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Exploring Voice Navigation System Usage in Healthy Individuals: Towards Understanding Adaptation for Patients with Dementia

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Abstract Dementia, a leading cause of death, often initiates with spatial cognitive impairment. Assisting spatial cognition may not only address challenges faced by individuals with spatial cognitive impairment but also facilitate the prevention of dementia. While previous studies have explored voice navigation for the visually impaired, its utility for those without visual impairment remains unexamined. To provide insights for spatial navigation in the elderly, in the present study, we evaluated the usefulness of voice navigation in healthy university students. In a randomized controlled trial, forty students were assigned to either a paper map only group or a paper map and Google Maps voice navigation group and instructed to navigate a predetermined 800-meter route in a park. The effectiveness of voice navigation was evaluated through various means, including time taken to reach the destination, accuracy of the route followed, and participants' experience. The results show that the two groups did not differ in terms of goal completion and time consumed. Nor did they differ in feelings of drowsiness, instability, uneasiness, pleasure, and relaxation. However, participants in the paper map only group demonstrated a decrease in local pain and eyestrains together with improved feelings of vigor at the goal compared to the start, which was absent in participants using both paper map and voice navigation. Although the effectiveness of the voice navigation was not confirmed, our study did provide important insights regarding in what ways voice navigation can be improved. Moreover, we were able to observe mood improvements in participants with a paper map only, which may indicate the effect of physical activity and exposure to the natural environment.

Key words: voice navigation system, usage, healthy individuals

Introduction

The average life expectancy in Japan reached 81.47 years for men and 87.57 years for women in 2021, thanks to medical advancements. As of October 1, 2022, the percentage of people aged 65 and over in Japan (aging rate) was 29.0%,[1] classifying it as a super-aged society. Concurrently, the prevalence of dementia has escalated, affecting approximately 4.62 million individuals in 2012, representing 15% or 1 in 7 of those aged 65 and over. This figure is projected to rise to 7 million (20%) by 2025.[2] As dementia rates surge, it has become one of the leading causes of death, ranking 9th for Alzheimer's disease and 10th for vascular and other dementias in 2021.[3]

The challenges of dementia extend beyond healthcare. Hospitalization of dementia patients often leads to prolonged stays due to comprehensive care needs, complicating the discharge or transfer procedures. In this context, "aging in place," or receiving care in one's familiar environment until the end of life, becomes crucial for maintaining dignity in Japan's hyper-aged society.

Dementia is classified into four types: Alzheimer's, cerebrovascular, Lewy body, and frontotemporal. There is ongoing progress in developing therapeutic drugs and the effectiveness of fundamental drugs, from those that slow the progression of the disease to those that potentially cure it. This advancement was announced in November 2022, offering hope for treatments for Alzheimer's disease.[4,5]

Alzheimer's dementia often begins with spatial cognitive impairment,[6,7] a complex ability involving processing distance, angle, and direction information.[8] While mild cognitive impairment increases the risk of progressing to dementia, a certain percentage of individuals revert to normal cognitive function, highlighting a potential window for dementia prevention.[9] Therefore, enhancing spatial cognition is expected to support the prevention of Alzheimer's dementia. In addition, supporting spatial cognition may help maintain physical activity, potentially delaying or preventing dementia onset.[10]

Our study focuses on voice navigation as a tool to aid spatial cognition, particularly targeting the challenges experienced by individuals with spatial cognitive impairment who often encounter challenges in interpreting maps and other visual-spatial information. While previous studies have explored voice navigation for the visually impaired,[11,12] its application for those without visual impairment remains unexamined. To assess the usefulness of voice navigation in supporting spatial cognition among older adults and people with disabilities, we first need to understand its effectiveness in healthy individuals. This study, therefore, aims to evaluate the impact of voice navigation on healthy college students.

Methods

Study design

This study was a single-blinded, randomized controlled trial (RCT).

Participants

Forty college students were recruited from the authors' university through voluntary participation. Exclusion criteria included the inability to walk normally due to conditions such as broken bones or poor physical condition, and age over 30 years. The study was approved by the Institutional Review.

