ORIGINAL ARTICLE

NON-INTRUSIVE, VISUAL-LESS WEARABLE HAPTIC STIMULI NAVIGATIONAL ASSISTANCE FOR ELDERLY WITH DEMENTIA

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ABSTRACT

Age is typically affiliated with the decline of cognitive function and the probability to be diagnosed with neurodegenerative disease, namely dementia. Of all dementia-related deficits, the paper highlights on the decline of wayfinding ability, since it is interrelated with mobility, autonomy, caregiving burden and eventually institutionalization. The sense of directions in elderly is also affected by the sensory changes, while the most obvious sensory declines are both vision and hearing. Hence navigation systems that support mainly on visual and auditory may not be the best option for them. A concept of wearable navigational assistance that is non-intrusive and uses haptic stimuli instead of visual and/or audio signals is presented in this paper. A Usability Test (UT) was performed towards the elderly with dementia at a selected nursing home to investigate how they perceive haptic-feedback as a modality of navigation. The assessments involved three phases: (1) orientation or training, (2) navigation test and (3) further navigation test. Results indicate the potential efficacy of haptic modality as a navigation signal. Improvement on subjects' navigational performance was shown especially during the further navigation test, signifying the familiarization of the intervention. Employing the haptic modality could be a beneficial substitute for navigational purpose when vision and audio are less appropriate. Nevertheless, as much as the encouraging outcomes from the results and analysis of the assessments are valuable, the constructive reviews attained are indeed important for the future development of the device system.

Keywords: Elderly with dementia, spatial disorientation, navigational assistance, haptic stimuli, wearable device

INTRODUCTION

Ageing population is not uncommon; it exists in almost all the countries in the world. According to the report by the United Nations on World Population Ageing 2013[1], the section of elderly individuals aged 60 or older has risen worldwide from 9.2% in 1990 to 11.7% in 2013. As a share of the world population, this rate will continue to develop, reaching 21.1% by 2050. Consequently, as the world population ages, the worldwide prevalence of dementia of Alzheimer's disease (AD) type was 26.6 million in 2006, and it is estimated to increase to 106.2 million by 2050[2]. The worldwide ageing of the population will more than triple the projected number of demented persons between 2010 and 2050[3]. Although there are some indications that dementia incidences may be decreasing, current data are scarce and inconclusive[4].

Dementia is an important cause of disability and dependence among older people. AD and other dementias rank as the fourth most important disorder in high income countries after depression, hearing loss, and alcohol abuse, for all age-group[5]. Among older people in countries with low and middle incomes, dementia is the most important independent contributor to disability.

In parallel, older adults are typically experiencing the age-related changes such as slower cognitive functions as well as the decline of sensory acuity and physiological capacities. What makes it worse is that this deterioration of basic needs increases as they grow older. The increasing number of people with disabilities influences the perspective of a growing body of research on technological solutions or assistive technology for these specific needs. In addition, it may lead to a significant impact on the design and development of assistive technology systems, while at the same time demonstrates the potential and niche markets for products designed for older and disabled people.

As users are often considered as the main consumers, users with special needs and unique incapability as well as the senior citizens have always been neglected in view of the design of commonly used or everyday products. The pressing need to design with respect to this group of people should be further encouraged. It is important to find ways to promote the functional capacity of older people to ensure their sustainability in health and social care system, while at the same time enriching the good quality of life.

The key issue emphasized in this paper is the mobility in elderly mainly with cognitive impairment. Mobility refers to a person's ability to move independently and safely from one place to another[6]. Individual's stable mobility is indeed beneficial for everyone and for numerous reasons, regardless of the age ranges. Outdoor mobility for older adults in particular, is highly essential for

accessing the commodities, using public facilities, socializing purposes, and also for physical activities. These necessities and many others are hard to achieve without a stable mobility. Consequently, older adults could not have the access they need the most without the help and supervision from others if their mobility is debilitated. This indicates that one significant factor to maintaining the independence in old age is mobility.

It is the norm that when we grow older, the limitations in mobility are beginning to be noticeable. In fact, mobility decreases with advancing age, and it is the obvious earlier sign of further (physical and social) functional declines[7, 8]. This will result in the increase of assistance, supervision and burdens, which leads to the risk of institutionalization[9].

In conjunction with this, oriented search is linked with cognitive mapping and several other spatial-related cognitive processes[10]. In oriented search, the individual often orientates based on the source of destination, then systematically searches until he/she reaches the intended destination. For normal persons without sensory disability, they tend to rely profoundly on visual, despite the accessibility for the other senses[10].

On the contrary, for persons with visual impairment or blind people, they may be depending on auditory, vestibular (sense of balance) and proprioceptive (sensory receptor that detects the body position/motion by responding to stimuli arising within the organism) information[10]. Nonetheless, in the case of dementia, since the older adults experience sensory decline due to ageing, it affects their sense of directions indirectly. This problem may gradually worsen their spatial cognition[11] that is needed for precise wayfinding. The limitations caused by sensory declines as a consequence of dementia are similar to the limitations caused by senescence (or biological ageing)[12]. The differences could be apparent in terms of interpreting the information gathered.

