Research Letter

Deriving tourism activity ability through participation in virtual sightseeing tours for frail and pre-frail people

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Abstract

To promote tourism among the elderly, this study attempted to derive the tourism activity ability of 10 elderly individuals using a previously developed virtual sightseeing tour system. The recruited subjects were self-reported as frail or pre-frail. A course with an elevation change of 2 km was prepared, lasting up to 90 minutes, and subjects walked until fatigued. Seven subjects were able to complete the tour at the set pace. Fatigue from tour participation was measured using objective indicators: heart rate, number of steps, and amount of activity. Subjective indicators were assessed using the Japanese version of the Multidimensional Fatigue Inventory and the Visual-analog Scale. Principal component analysis was performed on these five variables (three objective and two subjective). Tourism activity ability was derived from the principal component scores and tour observations. Ultimately, enabling elderly individuals to objectively assess their own tourism activity ability and to formulate realistic travel plans based on this assessment is expected to enhance their willingness to participate in tourism and contribute to tourism promotion. As a foundational stage toward this objective, this study enabled the derivation of tourism activity ability among frail and pre-frail elderly individuals, for whom outdoor experiments are difficult, by employing a virtual sightseeing tour system.

Keywords

tourism activity ability, virtual sightseeing tour system, objective and subjective indicators, principal component analysis, frail and pre-frail people

1. Introduction

Japan's total population peaked in 2018 and has since declined, raising concerns about the shrinking domestic travel market. While the inbound market is expected to continue growing, it remains vulnerable to factors such as infectious diseases and international political situations. Therefore, maintaining and expanding the domestic market is essential for securing a stable traveler base [Kakee, 2015].

According to the Travel and Tourism Consumption Trends Survey, the average number of domestic overnight trips for tourism and recreation purposes in 2023 was 1.36 [Japan Tourism Agency, 2023]. By age group, people up to their 60s were at or above the average, but for those in their 70s, it was 1.12 trips for men and 0.95 trips for women, and dropping further for those in their 80s. Factors inhibiting overnight tourism trips include "lack of financial means" and "lack of time" at high rates across all age groups. However, by age group, "health reasons" became the highest factor for those aged 70 and above [Japan Tourism Agency, 2019].

Sawada and Oyabu [2023] defined tourism activity ability as "the ability to enjoy sightseeing at a destination without feeling fatigued the following day." An experimental tour was conducted at Kenrokuen Garden in Kanazawa City, a designated special place of scenic beauty in Japan. It was revealed that for older adults gaining awareness of their own tourism activity ability leads to increased confidence. Furthermore, it suggests that elderly individuals with health concerns may experience reduced travel anxiety and increased motivation to travel by understanding their tourism activity ability. To verify this effect, Sawada and Matsuo [2025] developed a virtual sightseeing tour system for fatigue assessment accessible to elderly individuals experiencing frailty or pre-frailty. Frailty refers to a state of increased physical, mental, and social vulnerability associated with aging, representing an intermediate stage between healthy status and requiring care. Pre-frailty denotes the stage preceding frailty, representing an intermediate stage between healthy status and frailty.

This study aims to derive the tourism activity ability of frail and pre-frail elderly individuals using a developed virtual sightseeing tour system.

2. Virtual sightseeing tour system

Figure 1 shows the system developed by Sawada and Matsuo [2025]. This system replicates the experimental tour conducted by Sawada and Oyabu [2023] indoors and was constructed at a university in Japan. Three projectors and three screens were placed in a 1st floor classroom. Subjects were assigned standing positions in front of each screen. They watched a guide video on Screen A, then moved to Screen B. At Screen B, they watched a video for the next explanation spot and moved to Screen C. After viewing the next video on Screen C, subjects exited the classroom, passed through the hallway and cafeteria, and returned to the original classroom. This sequence was repeated 11 times. The 90-min course at Kenrokuen Garden concluded with climbing stairs to the top of the artificial hill (Mt. Tsukiyama). Since the height of Mt. Tsukiyama was nearly identical to the height of the 3rd floor of the university building where the system was installed, subjects climbed the stairs to the 3rd floor and viewed an explanatory video about Mt. Tsukiyama summit on Screen D inside the classroom. To ensure the total walking distance was 2 km, during the 11 repetitions on the 1st floor, only once did subjects exit the classroom immediately after viewing Screen A and proceed around the cafeteria. Target passage times were set for each explanation spot to ensure the total time spent watching videos and moving was 90 minutes. The time required to exit the 1st floor classroom, pass through the cafeteria, and return to the original classroom was set at 2 minutes and 20 seconds, and subjects were guided accordingly.

The primary objective of this study was to derive the tourism activity ability of elderly individuals. As the next step, we aim to examine psychological changes, including whether awareness of their own tourism activity ability can motivate them to participate in actual travel. For this purpose, we developed a virtual environment that reproduces the atmosphere of Kenrokuen Garden.