Board of the last author (Approval No. 747-3) and conducted per the latest version of the Declaration of Helsinki. Participants provided written informed consent before the study following detailed explanations about the study.

Procedure

Participants were randomly assigned to either an intervention group or a control group, with 20 individuals in each (see Figure 1). The randomization was conducted using the website Randomization.com, maintained by Dr. Gerard E. Dallal. Forty subjects were randomized into ten blocks, the scheme of which can be replicated using the seed 12027. The intervention group used both a paper map and Google Maps voice navigation, whereas the control group relied solely on a paper map. Google Maps was used to assess the effectiveness of voice navigation due to its widespread usage. Before beginning,

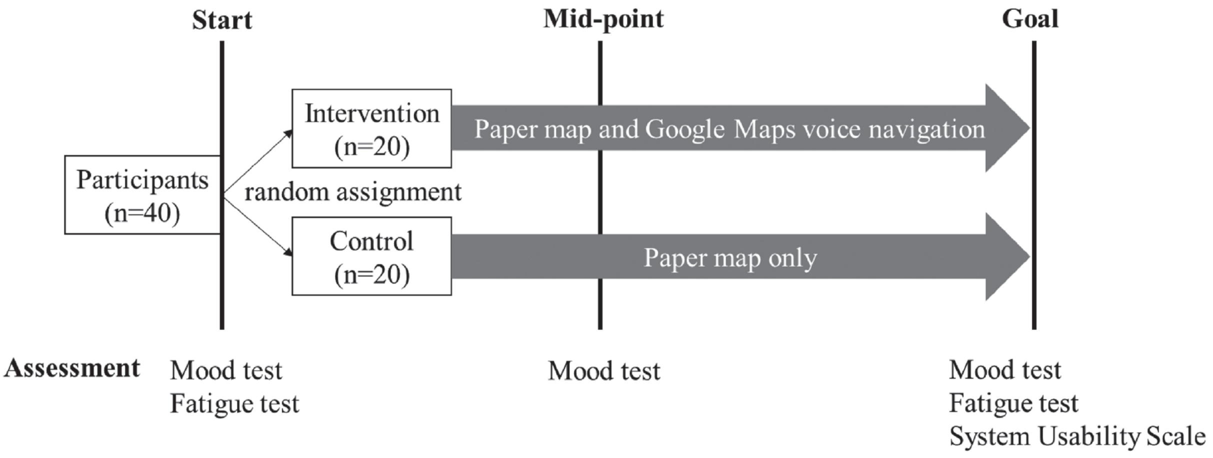


Fig. 1 Flow diagram of the study procedure

each participant was given a paper map and received the following instructions from the same researcher: 1) to walk along a predetermined route (approximately 800 meters) in the park to reach the goal and 2) to walk along the transit points (see Figure 2). If the participants could not continue the experiment for any reason, such as feeling unwell or losing their way, they could contact the researcher who was following them from a distance of 4 meters. The researcher observed from a distance to ensure safety and minimize interference. The study measured the effectiveness of voice navigation through various methods, including the time taken to reach the destination, the accuracy of the route followed, and participants' experiences. Specifically, mood and fatigue tests were conducted at the start and goal points, with the mood test also being administered at the mid-point. At the goal point, participants in the intervention group also filled out the System Usability Scale (SUS).

Fig. 2 The predetermined 800-meter route within Tokiwa Park in Ube City, Yamaguchi Prefecture

Assessments

Mood test: The Chen-HAgiwara Mood Test (CHAMT), which consists of three test items evaluating pleasure, relaxation, and vigor using a 100 mm visual analog scale,[13,14] was employed to evaluate participants' mood at the beginning (start point), middle, and end (goal point).

Fatigue test: The Fatigue Feelings Test (Jikaku-sho Shirabe) developed by the Japan Society for Occupational Health[15] was employed. This test uses 25 items to evaluate feelings of drowsiness (Factor Ⅰ), instability (Factor Ⅱ), uneasiness (Factor Ⅲ), local pain or dullness (Factor Ⅳ), and eyestrain (Factor Ⅴ).

