using images and metadata of its exhibits, under the collaboration of the museum authorities.

4.1 Evaluation Task

We had participants play the treasure hunt game on-site at the museum and later investigated whether they remembered the exhibits they searched for and those they saw along the way. The participants consisted of eight university students.

Initially, participants received an operation explanation for the museum guide app, and freely appreciated the exhibits at the museum site for 30 minutes. After that, we gathered the participants and generated a treasure hunt game based on each person's log up to that point. They then started playing the treasure hunt, moving around the exhibition hall until they collected four stamps. After they finished collecting all stamps, they returned to the preparation room and answered a questionnaire regarding the usability evaluation.

Specifically, the questions first asked if the participant was personally interested in the museum itself, the cultural anthropology that was the subject of the experiment, and puzzle-solving games. On a five-point scale, they were then asked to provide an overall rating for fun, usability, design, *etc.*. Similarly, they were asked to rate whether the image, map, tags, and description were useful in the quiz. Lastly, they were asked to give free-form answers on points such as what they liked, what quizzes they enjoyed, what they disliked, what they would like to see improved, and any other comments.

In addition, all participants were asked two weeks later what exhibits they remembered. For the memory survey, participants were first asked to write on paper what exhibits were answers to the quiz and quiz sentences they remembered, to confirm their recall ability. Next, in a recognition task, seen and unseen exhibits were mixed and presented to see if they could correctly discriminate.

4.2 Compared Methods

Four methods were compared within the participants to measure the effect of the interest in the exhibits themselves, personalization, and showing the viewpoint on memory consolidation. In the game, players need to search for four exhibits. During the experiment, these four exhibits were split into two that would be interesting for anyone and two that were tailored to the individual. Then, for each, they searched with and without a given viewpoint. To prevent order effects, the sequence of questions is randomized for each individual.

4.3 Experimental Result

This section verifies whether the proposed system was accepted and whether it affected memory consolidation. Firstly, as an evaluation of whether gamification

was accepted, Table 1 shows the results of a usability survey immediately after the actual experiment. The results showed that while the fun of the treasure hunt game itself was highly rated, usability was not rated as highly. It was found that the quality of the hints was particularly low-rated. Also, map-based hints seem unhelpful.

Next, to measure whether gamification helped learning, table 2 shows the degree of memory retention after two weeks. Searching for exhibits in a treasure hunt leads to stronger memories than just viewing them. Personalization and showing viewpoints have limited effects, but searching for catchy exhibits helped memorization.

5 Discussion

Firstly, the results of the usability evaluation are discussed. Nearly all participants expressed that they found the treasure hunt game enjoyable. Especially noteworthy were comments relating to enjoyment, which suggested that gradually revealing hints and walking around the location, while examining all possible candidates, was considered fun.

Regarding usability, the overall evaluation was not high. Among the freely written comments related to usability, the first notable issue was dissatisfaction with the guide app itself, used as a platform for the treasure hunt game. Specifically, participants pointed out the inconvenience of having to search for each exhibit in the guide while in front of it, even if they thought they had the correct keyword in the search function, and the exhibit did not appear. This suggests a need for a feature that allows finding "the exhibit in front of you" without keyword searching, potentially using a beacon or AR technologies.

Additionally, numerous comments were observed about integrating the guide app and the treasure hunt system. Specifically, even though the ID was displayed in the guide, the need to manually note it and then re-enter it was identified as one reason for the low rating. Also mentioned was the difficulty in reading and inputting the small exhibit ID displayed at the museum site. The exhibit IDs at the site are often written small at the bottom right of the description plate in a dimly lit venue, which might not have been suitable for users to input.

Improvements such as recognizing the location using beacon technology or image recognition, and considering the exhibit found if the user is in front of it or takes a picture of it, could be considered for these input-related issues.

Regarding the effectiveness of hints, some participants found the map-based hints unhelpful. This is generally because museums organize their exhibit spaces according to specific themes. Once a tag is visible, it is possible to predict the exact location of an exhibit more accurately than using a map. Therefore, when operating such a system, it is crucial to consider the granularity of hints and devise ways to ensure that tags related to regions are not revealed before the map.

