Utilization of Audio Guide for Enhancing Museum Experience
Relationships between Visitors' Eye Movements, Audio Guide Contents, and the Levels of Contentment

Kazumi Egawa[1] and Muneo Kitajima[1,2]
[1]*University of Tokyo, Bunkyo, Tokyo, Japan*
[2]*Nagaoka University of Technology, Nagaoka, Nigata, Japan*

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Abstract: Museums provide the opportunities of acquiring knowledge concerning artistic, cultural, historical or scientific interest through a large number of displays. However, even if those masterpieces are visually accessible to all the visitors, the background of these works of art is not necessarily acquired because the visitors do not have enough knowledge to fully appreciate them. Audio guide is a commonly used tool to bridge this gap. The purpose of this study is to gain understandings of relationships between visitors' eye movements for acquiring information by seeing, the contents of the audio guide that should help them to understand the objects by hearing, and the levels of contentment from the museum experience. This paper reports the results of an eye tracking experiment in which nineteen participants were asked to appreciate a variety of pictures with or without audio guide, to fill in a questionnaire concerning subjective feelings, and to attend a follow-up interview session. It is found that the participants could be classified into four categories, suggesting an effective way of providing audio guide.

1 INTRODUCTION

Acquiring knowledge is an essential activity that all people should conduct; in some cases, it is for accomplishing certain task goals, and in other cases, it is not related with any concrete superordinate purpose but "acquiring knowledge" itself becomes the goal of people's activities. In any cases, by accomplishing the activity of acquiring knowledge, people should find the feeling of satisfaction, or contentment, and the acquired knowledge should contribute to establish new connections in the existing network of knowledge in their brains, which would become a basis for acquiring a series of new knowledge in the future.

1.1 Acquiring Knowledge at Museum

In recent years, museum has been considered as one of suitable places for learner-centered learning and lifelong learning. This is because of the form of learning that is presented at museum. Museum is a building in which objects of artistic, cultural, historical or scientific interest are kept and shown to the public. People visit a museum building and approach an object in which they are interested, stay a while in front of the object to study it, then approach to another. This process continues until they decide not to do so. This style of learning is considered as "self-paced learning". It is an effective learning method to improve performance (Tullis and Benjamin, 2011), guided by their motivation. When the works of art in the museum are displayed in such a way to facilitate self-paced learning, it would make possible learner-centered learning. A critical condition for lifelong learning would be the maintenance of motivation of learning. Museum setting provides a necessary condition for it.

This paper focuses on experience at museum and deals with the question how the activity of knowledge acquisition is carried out at museum. Museum is the place where a variety of valuable opportunities for acquiring knowledge are provided to people. Museum novices visit for the purpose of acquiring knowledge about the works displayed there. The content of knowledge about the works must not be general but highly individual because the information concerning the objects, which is general and accessible via explanation boards, has to be integrated with the existing

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network of knowledge in the person's brain to become his/her knowledge.

1.2 Comprehending Objects at Museum with Seeing and Hearing

Comprehending objects displayed at museum is analogous to comprehending texts on a book. According to the construction-integration theory of text comprehension (Kintsch, 1988; Kintsch, 1998), the cognitive processes for comprehension involve two stages: 1) activation of knowledge to construct a knowledge network that is associated with the representations resulted from perception of the object a person is looking at, which is an automatic activation process of relevant knowledge stored in his/her long-term memory for the perceived object, followed by 2) a network integration process to obtain a coherent meaning of the perceived object that is consistent with the current context, which could be an automatic unconscious process or a deliberate conscious process depending on the level of difficulty involved in the comprehension process.

In some cases it is not necessary to activate additional knowledge for gaining the feeling of comprehension if the object is familiar to him/her. In other cases, however, it requires more cognitive steps to fully comprehend the object by overpassing inferences because the object is too difficult to gain an immediate understanding. This paper deals with the latter case, and seeks a way to alleviate this difficulty by timely providing audio guide, which should interfere at the minimum with the visual modality of a museum novice which is used by him/her heavily for observing the object. The content of audio guide should activate necessary knowledge to comprehend the object through another modality than visual. If the information provided by audio should activate the part of knowledge that is missing in the knowledge activated by the visual information, the person is likely to reach better comprehension state, that is not being able to achieve otherwise.