System Usability Scale: A satisfaction survey of voice navigation using the SUS, developed by John Brooke,[16] was employed. This scale uses 25 items rated on a 5-point ordinal scale. In general, scores below 70 indicate a possible lack of consideration for usability, whereas scores above 70 indicate satisfaction with usability.

In addition to the above assessments, participants also underwent a cognitive test before the RCT using touchscreen devices known as the Cognitive Function Evaluation Support System “Touch M,” developed by Human Corporation.[17]

Data analysis

Statistical analysis was conducted using IBM SPSS Statistics version 27. We used the Chi-square test and Fisher’s Exact Test (when the expected count of a cell is below 5) to compare ratios across groups. For continuous variables, the selection between the independent sample t-test and the Mann–Whitney U test was determined by the normality of the data. The repeated measures analysis of variance (ANOVA) was employed to analyze the means of multiple within-subject measurements. Where a significant group*time interaction was detected, a paired test or Wilcoxon Signed Rank Test was employed to compare changes within each group. The significance level was set at $p < 0.05$.

Results

Participants’ characteristics

As reported in Table 1, the 40 participants included 7 male and 33 female participants, with an average age of 20.85 ± 1.55 years. There was no significant difference in the distribution of sex ($p = 1.000$, Fisher’s Exact Test) and age ($p = 0.841$, Mann–Whitney U test) between the control and intervention groups. The mean percentage of correct responses by Touch M was 89.05% ± 11.09% in the control group and 88.45% ± 11.75% in the intervention group, with no significant difference between the two groups ($p = 0.925$, Mann–Whitney U test). There was no difference in the rate of participants who had ever been to the park between the control and the intervention groups ($p = 0.744$, χ^2 test).

Goal completion and time consumed

Table 2 shows that 20 participants in the control group and 17 in the intervention group reached the goal, with no significant difference between the two groups ($p = 0.231$, Fisher’s Exact Test). For these participants, the average time taken to reach the goal was 607.60 ± 123.84 seconds in the control group and 657.76 ± 257.17 seconds in the intervention group, with no significant difference between the two groups ($p = 0.869$, Mann–Whitney U test). Among those who reached the goal, three participants in the control group and five in the intervention group used the correct route, with no significant differences between the groups ($p = 0.428$, Fisher’s Exact Test).

Table 1 Participants’ characteristics

Item		All (n=40)	Control (n=20)	Intervention (n=20)	p-value	Statistical method
Sex	Male	7	4	3	1.000	Fisher’s exact test
	Female	33	16	17		
Age (years SD)		20.85 ± 1.55	20.80 ± 1.70	20.90 ± 1.41	0.841	M-W U test
Touch M score (% SD)		88.75 ± 11.28	89.05 ± 11.09	88.45 ± 11.75	0.925	M-W U test
Previous visit		25	13	12	0.744	χ^2 test
Previous visit (times SD)		1.30 ± 1.42	1.35 ± 1.57	1.25 ± 1.29	0.989	M-W U test

Table 2 Comparison of outcome

Item	All (n=40)	Control (n=20)	Intervention (n=20)	p-value	Statistical method
Goal completion	37/40	20/20	17/20	0.231	Fisher’s Exact Test
Time to Goal (Seconds)	630.65 ± 195.27	607.60 ± 123.84	657.76 ± 257.17	0.869	M-W U test
Participants following the correct route	8/40	3/20	5/20	0.428	Fisher’s Exact Test

Mood and fatigue

Regarding the fatigue survey (Figure 3), the repeated measures ANOVA revealed no significant group*time interaction for drowsiness, instability, and uneasiness (all p > 0.10). However, there was a significant group*time interaction for local pain (F = 5.382, p = 0.026) and eyestrain (F = 4.253, p = 0.046). Meanwhile, participants in the control group exhibited a reduction in local pain and eyestrain at the goal compared to the start (p = 0.031 and 0.039, respectively, Wilcoxon Signed Rank Test). In contrast, participants in the intervention group did not experience any significant changes in local pain or eye strain (p = 0.480 and 0.665, respectively, Wilcoxon Signed Rank Test).

