Original Article

Effect evaluation of video content and audiovisual devices on VR tourism for young people

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Abstract
After the conclusion of the COVID-19 pandemic, Japan has witnessed a substantial influx of foreign tourists. However, owing to the demographic challenges posed by an aging population, the domestic tourism market in Japan continues to face significant obstacles. With the proliferation of smart devices, the emergence of virtual tourism has become a feasible avenue for potential growth within the tourism sector. In this study, we focused on the prevailing forms of virtual tourism media, specifically 180-degree and 360-degree videos, as well as mainstream audiovisual devices, namely virtual reality (VR) and smartphones. We conducted an experiment to evaluate the content of the videos by employing a combination of questionnaire surveys and near-infrared spectroscopy (NIRS) technology. The analysis of the results indicates that 360-degree video content may give a more relaxed experience than 180-degree video content with VR glasses among young people for virtual tours. From the results of questionnaire, young people preferred 360-degree video content to 180-degree video content, and they preferred VR glasses to smartphones as a device for virtual tours.

Keywords
VR, virtual tourism, NIRS, 360-degree video, Z-score

1. Introduction

In terms of global tourism trends, the international tourism market has consistently occupied the position of the third-largest export industry in the world's gross domestic product (GDP) since 2010 [Ministry of Land, Infrastructure, Transport and Tourism, 2020]. According to a study conducted by the World Travel and Tourism Council, tourism contributed approximately 10.4 % of global GDP in 2019 [Ministry of Land, Infrastructure, Transport and Tourism, 2021]. All of this makes tourism an important part of the global economy.

Tourism is also an important key industry in Japan, which claims to be a tourism-oriented country. In 2019, the number of foreign tourists coming to Japan reached 31.88 million and their total spending reached 4,813.5 billion yen [Ministry of Land, Infrastructure, Transport and Tourism, 2022]. The COVID-19 pandemic is changing tourism forms and new tourism forms need to be explored.

The impact of COVID-19 has precipitated a myriad of transformative changes in daily life. Notably in Japan, by the year 2020, a striking 96.8 % of universities had implemented online teaching initiatives [ReseEd, 2021], and over 50 % of Japanese enterprises had adopted telecommuting practices by 2022 [Ministry of Internal Affairs and Communications, 2023]. Simultaneously, the widespread adoption of VR devices and other smart technologies has rendered virtual tours an increasingly prominent facet of the tourism landscape in recent years. This shift is evidenced by the growing accessibility of devices designed for virtual tour experiences and the expanding array of content available for such tours. Furthermore, the utilization of the internet among the Japanese populace has demonstrated a discernible upward trajectory [Ministry of Internal Affairs and Communications, 2023]. Consequently, it is plausible to posit that virtual tours hold substantial potential for development as an emerging dimension within the tourism industry.

In accordance with a report from Kankokeizai News, findings from a 2022 survey on virtual reality (VR) conducted by Dokodemodoor Trip revealed that within the demographic of young individuals in Japan, the highest adoption and ownership of VR were observed among those aged 20 to 29 [Kankokeizai News, 2022]. This leads us to posit that Japanese youth exhibit a heightened openness to virtual tours. Consequently, for the purposes of this research, we have identified this age group as our designated experimental subjects.

2. Previous research

The number of studies on virtual tourism has increased in recent years and yielded promising results. Srifar [2018] conducted a comparative analysis of the efficacy of 360-degree tourism videos filmed from a fixed camera perspective against those filmed from a moving camera perspective. It has been observed that videos captured from a static camera perspective exhibit greater user satisfaction, where it is less likely to induce vertigo and more efficacious in relieving feelings of unease compared to videos shot with a moving camera.

In addition, according to Okada et al. [2019], using functional near-infrared spectroscopy (fNIRS) technology to compare changes in cerebral blood flow while subjects watched 2D and 360-degree VR videos, the results showed that 360-degree VR videos were more immersive.

Following previous research, we deduce that virtual tours hold promise as a novel and potentially positive form of tourism. A diverse array of virtual tour formats is currently accessible through online platforms, encompassing an extensive range of options, including 180-degree and 360-degree videos. Nevertheless, it is noteworthy that there exists a noticeable research gap in the evaluation of the content featured within these virtual tours.