1.3 Measuring Conscious/Unconscious Processes in Comprehension

The processes of comprehending an object start with the processes of observation, which could be controlled either consciously or unconsciously, in other words, they could be deliberate or automatic. It is known that the processes controlling human activities are dual, known as the dual-processing theory (Kahneman, 2003; Evans, 2003; Evans and Frankish, 2009; Evans, 2010). In addition, the working of long-term memory should be regarded as autonomous, which means that the memory reacts to the representation of perception automatically and it does not behave as a passive data-store, similar to a database system that stores a huge amount of digital data (Kitajima and Toyota, 2013; Kitajima, 2016).

Visual information processing starts with feeding visual stimuli to the brain, followed by either unconscious or conscious information processing for comprehending objects. Gaze points of a person should indicate the visual information of the object that might be used for further unconscious or conscious processing with automatic knowledge activation in long-term memory, that should contribute to reaching comprehension of the object. Note that the memory activation process is autonomous, not controlled top-down by higher cognitive processes that issue the command of retrieval of necessary portion of knowledge.

The locations where the visitors are looking at, i.e., the gaze points, are measured by using the eye-tracking technology. If the network of knowledge is activated sufficiently, he/she would gain the feeling of satisfaction, or contentment, which is measured by questionnaire or interview. This paper addresses the possibility of facilitating knowledge activation via the audio modality by providing audio guide, which is subsidiary to the visual modality in appreciating objects at museum.

1.4 Purpose and Outline of the Paper

For the purpose of enhancing self-paced learning, this paper studies the effect of audio guide on the levels of contentment of museum novices by analyzing the patterns of eye movements while appreciating objects with or without audio guide. This paper starts with a section describing a model of contentment in museum experience and explaining visual information acquisition in museum experience. Then, the following section describes an eye tracking experiment conducted with nineteen museum-novice participants, who were asked to appreciate a variety of paintings with or without audio guide. Finally, the last section is presented for describing the results of experiment and discussion concentrating on the possibility of enhancement of self-paced learning at museum for museum novices with timely provision of audio guide.

2 MUSEUM EXPERIENCE

People visit museum to study objects they are interested in. It is carried out mainly by observing objects through their eyes. As the results of their observation, they have different levels of feeling of satisfaction, or contentment. In the following subsections, contentment in museum experience and visual information acquisition in museum experience are described.

2.1 Contentment in Museum Experience

In the study of investigating elicitation of emotions while viewing films, the following types of emotions are considered (Gross and Levenson, 1995):

relief	anger	surprise
arousal	sadness	fear
interest	tension	pain
contempt	disgust	happiness
confusion	embarrassment	amusement
contentment		

In the present study, it was assumed that similar emotional reactions would occur while studying objects at museum. These sixteen emotion types are used to investigate the emotional structure of contentment through the internal relationships among the emotion types listed above. People visit museum for the purpose of acquiring knowledge. They would have a feeling of satisfaction on accomplishment of the goal. This type of contentment is named "Cerebral Happiness" which is accomplished by "The Intellect", one of seventeen happiness goals proposed by Morris (Morris, 2006). In the present study, the sixteen emotional states that should occur in response to the activity of observing objects, and the degree of Cerebral Happiness is measured by having the participants fill in the questionnaire as shown by Table 1. Q1 is for measuring emotional state and Q2 through Q9 are for measuring Cerebral Happiness.