3. Experiments using the constructed system

3.1 Subjects

Elderly individuals with frailty or pre-frailty were recruited as subjects. Using the National Center for Geriatrics and Gerontology's revised J-CHS criteria [National Center for Geriatrics and Gerontology, 2020], applicants self-assessed or had family members assess their frailty or pre-frailty status. Subjects included 3 men (1 in his 70s, 1 in his 80s, 1 in his 90s) and 7 women (2 in their 70s, 3 in their 80s, 2 in their 90s) living at home.

3.2 Experimental methods

The experimental procedure is shown in Figure 2. To derive tourism activity ability, objective indicators—heart rate, number of steps, and amount of activity—were measured. Additionally, two types of fatigue surveys, described later, were conducted as subjective indicators. Subjects completed Fatigue

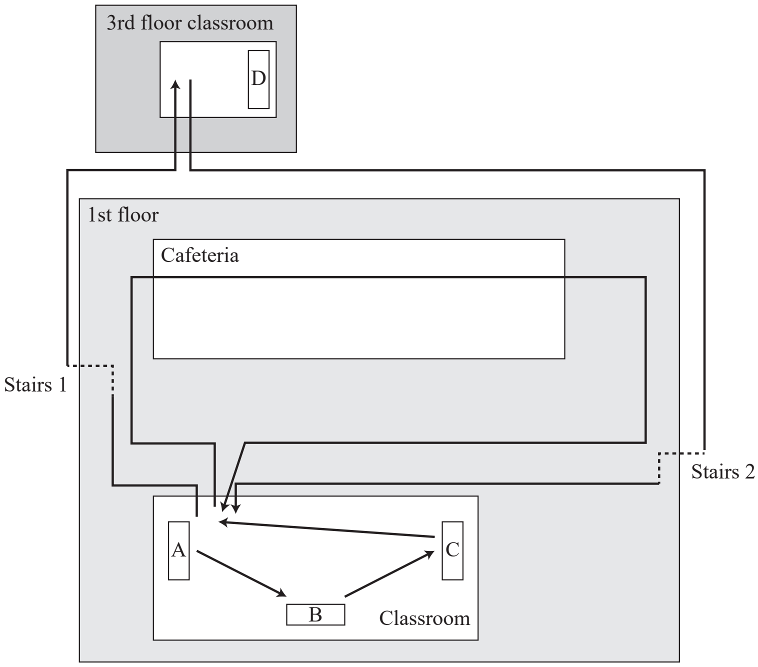

Figure 1: Image of the virtual sightseeing tour system

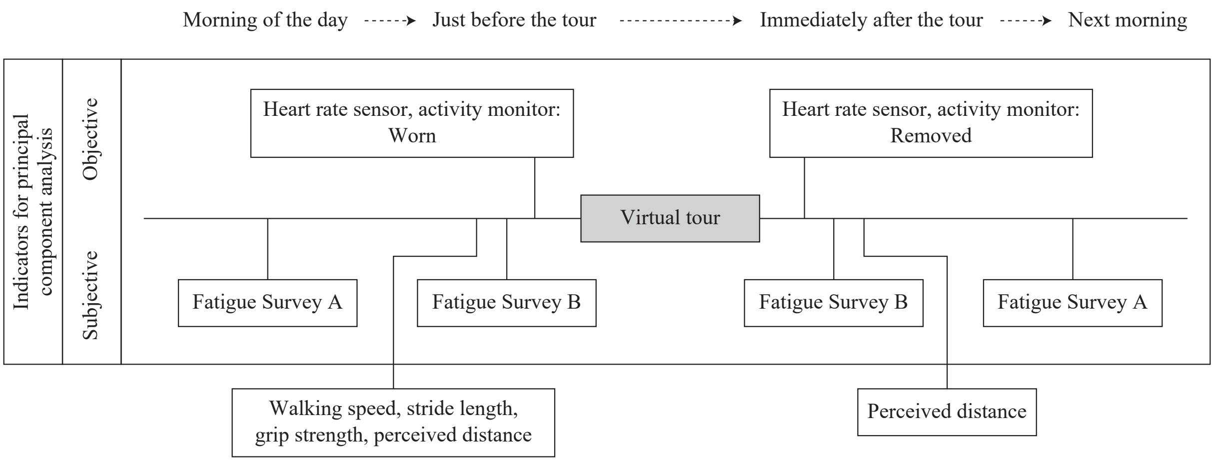

Figure 2: Experimental procedure

Survey A at home on the day of the virtual tour and the following morning (30 minutes after waking and before breakfast). Fatigue Survey B was conducted immediately before and after the tour. Subjects wore heart rate sensors and activity monitors during the tour.