To address this lacuna, our study undertook a systematic assessment of the content present in different categories of virtual tours. This evaluation was executed through a multifaceted approach, involving the examination of cerebral blood flow variations in young individuals during their exposure to a variety of virtual tour experiences. Additionally, a comprehensive questionnaire survey was administered to gather insights and feedback from the participants.

The amalgamation of these diverse methodologies provides a comprehensive understanding of the content quality within virtual tours and the associated user experience. This study contributes to the discourse regarding the potential of virtual tours as an emerging and potentially beneficial dimension within the tourism industry.

3. Experiment

3.1 Overview of experiment

The purpose of this experiment was to ascertain the preferences of Japanese subjects during a virtual travel experience. The subjects were 9 Japanese youths in their 20s (7 males and 2 females). In this experiment, subjects compared two devices, VR glasses or smartphones, to find out which device was preferred during the VR sightseeing experience. They viewed 180-degree and 360-degree videos on each device. Changes in cerebral blood flow were measured by near-infrared spectroscopy (NIRS) while subjects watched the videos. These objective physiological measurements were then integrated with the data collected in questionnaires for comparative analysis from both objective and subjective perspectives. In addition, this study also investigated the perceptual differences that occur with the use of VR glasses as opposed to smartphones.

NIRS is a technique employed to quantify brain activity by evaluating changes in the absorption of near-infrared light caused by hemoglobin. Near-infrared light, which has a wavelength of 700 to 1000 nanometers, is less absorbed by hemoglobin than mid and far-infrared light, and thus brain activity can be measured without exposing the individual to infrared light [Fukuda, 2011].

In this experiment, NIRS was used to monitor brain activity while participants were experiencing a virtual travel experience. We used a 2-channel portable brain activity measurement device called HOT-2000 [NeU, n.d.], shown in Figure 1. The VR glasses used in this experiment are shown in Figure 2. This device was used because it is lighter than VR goggles, which we believed would reduce the burden on the participants. The participants wear NIRS and VR glasses on their heads and operate the VR glasses with a smartphone. The image of the experiment is shown in Figure 3.

Figure 1: Near-infrared spectroscopy (NIRS) device

Figure 2: VR glasses for watching the videos

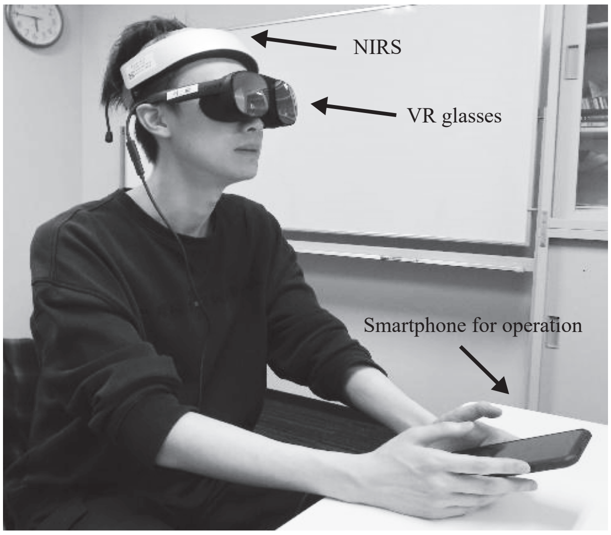

Figure 3: Male subject wearing NIRS equipment and VR glasses in the experiment

3.2 Videos used for the experiment

The virtual sightseeing videos used in this experiment were filmed at four different tourist sites in the suburbs of Tokyo: a park, a mountain, a Japanese garden, and a building (Figures 4, 5, 6, 7). There were three spots per site, each edited to 30 seconds, for a total of 90 seconds of video, and 180-degree and 360-degree video formats were created from them, resulting in a total of eight videos.

3.3 Questionnaires for evaluating virtual tourism contents

In this study, three types of questionnaires were prepared to assess participants' subjective perceptions. First, information

Figure 4: Example of video content: A park with cherry blossoms

Figure 5: Example of video content: At the top of the mountain

Figure 6: Example of video content: Japanese Garden

Figure 7: Example of video content: Tokyo Tower

about the VR experience and travel habits was collected before the experiment began. Second, during the experiment, impressions of each video were collected. At the end of the experiment, participants were asked about their overall impressions after watching the videos and how they envisioned their future life. The questions in these questionnaires are shown in Tables 1 and 2.