2.2 Knowledge Acquisition in Museum Experience

2.2.1 Eye Movement in Museum Experience

Museum experience involves appreciation of objects. Since most part of information is visual, eye movements are important information to understand appreciation behavior of museum visitors (Solso, 1996; Yarbus, 1967b). Figure 1 illustrates the perceptual and cognitive processes that are carried out in the brain while appreciating objects. The appreciation process goes as follows:

1. Perceives via vision the information conveyed by painting that exists in the external physical world,
2. Detects visual features such as edges of the perceived objects on the retina via optical processes, and then transmits the results by electrical information to the brain,
3. Associates the information processed in the visual cortex with the knowledge stored in the cerebral cortex to learn and/or estimate the objects, which is called semantic processing,
4. Initiates eye movements and/or body movements in response to the results of the semantic processing.

The pattern of eye movements is an external parameter that should reflect the intension or purpose of the museum visitors (Yarbus, 1967a).

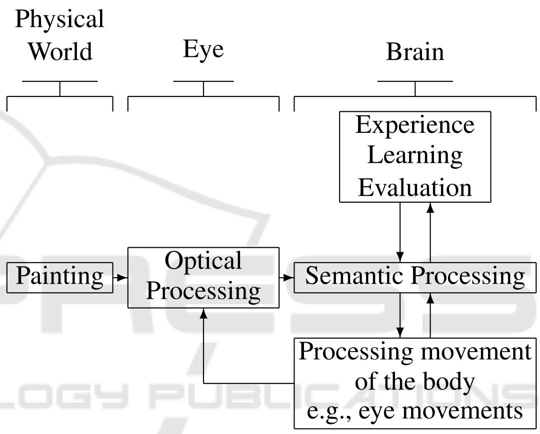

Figure 1: Cognitive Model (Solso, 1996).

Figure 1 illustrates a cyclic process of optical processing, semantic processing, and motor processing, i.e., eye movements. It is reported that the number of cycles carried out for a single object depends on the degree of the smoothness of learning of the object, which is proportional to the length of time to appreciate the object. The shorter the appreciation time becomes, the less effective the museum novice feels his/her learning progress (Okumoto and Kato, 2010). The appreciation time could be additionally characterized by the change of the number of fixations per unit time as appreciation behavior develops (Jacob and Karn, 2003). This paper uses these factors to characterize the museum novices' appreciation behavior.

2.2.2 Using Audio Guide to Enhance Museum Novices' Experience

This paper focuses on the addition of audio guide, which should have effect on the cycle introduced by

Table 1: Evaluation items of subjective contentment.

Question	*Content*
Q-1)	For the following 16 kinds of emotions, please answer the strength that you have felt.
	1) relief, *2) anger*, *3) surprise*, *4) arousal*, *5) sadness*, *6) fear*, *7) interest*, *8) tension*, *9) pain*, *10) contempt*, *11) disgust*, *12) happiness*, *13) confusion*, *14) embarrassment*, *15) amusement*, *16) contentment*
Q-2)	I felt contentment from painting appreciation.
Q-3)	It was my favorite painting.
Q-4)	I found the meaning of the painting.
Q-5)	I found the value of the painting was found.
Q-6)	I wanted to know more about the painting.
Q-7)	That study has developped new knowledge.
Q-8)	I found where should I watch.
Q-9)	I wanted actually to go to a museum of art.

Figure 1, especially during the semantic processing. In order to deal with additional information channel, it is necessary to consider the semantic processing with a broader perspective in which the object is comprehended using various sources of information including the directly perceived information as shown in Figure 1.

Comprehension process involves knowledge activation process, triggered by perceptual information acquired from the external environment, the appearance of objects in museum in the specific context of this paper, and currently activated knowledge through the preceding cognitive processes including expecting what to happen, reflecting on the past events, making inferences of what comes next, etc. Comprehension is achieved solely on the ground of the activated knowledge.