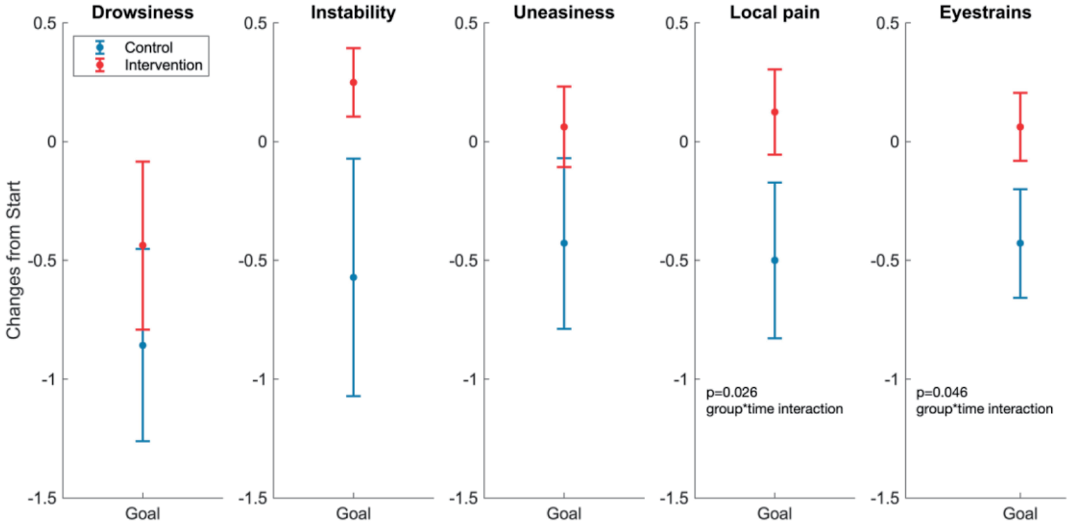
For the mood survey (Figure 4), the repeated measures ANOVA showed no significant group time interaction for pleasure and relaxation (all p > 0.50). However, there was a significant group time interaction for vigor (F = 4.711, p = 0.020). Participants in the control group exhibited an increase in vigor from the start to the mid-point (p = 0.006, paired t-test), which was maintained until the goal (compared to the start, p = 0.010, paired t-test). In contrast, participants in the intervention group did not show any significant change in vigor across the three points (all p > 0.50).

Removing the influence of previous visits to the park

Among all participants, 15 (37.5%) had previously visited the park twice or more times. Excluding these participants removes the significant group*time interaction for local pain (F = 3.757, p = 0.061) and eyestrains (F = 3.421, p = 0.074) while leaving other results unchanged. There was no significant difference regarding goal attainment, time taken, or use of the correct route. For mood, repeated measures ANOVA revealed a significant group*time interaction for vigor only (F = 5.379, p = 0.015). Participants in the control group demonstrated an increase in vigor from the start to the mid-point (p = 0.004, paired t-test), which was maintained until the goal (compared to the start, p = 0.014, paired t-test). In contrast, those in the intervention group did not show any significant change in vigor between the three points (all p > 0.40).

Post-intervention survey

Participants in the intervention group completed the SUS upon finishing the experiment at the goal point. The mean score was 54.5 ± 19.6. Half of the participants gave ratings of 50 or less (Figure 5). The number of participants giving ratings of 80 or higher was three (15%), while those giving ratings of 70 or higher were 6 (30%).



Group*time interaction indicates the interaction between intervention group and evaluation time.