The difficulty of the treasure hunt showed variability among individuals (which was expected, as two of the quiz questions were tailored to the indi-

viduals), and the average rating was not high. Comments regarding the quiz quality were largely positive, such as “Indeed, it accurately captured my interests”. There were also opinions like “It’s recognizable even without hints”, “The photo doesn’t resemble the actual object”, and “The regional name tag narrows down the target too much”.

Feedback was also received regarding the appreciation experience itself through the treasure hunt game. Comments about the effort required. Such as, the museum is too large, so after collecting logs for 30 minutes, solving four quiz questions was tiring, and they got tired because they had to move to an area they had already visited.

To operate such gamification in the museum, estimating interest in advance through preliminary questions or personalizing the game based on logs collected during gameplay might be beneficial. Additionally, considerations should be made for adjusting the number of stamps to collect or considering the proximity of the exhibits for the treasure hunt.

Next, the impact of the treasure hunt game on the retention of the target exhibits in memory is discussed. Overall, it was found that the exhibits targeted in the treasure hunt left a strong impression, with 84 % of the participants able to recall those exhibits. Prompting participants to search for exhibits using hints might increase the possibility of those exhibits remaining in memory.

Next, we will focus on the order effects for analysis. In this experiment, the order was changed depending on the person, so the order effects should not appear between the methods. However, it is conceivable that the memory consolidation effect of the treasure hunt may decrease with familiarity. We counted how many exhibits the subjects remembered in the treasure hunt, which they solved in different orders. Seven participants could recall the answers to the first, second, and third questions, and six participants could recall the answer to the fourth question (out of eight participants). Completing four consecutive treasure hunts requires walking around the museum for an hour. Therefore, the degree of memory retention may decrease because participants get tired and accustomed to the game.

Next, we verified the effects of personalization and explicit presentation of viewpoints. Overall, they tended not to remember when asked to find exhibits considering personal interests compared to when they were asked to find manually selected exhibits. One potential reason could be the difference in the effect on memory between the intrinsic interest of the exhibit and the alignment with personal interest. The exhibits selected manually were exciting and surprising (for example, food samples not typically found in museums, cute animal statues, *etc.*).

On the other hand, the personalized treasures were similar to the exhibits that the participants had repeatedly seen in the early stages. They might have struggled to recall exhibits that felt repetitive or lacked novelty. Furthermore, many personalized treasures were understated, reflecting the nature of many museum exhibits. Therefore, it’s essential to consider the inherent charm of the exhibits when designing the treasure hunt.

Next, we analyze the effect of highlighting a viewpoint suggested. Many participants in the interview survey reported not noticing the guidance about these critical viewpoints. Our game's rules focus on finding the target exhibits with as few clues as possible, causing participants to concentrate solely on the hints and ignore the given directives. This issue suggests a flaw in game design: the structure that encourages productive viewing is not synchronized with the reward system. To fix this, it might be necessary to adopt a system where rewards are granted only when they view the exhibit with attention to the highlighted viewpoint (*e.g.*, they must take pictures of different parts of the treasure and the exhibits they have seen to get a stamp).

Lastly, we discuss the importance of difficulty level. In the interviews, most participants mentioned the difficulty of the quiz. For example, one participant stated that the exhibit was difficult to find and remained in their memory because it was displayed in a different area than they had imagined. Another participant mentioned that they could not remember the exhibit because they accidentally found the correct exhibit in one try with a tag search, without even looking at the actual object. To make it an enjoyable and educational game, it would be necessary to keep it easy enough for anyone to clear, yet challenging enough to be memorable.

6 Conclusion

In this study, we proposed a method to enable proactive museum appreciation by gamifying museums with a personalized treasure hunt format. We implemented a prototype that integrates with an actual museum guide app, analyzes individual logs, and generates quizzes. The experimental results showed that such a game experience was enjoyable for users, and the exhibits they sought remained in their memory more than those they simply viewed.

However, the effect of personalization was limited, and there was a tendency for eye-catching exhibits sought out simply to be more easily remembered. Room for improvement was found in the method of presenting desired viewpoints and in how hints are provided. Future modifications are being planned to make the treasure hunt more practical, including adjustments to the difficulty level and selecting catchy exhibits.

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