In order to take into account the simultaneous, asynchronous, and automatic activation of knowledge through visual and audio information channels, resulting in a motor behavior of eye movements after processing visual-audio information, this paper adopts a comprehensive unified model, MHP/RT (Model Human Processor with Realtime Constraints), that is capable of simulating action selection processes by underlying perceptual–cognitive–motor processes and autonomous memory activation process (Kitajima and Toyota, 2013; Kitajima, 2016). The heart of the model is that coherent behavior in the ever-changing environment is possible by synchronization of automatic unconscious processes and deliberate conscious processes by using activated portion of memory with the process of resonance. One of the case studies that applied MHP/RT to understand people's behavior was effectiveness of guidance information provided from a person sitting in the passenger seat of a car to the driver who was not familiar with the area he/she was driving (Kitajima et al., 2009; Kitajima, 2016). The degree of effectiveness was dependent on the contents of activated knowledge of the driver. This paper considers that this is a similar situation, where a museum novice would be benefitted by the provision of audio guide while observing objects. When audio guide is provided *timely*, it should be most effectively used to enhance the existing knowledge of the museum novice. The timing would be characterized in relative to the perceptual information that has been collected from the environment visually. It is assumed that the museum novice should have a feeling of satisfaction if the information provided though audio guide is smoothly integrated with the then-activated knowledge to form more complete knowledge, necessary for understanding the object.

3 EYE TRACKING EXPERIMENT

An eye tracking study was conducted to understand the effects of audio guide on the eye movement pattern and the level of contentment of museum novices who had intension of acquiring knowledge concerning the objects used for the experiment.

3.1 Participants

Nineteen undergraduate students received course credit for participation in the present study (all museum novices, 15 males, 4 females, average age = 21.4, SD = 0.6). All had normal or corrected-to-normal vision and naive about the purpose of this experiment.

3.2 Stimuli

In order to simulate the activity of viewing painting, six images of painting and three audio guides were prepared with permission from the Bridgestone Museum of Art.

Three types of painting, i.e., portrait, landscape, and abstract, were selected since people tend to look at overt elements such as faces or objects. Landscape has many elements, abstract has no elements, and portrait is between them. Two artistic works were used for each type of painting, and one of the works was presented with audio guide, and the other without it. The set of stimuli with audio guide is called “audio guided set”, and the one without audio guide, “no assistance set” hereafter in this paper. Six paintings were presented on a PC display one by one to each participant.

3.3 Apparatus

Stimuli were controlled by Microsoft Powerpoint 2013 and were displayed on a 35 inch LCD monitor in a testing room equipped with soft lighting and sound attenuation. Eye movements were recorded using an eye mark recorder of nac (EMR-9), which had a sampling rate of 60 Hz and a coverage area with the horizontal angle of 44 degrees and the vertical angle of 33 degrees. Participants were seated approximately 1100 mm from the monitor and made responses using a mouse. Their chins were fixed using a chin support. The experiment was carried out with one participant at a time. Figure 2 depicts the arrangement of the experiment.

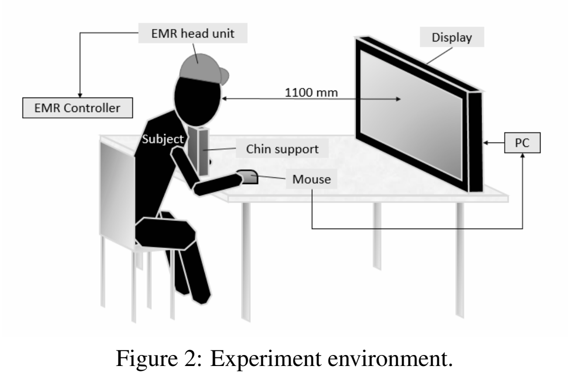

Figure 2: Experiment environment.

3.4 Evaluation

The 25 items listed in Table 1 were evaluated by a questionnaire using seven-point scale (1 = weak, $\cdots$, 7 = strong). Eye movements were evaluated using two parameters; the viewing time and the frequency of fixations.

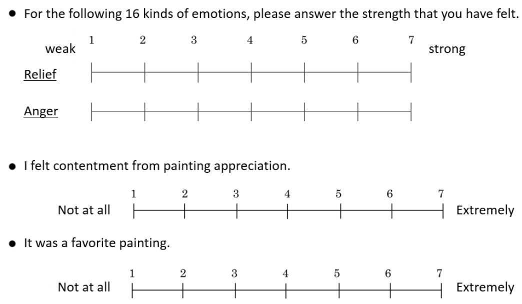

Figure 3: A part of a questionnaire.