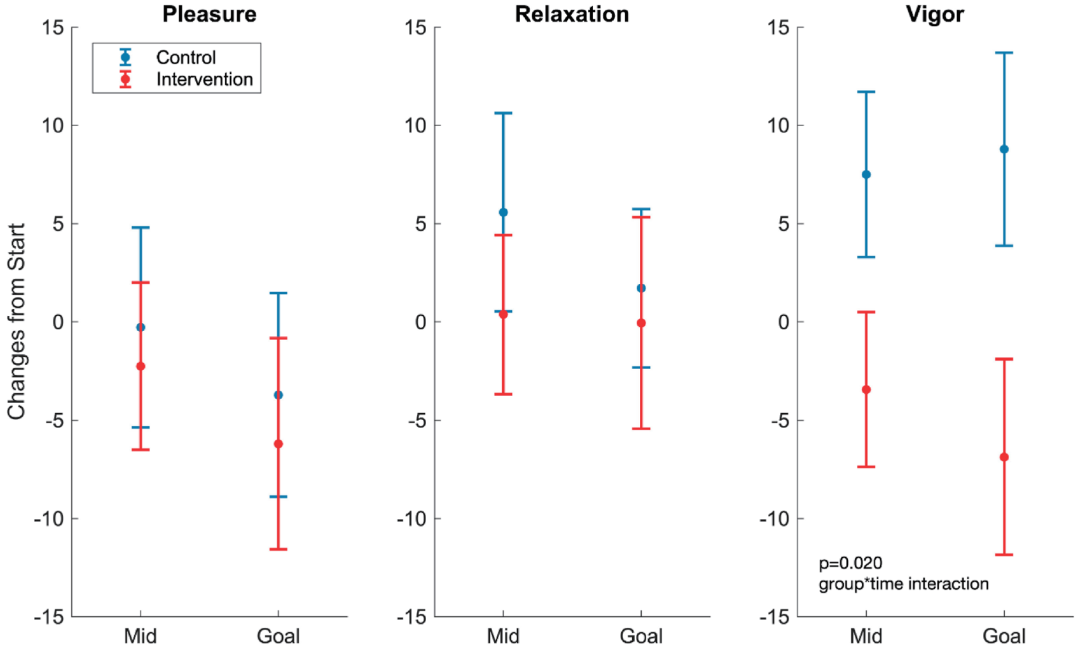
Fig. 3 The effect of intervention on fatigue. Data are shown as mean ± standard error. Control and intervention are shown in blue and red, respectively.

Discussion

Effectiveness of voice navigation

In this experiment, the effectiveness of voice navigation was not confirmed, as no differences in goal completion and time taken were identified. Moreover, the mean score of the satisfaction survey (SUS) was less than 70, indicating limited usability.

In addition, while there was no change in mood and fatigue in the intervention group, participants in the control group demonstrated a decrease in local pain and eyestrains, along with improved mood in terms



Group*time interaction indicates the interaction between intervention group and evaluation time.

Fig. 4 The effect of intervention on mood. Data are shown as mean ± standard error. Control and intervention are shown in blue and red, respectively.

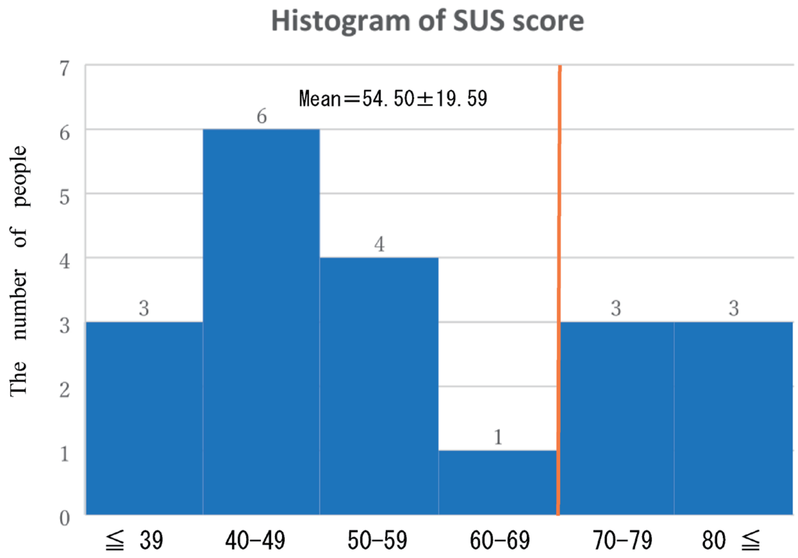


Fig. 5 Histogram of the score of System Usability Scale (SUS) used to evaluate satisfaction with the voice navigation system.

of feelings of vigor at the goal compared to the start point. The control group exhibited significant recovery from fatigue in terms of feeling drowsy and sluggish at the start and the finish line, but this improvement was not observed in the intervention group.