The questions in each questionnaire were categorized and comparisons were made in each category. The questionnaire on impressions has three categories: satisfaction, emotion, and comparison with a real trip (Table 1). The questionnaire on effects has two categories: impact on future life, and overall

Table 1: Questions for evaluating impression on the video contents and categories of questions

No.	Impression Question	Category
1	I was satisfied with the virtual sightseeing experience.	Satisfaction
2	I felt like I was really there.	
3	Increased willingness to visit tourist destinations that they have experienced virtually.	
4	I would recommend virtual tourism to others.	
5-1	I had fun when I experienced virtual tourism.	Emotion
5-2	I was healed when I experienced virtual tourism.	
5-3	I was able to relax when I experienced virtual tourism.	
5-4	When I experienced virtual tourism, my heart was enriched.	
5-5	It was refreshing to have a virtual tourism experience.	
6	How does it compare to actual tourism?	Comparison with a real trip

Table 2: Questions for evaluating effectiveness of the video contents and categories of questions

No.	Effectiveness Question	Category
1	Increased motivation to take care of their health and physical condition in future.	Impact on future life
2	Increased willingness to go out daily in future.	
3	Increased willingness to travel in future.	
4	Increased willingness to communicate in future.	
5	Increased willingness to participate in society in future.	
6	Increased motivation for rehabilitation and exercise in future.	
7	Which do you think is better, a smartphone or VR glasses?	Overall comparison
8	Which provided a greater sense of presence (the feeling of being there) for you, the smartphone or the VR glasses?	
9	Which do you think is better, VR glasses or a smartphone? (180-degree)	
10	Which do you think is better, VR glasses or a smartphone? (360-degree)	
11	Which do you think is better, 180-degree or 360-degree? (smartphone)	
12	Which do you think is better, 180-degree or 360-degree? (VR glasses)	

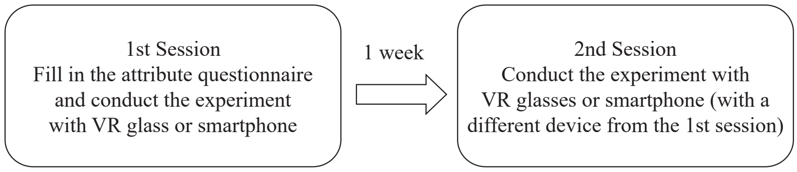

Figure 8: Overall sequence of the experiment

comparison (Table 2). Each questionnaire question was rated on a 5-point Likert scale, with 1 being "strongly disagree" and 5 being "strongly agree."

3.4 Experimental procedure

The experiment was conducted in two separate sessions. Participants were divided into two groups. One group first watched the videos using VR glasses, and one week later watched the videos using a smartphone. The other group watched the videos in the reverse order. The eight videos were watched in random order, with care taken to ensure that the same destination was not watched consecutively. The overall order of the experiment is shown in Figure 8 and the procedure of the experiment in each session is shown in Figure 9.

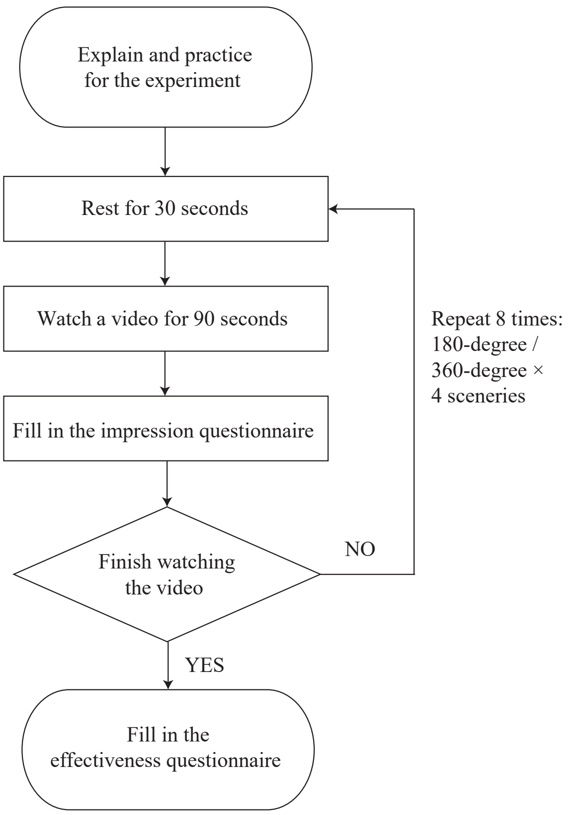

Figure 9: Procedure of experiment for each session

4. Results

The following results were obtained from the abovementioned experiments. For the questionnaire results, the scores for questions in the same category were averaged to make the following comparisons:

- A comparison of 180-degree videos and 360-degree videos when viewed with a smartphone.
- A comparison of 180-degree videos and 360-degree videos when viewed with VR glasses.
- A comparison of VR glasses and a smartphone when viewing 180-degree video.
- A comparison of VR glasses and a smartphone when viewing 360-degree video.
- An overall comparison between VR glasses and a smartphone.

For analysis, the following *Z*-score was used. The *Z*-score is a measure of how far a given data point is from the mean of the distribution, in units of standard deviation. The changes in cerebral blood flow shown in Figure 10 are the averages of the *Z*-score for both the right and left sides of the brain.

$$z = \frac{X - \mu}{\sigma} \qquad (1)$$

In this equation, X is the observed data point, μ is the mean, and σ is the standard deviation. In this experiment, X is the NIRS HbT change (change in blood flow). The mean μ and standard deviation σ are calculated using values from the last 20 seconds of the rest period. The *Z*-score is calculated from the beginning of the viewing of the virtual tourism content. In order to avoid discrepancies in each data, the *Z*-score at the start of viewing is corrected to 0 and used for data analysis. If the *Z*-score is 0, the data point is identical to the mean, and a positive or negative value indicates deviation from the mean. This score can be used to standardize and compare data from different distributions and scales. When the *Z*-scores for two types of contents or devices (180-degree video vs. 360-degree video, or a smartphone vs. VR glasses) shows the difference in its comparison, the content or device with the lower score seems to give a more relaxed experience. Because the data used in this analysis is the change in blood flow and when the change of blood flow illustrates lower values, it means that the brain activity seems less active, which could explain the subject may be more relaxed.

The *Z*-scores displayed in Figure 10 represent the averaged values across the 9 participants during the viewing of the 90-second video, which consists of four types of 15-second scene. At each second on the x-axis of the graph, all experimental participants watched the same video content, but the specific view they paid attention to could be different due to the type of video versus the audiovisual device.