3.5 Procedure

First, participants were asked if they had understood the purpose of the present study and agreed to participate. After adjusting participant’s sitting posture and fixing his/her chin, a calibration process was carried out to ensure that the visual object and the eye mark were located at the same position.

Before starting the experiment, each participant was told to watch the displayed images carefully, to do his/her best not to move his/her head, and to remove the image by clicking when he/she felt enough. After that, a practice session was carried out with an image.

Participants were explained the experimental procedure. In the experiment, all participants viewed 3 non-assisted images first and then followed by 3 audio-guided images. Participants were allowed to have a break after finishing the non-assisted images if they requested it. Three images in each section were shuffled according to the latin square method. The order was chosen by Table 3. When the participants clicked to remove each image, they were asked to fill in a self-evaluate questionnaire shown by Table 1. At the end of the experiment, participants were interviewed about their reasoning in their evaluations and whether they had seen the images before.

4 RESULTS

Due to the change in position of EMR head unit during the break, participant 19’s eye movement cannot be measured accurately. Therefore, participant 19’s audio-guided data was removed from the analysis.

4.1 Contentment and Eye Movements

In this part, in order to clarify the relationship between contentment evaluation and eye movements, the correlations between them were examined. Table 4 shows the significant correlation coefficients be-

Table 2: List of the stimuli used for the eye tracking experiment.

Type	*Artist*	*Title*	*Date*	*Length of audio guide [sec.]*	*ID*
Portrait	Sekine Shoji	Boy	1919	-	P
Portrait	Fujishima Takeji	Black Fan	1908-09	65	Pa
Landscape	Asai Chu	Laundry Place at Grez-sur-Loing	1901	-	L
Landscape	Paul Cezanne	Mont Sainte-Victoire and Chateau Noir	1904-06	79	La
Abstract	Paul Klee	Island	1932	-	A
Abstract	Zao Wou-Ki	07.06.85	1985	87	Aa

Table 3: The presentation order of stimuli.

	Non guided			*Audio guided*		
	1	2	3	4	5	6
Pattern 1	L	A	P	Aa	Pa	La
Pattern 2	P	L	A	La	Aa	Pa
Pattern 3	A	P	L	Pa	La	Aa

tween all evaluation items of subjective contentment and items of eye movements. As shown, positive emotions such as happiness and amusement mainly have an effect on viewing time and frequency of fixations. And it shows the feeling of knowledge acquisition decreases as the frequency of fixations increase.

4.2 Audio Guide on Portraits

In this part, only two portrait images from the no assistance set and the audio-guided set were analyzed. There was no significant statistical difference such as the average of all participants, but the following tendency was seen. Also at this point it was suggested that there are two attributes as follows.

The experimental result indicates that audio guide did affect the viewing time and the frequency of fixations. Most of the participants, as it can be observed for participants 6 and 9, tended to evaluate their contentment low when there is no assistance. On the other hand, contentment evaluation tended to be high when there is an audio-guide assistance. However, there were some participants, as it can be observed for participants 1 and 17, who evaluated contentment to be high although there is no assistance and stated even higher contentment evaluation for audio guide. Therefore, the results of participants 6, 9, 1, and 17 were examined.

Audio-guide changed not only the contentment evaluation but also how the participants perceived the images, because audio-guide provided the information regarding images and the images' point of interest. Figures 4 to 6 graphically illustrate the change of contentment. As shown in Figures 5 and 6, all participants could not feel Cerebral Happiness without audio guide, but they could feel it with audio guide.

In the viewing time aspect, audio-guide assistant increased most participants' viewing time greatly exceeding the length of the audio-guide assistant, which was about 65 seconds as shown in the Figure 7. Conversely, there were some participants such as participant 1 and participant 17 whose viewing time didn't change significantly. The experiment result indicates that the change in the viewing time tended to conform with the contentment evaluation.