As mentioned in the methods, the current experiment was conducted in a park. Therefore, participants in the control group may have been freely enjoying the scenery of the natural environment and getting to the target location without being distracted by voice navigation. The mood improvement effects of exposure to green natural environments have been well documented.[13,18] In other words, the voice navigation used in this study may have occupied the participants' attention and interfered with the mood-improving effects of the natural environment.

Factors that hindered the effectiveness of voice navigation

It is possible that the voice navigation we used in this study did not work well with the paper map we prepared, as it was originally designed to be used with images that captured location information.

After the experiment, researchers checked the voice navigation and found that there were six navigational instructions given during the whole experiment—three based on cardinal directions (east, north, northwest), and the other three involved turning left twice and turning right once. Therefore, individuals without a sense of direction may struggle to follow the voice navigation system's instructions to head east, west, south, or north.

The fieldwork was conducted in a park with a clear view for safety reasons. However, the absence of landmarks may have made it extraordinarily difficult for participants to understand the voice navigation instructions. If they had been navigated left and right, there might not have been a problem.

Therefore, we cannot conclude that voice navigation is not useful as a spatial cognition support.

Prospects for voice navigation

Voice navigation is beneficial for healthy individuals, but there are numerous challenges in aiding spatial cognition. It is considered effective for linking voice and map (visibility) and for signaling by vibrating the electronic terminal when it is time to make a turn. Furthermore, it was thought that navigating left and right, rather than east, west, north, or south, would be effective for those without a sense of direction.

The use of GPS for individuals with dementia who tend to wander is challenging, and ongoing research aims to create devices tailored to the specific needs of each individual based on their level of disability and mobility.[19] It is anticipated that a navigation system guided by a person's voice could provide reassurance and assistance to individuals with dementia. Therefore, the development of voice navigation systems that are useful for individuals with spatial cognitive impairment will also require more individualization.[12] An over-reliance on devices can potentially put individuals at risk.

Expectations for physical activity

In this study, the control group exhibited some improvements in mood and a reduction in fatigue that were not observed in the intervention group. This is considered to represent the effect of the walk. As mentioned in the introduction, physical activity is one way to prevent dementia.[10] Walking is a physical activity that individuals can easily incorporate into their daily lives because it is less physically and mentally demanding. Therefore, even young and older individuals who do not typically exercise can easily participate in it.

A correlation between being homebound and depressed and cognitive impairment is reported, implying that engaging in outdoor activities can help prevent dementia.[20] Therefore, we recommend that individuals continue to walk safely outside with support as it is more likely to prevent dementia than staying indoors and avoiding going out due to spatial-cognitive decline.

The eventual goal of this study is to develop an outdoor physical activity program that can enhance spatial cognitive function. Our research is just getting started, and the next step is to establish the usefulness of voice navigation, which is accessible even to those without a sense of direction.

Limitation

In this randomized controlled study, for unknown reasons, there was an initial difference between the control and intervention groups in terms of fatigue levels and mood test results. The voice navigation application and the paper maps used in this study were not properly synchronized. Directional instructions were inconsistent, mixing east–west with north–south, and left–right. Additionally, there was a time lag in the delivery of instructions, potentially impacting the study results. These are all limitations of the study. Moreover, the test was conducted during the day, but participants were probably unaware of the direction in which they were facing. Therefore, it is possible that some of the navigation was not effective. Although the experiment was conducted with 40 participants, it was challenging to ensure consistent conditions for all participants. This posed a significant obstacle in demonstrating the effectiveness of a device such as voice navigation.

Conclusion

The results of the voice navigation intervention did not demonstrate the effectiveness of this study. There were no differences from the control group in mood, fatigue, or time required. Additionally, the intervention group presented less satisfactory results. The method of navigating using electronic terminals needs to be examined and improved to enhance support for spatial cognitive functions.

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Institutional Review Board Statement

This study was approved by the Ethical Review Board of Nursing and Laboratory Science Yamaguchi University Graduate School of Medicine (Approval number 747-3). It was conducted in accordance with the principles of the Declaration of Helsinki (2013, Fortaleza Amendment).

Informed Consent Statement

Written informed consent was obtained from all participants involved in this study.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

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