As an objective indicator, the WHS-3 heart rate sensor (manufactured by Union Tool) was used to measure heart rate variability during the tour. The average heart rate per minute was used to calculate the exercise intensity (HRR) for each minute. The number of minutes exceeding 40 % exercise intensity was counted. Amount of activity and number of steps during the tour were measured using the activity monitor HJA-306 (manufactured by Omron). Amount of activity and number of steps during the tour were calculated from the difference between values immediately before and immediately after the tour.

The Japanese version of the Multidimensional Fatigue Inventory (MFI) [Sugaya et al., 2005] was used as subjective indicator Fatigue Survey A, and the Visual Analog Scale (VAS) was used as Fatigue Survey B. The MFI consists of five factors (20 items): "general fatigue," "physical fatigue," "reduced activity," "reduced motivation," and "mental fatigue." However, since physical fatigue is considered the primary concern in tourism activities [Sawada et al., 2024], the analysis focused on responses to the four items under "physical fatigue." For details on the derivation methods for the number of times exercise intensity exceeded 40 %, the MFI (Physical Fatigue), and the VAS, refer to Sawada and Oyabu [2023].

Initial settings such as stride length, date of birth, weight, and height are required for using the activity monitor. Therefore, immediately before the virtual tour, walking time and number of steps over a 4 m distance were measured to calculate stride length and walking speed. Additionally, grip strength and perceived distance were measured. Grip strength is one factor in assessing frailty. Perceived distance was not analyzed in this study. A photo taken during the virtual tour is shown in Figure 3.

Before the tour began, subjects were informed of the following and guided at the set pace:

Figure 3: Virtual tour scene

- The course is up to 90 minutes and 2 km long, with stairs up to the 3rd floor at the end; do not overexert yourself.
- The experiment will end if you report feeling too tired to stand or if you fall behind the tour's set pace.

4. Derivation of tourism activity ability

Sawada and Oyabu [2023] established the following three courses within Kenrokuen Garden:

- Course A:
  40 minutes, 700 m (no significant elevation changes)
- Course B:
  60 minutes, 1.3 km (some slight elevation changes)
- Course C:
  90 minutes, 2 km (including steep stairs)

Principal component analysis was then performed using SPSS (ver. 25) on the five types of data obtained from the experiment: amount of activity, number of steps, number of times exercise intensity exceeded 40 %, MFI (physical fatigue), and VAS. The results showed that all factor loadings for the second principal component were positive. Since the value of the second principal component increased as the values of all variables increased, this second principal component was designated as "overall fatigue level."

Figure 4 shows a scatter plot of the first principal component scores and the second principal component scores. Table 1 shows the principal component score coefficient matrix. Higher values for the second principal component score indicate higher fatigue levels. In this study, the standardized values of the five variables in the virtual tour were substituted into the second principal component score coefficient matrix in Table 1 to calculate the second principal component scores. The results are shown in Table 2. The subject number in Table 2 corresponds to the numbers in Figure 4. The plots for the 40-min, 60-min, and 90-min courses in Figure 4 are the results from Sawada and Oyabu [2023]. The plots labeled "Virtual" are the results from the subjects in this study. Among the 10 subjects, 3 fell significantly behind the set pace and were excluded from the principal component analysis. Figure 4 plots the 7 subjects who were able to participate in the tour at the set pace and indicates the time they participated.

Subjects (1) and (2) participated in the tour at the set pace until the end. Although there were stairs up to the 3rd floor at the end of the course, they climbed them without difficulty. This means they walked the same 2 km course as the 90-min course in Figure 4. For the 90-min course of the experimental tour at Kenrokuen Garden, the minimum second principal component score for all participants was –0.484, and the maximum was 1.232. All participants were judged capable of participating without difficulty in a 90-min, 2 km tour with elevation changes. Subject (1)'s second principal component score was 0.311, and behavior during the tour showed no particular issues, leading to the judgment that they could participate without difficul-