For eye movements, most participants with audio-guided assistant tended to look at a certain location following the audio-guide resulting in reducing frequency of fixations. However, the frequency of fixations of some participants such as participant 17 increased instead. According to the interview, participant 17 stated that he was distracted by audio-guide. Moreover, he stated that he would like to have in explanation text instead of audio-guide. Figure 8 graphically illustrates the change of eye movements.

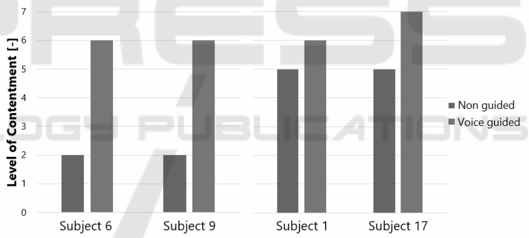

Figure 4: Effect on contentment.

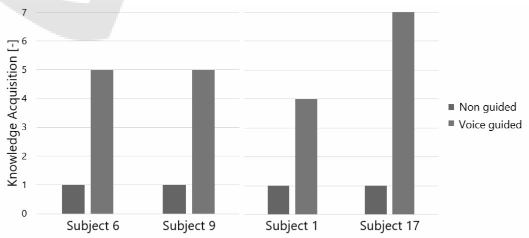

Figure 5: Effect on acquisition of knowledge.

4.3 Audio Guide and Viewing Time/Frequency of Fixations

In this part, all images were analyzed. To analyze the effect of contentment and audio-guide, a viewing time - frequency of fixations plot is created as shown in the Figures 9 to 11. Figure 9 does not show any obvious result. However, when the data between non-assisted and audio-guided assistant are separated, a

Table 4: Correlations between evaluations and eye movements in non-guided portrait.

	Happiness	*Amusement*	*Contentment*	*Q-7*
Viewing Time [sec]	0.508*	0.111	0.270	0.394
Frequency of Fixation [counts/sec]	-0.502*	-0.466*	-0.571*	-0.485*

* $p < .05$

Q-7: “That study has activated new knowledge.”

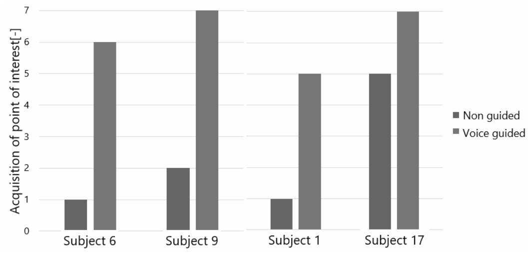

Figure 6: Effect on acquisition of point of interest.

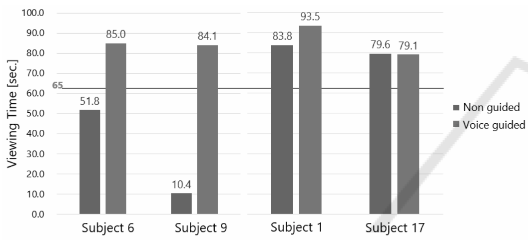

Figure 7: Effect on viewing time.

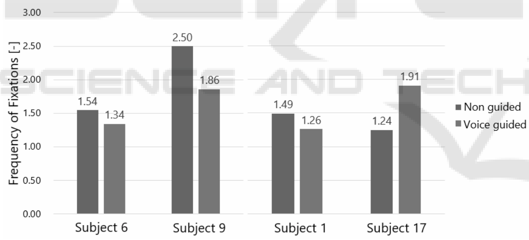

Figure 8: Effect on frequency of fixations.