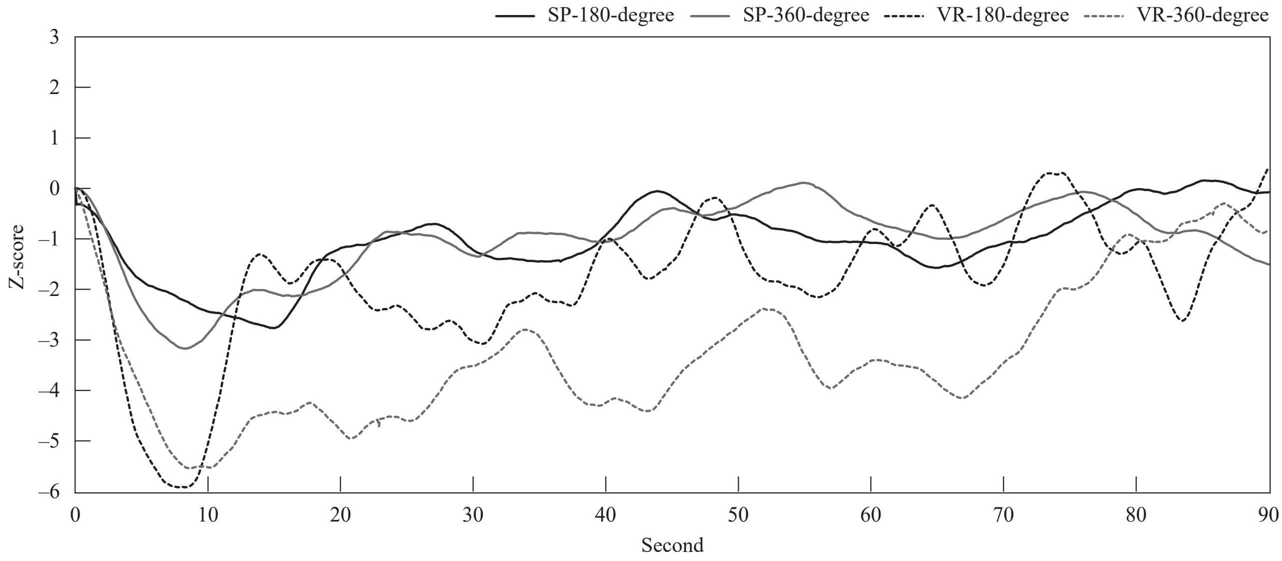

Figure 10: Comparison of the *Z*-scores between smartphone and VR glasses

4.1 Comparison between 180-degree and 360-degree videos (smartphone)

As shown in Table 3, 360-degree videos were more popular for experiencing virtual trips using a smartphone. However, in comparison with real trips, the mean values for both 180-degree and 360-degree videos were less than 3, and neither was as good as real trips. As shown in Figure 10, there is little difference in the change of values in 180-degree and 360-degree videos.

4.2 Comparison between 180-degree and 360-degree videos (VR glasses)

As shown in Table 3, 360-degree videos were more popular than 180-degree videos when using VR glasses to experience virtual travel. However, both video-viewing experiences were not as good as the real trip. Observing the curves in Figure 10, it becomes apparent that the curve corresponding to the 360-degree video is notably lower than that associated with the 180-degree video when participants are viewing content through VR glasses. This discrepancy suggests a hypothesis that under these conditions, 360-degree videos induce a more relaxed experience compared to their 180-degree counterparts.

4.3 Comparison between VR glasses and smartphone

The results shown in Table 4 collectively indicate that overall, VR glasses are preferred over a smartphone, but smartphones are slightly higher than VR glasses in terms of future impact on users. As can be seen in Figure 10, both curves for VR glasses are lower than the two curves for a smartphone, which suggests that both 180-degree and 360-degree video use of VR glasses leads to better relaxation than smartphones. Regarding the subjective opinions of the participants, from the results in Table 5, almost all of them preferred VR glasses and 360-degree videos. In response to Question 8 (Effectiveness Question) of the questionnaire, all nine participants in the experiment unanimously concurred that virtual reality (VR) offers a more immersive experience compared to smartphones.

Table 3: Comparison of average rating on impression questionnaire

		Smartphone average		VR glasses average	
		180-degree	360-degree	180-degree	360-degree
Impression question	Satisfaction	2.75	3.23	3.60	3.95
	Emotion	3.01	3.37	3.51	3.80
	Comparison with a real trip	1.23	1.44	1.39	1.78

Table 4: Total average rating on impression and effectiveness questionnaires

		Smartphone average	VR glasses average
Impression question	Satisfaction	2.99	3.77
	Emotion	3.19	3.65
	Comparison with a real trip	1.34	1.58
Effectiveness question	Impact on future life	2.98	2.94

Table 5: Results for participants on comparison questions in the effectiveness questionnaire

	Effectiveness question (n = 9)			
	Question No.	Smartphone	VR glasses	Almost same
Comparison	7	0	8	1
	8	0	9	0
	9	1	7	1
	10	1	8	0
	Question No.	180-degree	360-degree	Almost same
	11	1	7	1
	12	0	9	0

5. Discussion and conclusion

The analysis of questionnaire results and NIRS signal data in the experiment shows that 360-degree video content is more likely to be preferred than 180-degree video content by young people. The results also suggest that VR glasses are preferred compared with smartphones as a device for virtual tours. Both virtual tours are relaxing, but the relaxation effect of VR glasses is more pronounced. We believe that the relaxation effect may have been achieved because the videos in this case featured many scenes of parks, forests, and other natural settings. Based on these results, we believe that it may be preferable to experience 360-degree videos in a VR space using VR glasses.

These results imply that VR glasses may offer an enhanced virtual travel experience when contrasted with smartphones. Nonetheless, the positive influence on the emotional state and the prospects of young Japanese individuals remains inconspicuous. This could potentially be attributed to the current limitations in the clarity and video quality of virtual sightseeing content, which may not be sufficiently stimulating for the younger demographic. However, the effects may vary for individuals in other age groups. In light of these findings, future efforts should focus on the selection of exceptionally rare and spectacular scenic destinations in order to enhance the appeal of virtual tour content. In addition, we plan to conduct experiments on individuals from different age groups to verify whether the relaxation effects of VR glasses and 360-degree videos are universally applicable.

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