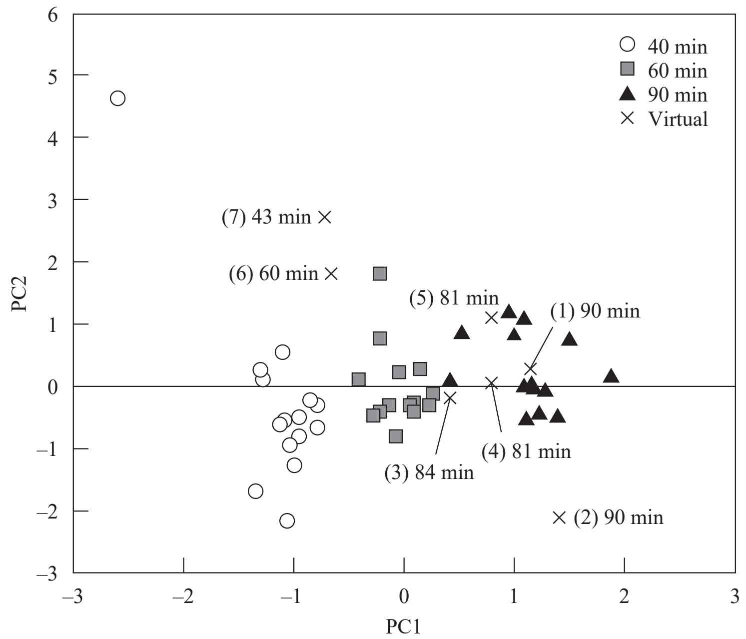

Figure 4: Scatter plot of principal component scores

Table 1: Principal component score coefficient matrix

	Components		
	1	2	3
Number of steps	0.489	0.209	0.048
HRR 40 %	–0.171	0.633	0.006
VAS	0.056	0.424	–0.763
MFI (Physical fatigue)	–0.118	0.501	0.589
Amount of activity	0.490	0.084	0.184

Notes: Factor extraction method = Principal component analysis. Component scores.

Table 2: Second principal component scores in virtual tours

Subject no.	Tour participation time (minute)	Second principal component scores
(1)	90	0.311
(2)	90	–2.070
(3)	84	–0.176
(4)	81	0.057
(5)	81	1.122
(6)	60	1.835
(7)	43	2.718

ty in a 90-min, 2 km tour with elevation changes. Subject (2)'s second principal component score was –2.07. A negative value indicates reduced fatigue compared to before the experiment. During the experimental tour at Kenrokuen Garden, negative values were particularly common on the 40-min course. Based on Subject (2)'s second principal component score and behavior during the tour, they were also judged to be able to participate without difficulty in a 90-min tour covering 2 km with uphill and downhill sections.

Subject (3) participated in the tour at the set pace for 84 minutes and walked 1670 m. Subjects (4) and (5) participated in the tour at the set pace for 81 minutes and walked 1670m and 1500m, respectively. Subject (3)'s second principal component score was –0.176, Subject (4)'s was 0.057, and Subject (5)'s was 1.122. Based on the second principal component score and their performance during the tour, it was determined that they could participate without difficulty in an 80-min tour with no significant elevation changes.

Subject (6) participated in the tour at the set pace for 60 minutes, though occasionally falling slightly behind, walking 1,200 m. The second principal component score was 1.835. The minimum second principal component score for all participants on the 60-min course at Kenrokuen Garden was –0.801, and the maximum was 1.825. Based on the second principal component scores and their behavior during the tour, it was judged that they "can participate in a 60-min tour without significant elevation changes," avoiding the phrase "without any problems."

Subject (7) participated in the tour at the set pace for 43 minutes, walking 818 m. During video viewing, the subject repeatedly flexed and extended their knees. Their second principal component score was 2.718. For the 40-min course of the experimental tour at Kenrokuen Garden, the minimum second principal component score for participants judged as "able to participate without difficulty in a 40-min, 700 m tour with no significant elevation changes" was –2.138, and the maximum was 0.575. The participant with a second principal component score of 4.661 was judged to have "problems participating in a 40-min tour without elevation changes" based on both the second principal component score and their behavior during the tour. For Subject (7), it was determined based on the second principal component score and their behavior during the tour that they "have problems participating in a 40-min tour without elevation changes," and the following explanation was provided.

> You were able to walk for 40 minutes at the tour's set pace. When fatigue levels were derived from heart rate, VAS (difference in fatigue immediately before and after the tour), MFI (difference in fatigue on the day of and the day after), number of steps, and amount of activity, subjective fatigue was high after the tour, indicating a high level of fatigue.

The system used in this study reproduced the actual walking pace of guided tours at Kenrokuen Garden. Since principal component analysis was performed based on data from the experimental tour at Kenrokuen, the virtual tour also assumes walking at the set pace. Consequently, it was not possible to assess the tourism activity ability of three subjects. The walking conditions of elderly individuals vary widely. Some can walk at the set pace but cannot walk for long periods. Others can walk a certain distance at a slow pace but cannot keep up with the set pace. Still others can only walk slowly for short periods. For future research, it is necessary to explore methods for deriving tourism activity ability tailored to various cases.

5. Conclusion

This study attempted to derive the tourism activity ability of 10 frail and pre-frail elderly individuals using a developed virtual sightseeing tour system. The tourism activity ability of 7 subjects who completed the virtual tour at the set pace were assessed. Future research will involve conducting interviews with subjects to clarify whether understanding their own tourism activity ability reduces psychological distance toward sightseeing tours and motivates them to go out.

Acknowledgments

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