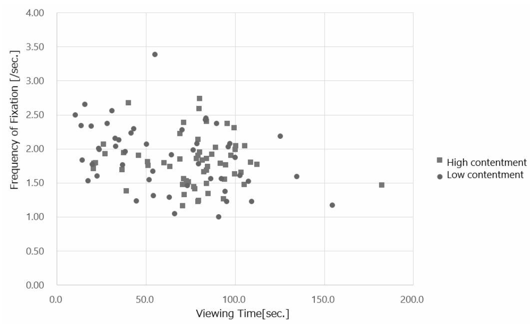

Figure 9: Time - frequency of fixations plot.

clear trend can be seen in Figure 10 and Figure 11. In non-assisted condition, the viewing time and the frequency of fixations did not have any clear interaction. On the other hand, these plots concentrated within the certain area for audio-guided condition.

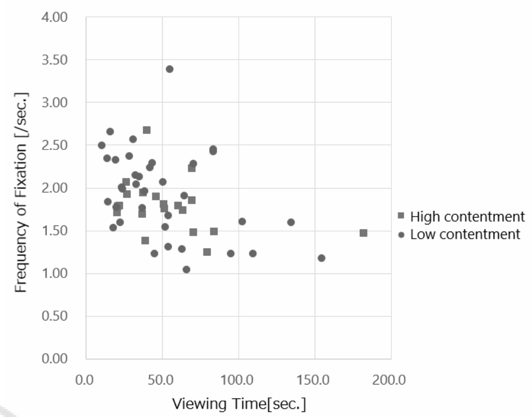

Figure 10: Time - frequency of fixations plot: non-guided.

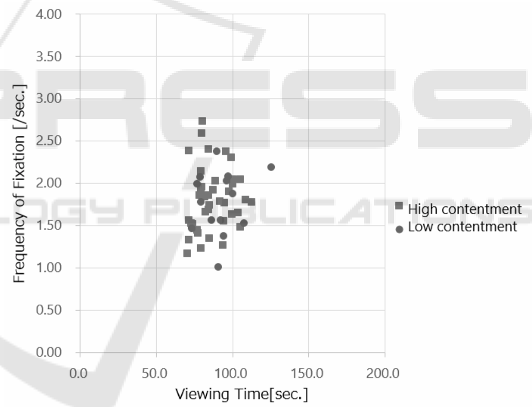

Figure 11: Time - frequency of fixations plot: audio-guided.

4.4 Cluster Analysis

By using participants’ contentment evaluation, a table of participants’ contentment acquisition was obtained as shown in the Table 5. This table was further analyzed with quantification method no.Ⅲ in order to see any trend in participants. In the result, the way of each acquisition of contentment was described in two dimensions: the first axis was “abstract painting – figurative painting.”, and the second axis was “guide is necessary – guide is unnecessary”. With the score resulted from quantification method no.Ⅲ, participants can be classified and grouped into four types as shown in Figure 12 using the Ward method. Although participant 16 was classified in Group C with the score, this participant had a different way to feel contentment. It was supposed that participant 16 might be a participant who doesn't feel contentment with paintings. Therefore, the score of participant 16 was not plotted.

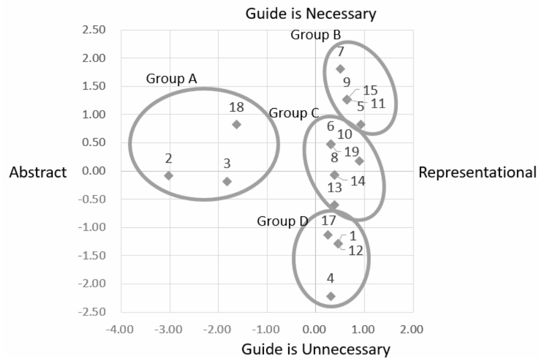

Figure 12: Contentment acquision.

5 DISCUSSION

5.1 Audio Guide

According to the interview, participants who perceived positive emotion evaluated their contentment high. This occurred because contentment is also a positive emotion, and it might be difficult to differentiate the positive emotions in the individual. The participants who evaluated high contentment tended to think about background of paintings, which would result in an increase in viewing time and a decrease in frequency of fixations. On the other hand, participants who perceive negative emotions while viewing a particular image didn't think about background of paintings.

However, as presented in Section 4.2, novices, who couldn't have any ideas without guide, got idea and felt contentment with audio guide. Audio guide led participants to watch the explained point without hesitation and the frequency of fixations tends to decrease.

Still, there are also novices think the audio guide is annoying such as participant 17. Most of novices can enjoy paintings with any information because of their ignorance about paintings. But the novices who needed specific information at that time think the audio guide is annoying and want the explanation text instead when audio guide lead them into another point. Difference between point of interest and audio guide might increase the frequency of fixations.

The concentrated phenomena presented in Section 4.3 is caused by audio-guided since it leads participants to look at the point of interest in the same sequence. In fact, the impressions of paintings with audio guide was the same for most of the participants.

5.2 Analysis of the Need of Particular Participant

The characteristics of the cluster classified in Section 4.4 were considered in this section.

- Group A
  They can't understand abstract without audio guide, but they could enjoy in their way(e.g. brushwork, colors).
- Group B
  They are classified as typical museum novices: it is difficult for them to have their own ideas. Although it is possible to feel contentment with audio guide, they want explanations of overt elements for audio guide instead of the information of artist.
- Group C
  They can enjoy paintings with audio guide, and also enjoy portrait and landscape which are easy to understand without audio guide.
- Group D
  They can feel contentment without audio guide. When the contents of audio guide is not they want to know or from the time constraints, audio guide annoys them.

6 CONCLUSION AND FUTURE WORKS

This paper studies the effect of audio guide on the levels of contentment of museum novices by analyzing the patterns of eye movements while appreciating objects with or without audio guide. For that we have done eye tracking experiments and show the effects of audio guide and possibility of using eye movements to estimate novice's contentment. Contentment can be used to differentiate each person's image perception. This information can be used to decide what kind of support a particular person needs and enhances novices' experience. Still, we could not get much statistically significant results, so it is important to improve the method in the future.

In this paper, we supported that providing an audio guide without additional displays such as text guide, which have been used widely in museums. Moreover, other assistances, e.g., text guide and video guide, should be considered in the future. Understanding the

Table 5: Contentment acquisition of each subject.

Participant Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Portrait	✓			✓								✓	✓				✓		
Landscape	✓	✓	✓	✓		✓		✓		✓		✓	✓	✓			✓		✓
Abstract		✓	✓															✓	
Portrait (Audio)	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Landscape (Audio)	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Abstract (Audio)		✓				✓	✓		✓	✓	✓		✓		✓		✓	✓	✓

✓: contentment, blank: not contentment

effectiveness of assistance for novices can be also extended after considering the length and timing of assistance.

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APPENDIX

Figure 13: Sekine Shoji, Boy, 1919, ID: P.

Figure 14: Fujishima Takeji, Black Fan, 1908-09, ID: Pa.

Figure 15: Asai Chu, Laundry Place at Grez-sur-Loing, 1901, ID: L.

Figure 16: Paul Cezanne, Mont Sainte-Victoire and Chateau Noir, 1904-06, ID: La.

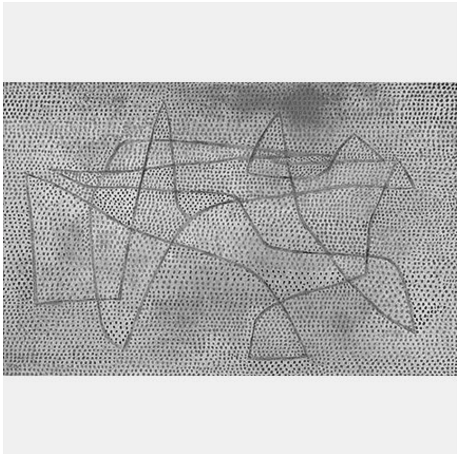

Figure 17: Paul Klee, Island, 1932, ID: A.

Figure 18: Zao Wou-Ki, 07.06.85, 1985, ID: Aa.