This paper highlights the question on the possible ways to improve or at least maintain the wayfinding ability (or capability to navigate) of older adults mainly with dementia from the design and technological perspective. Wayfinding disabilities lead to many negative implications on these individuals, their caregivers and society in general.

THE LIKELIHOOD OF VISUAL-LESS NAVIGATIONAL ASSISTANCE

As the most needed sensory for wayfinding, the decline in persons' vision and cognitive aptness due to ageing has an undesirable implication on their spatial skill. The loss of vision affects contrast sensitivity, visual processing and visuospatial that subsequently impairs the ability to orientate and navigate in the environment[13]. However, as we aged similar to vision and hearing, the sense of touch or tactile acuity is also progressively weakened[14, 15]. The weakening of manual function is due to the decreased tactile sensitivity that continues with age[16]. More importantly, during ageing, the perceptual impaired tactile acuity caused by physiological, structural, and metabolic changes may lead to the age-related sensorimotor and cognitive domain declines[17]. Nonetheless, even if this condition has an impact on older adults' cognitive ability, implicit memory for haptic-explored objects is preserved in individuals with mild dementia[18].

The conservation of complete haptic priming is proven with the assessment of a speeded object naming task, even though the recognition performance is highly impaired[19]. As reported, the priming effect is compatible with the healthy older or young adults. In implicit memory, things that we do not try to purposely remember are stored, because it is both unconscious and unintentional.

The most beneficial factor of preserved implicit memory could be to maintain the performance of the daily activities, such as riding a bike, driving a car or simple cooking tasks. Consequently, this would also work for therapeutic and training purposes for elderly with cognitive impairment; for example, in wayfinding intervention strategies that require constant practice of navigation task. Therefore, designing an intervention that involves the continuous practice of a task could benefit the people with dementia.

There is currently an increasing body of studies in the field of mobile human computer interactions (HCI) on the use of haptic or tactile modalities. This distinctive modality has been studied for a multiple application such as the virtual objects haptic feedback system[20], surgical tasks[21], the design of human-computer interfaces[22] and navigational instructions[23, 24, 25, 26]. Nevertheless, the current works aiming on wayfinding or navigational purposes often focus on individuals with severe visual impairment or blind people, not specifically on those with cognitive impairment.

In the study done by Zöllner et al.[23], they conceptualized a mobile navigational assistance with Microsoft Kinect and optical marker tracking for the indoor navigation of individuals with visual impairments. They created a belt embedded with vibrotactile outputs that were used to detect obstacles during wayfinding tasks. Likewise, Ertan et al.[24] in their study outlined a wearable navigation system using a vest-integrated haptic directional display. The system gives haptic signals to the users' back in the course of navigation.

In a different study, Mann et al.[25] reported on a blind navigation system with a Kinect 3D sensor range camera integrated with a vibrotactile helmet. The vibrating actuators embedded inside the helmet convert depth information into haptic feedback, to allow the users in identifying depths for collision avoidances.

Grierson et al.[26] on the other hand aimed to accomplish the similar objective with ours. They investigated the relevance of tactile signals in assisting people with dementia to find their way in their living environment, through the development of a wearable belt with vibrating motors. In their experiment, participants used vibrotactile signals to navigate multiple routes within a hospital.

This is where our design concept initiated but with a twist. It is essential to underscore the potential of haptic/tactile stimuli in order to help or enhance the wayfinding of people with cognitive impairments to cater their distinct requirements and problems. Another important point is that most of the navigational assistances previously described are the wearable technologies or devices. This is most likely because the wearability aspect improves handling and operating practicality[27, 28].

Haptic/tactile feedback offers a straightforward yet promising type of directional cues that enables users to focus on the environment with other senses (vision and hearing) during wayfinding[29]. Additionally, haptic simulation created from the vibrotactile signals are less disruptive than the auditory cues, which is a better substitute for continuous feedback[25].

Technological interventions that utilize haptic/tactile modality to assist wayfinding have shown positive results, though most of them were meant for visually impaired and blind people. Furthermore, most of the existing wayfinding intervention strategies, which include the above-mentioned studies[23, 24, 26] focus on indoor navigation. This means, further research on navigational assistance for outdoor wayfinding purposes are highly recommended.

A CONCEPT OF WEARABLE HAPTIC STIMULI NAVIGATIONAL ASSISTANCE

The goal of the study was to evaluate the potential for haptic stimuli navigational assistance that is wearable and non-intrusive. Based on the consideration of the previous works and the flaws the study thinks necessary to resolve, a new concept of assistive navigational device is proposed. This concept integrates haptic stimuli as the signals, instead of reading a map display or listening to speech instruction in the course of navigation.

The device offers the simplest navigational instruction data possible, which is left or right direction. The straightforward feature is essential to prevent distraction or confusion by the users i.e. people with dementia when using the device in the course of wayfinding[23]. This is important because even a minor interference may cause misdirection to the individuals with dementia. For this reason, as well as for the ease and practicality of handling by the users, this device is also meant to be wearable. The device is designed to be worn on the abdominal area, like a belt and has a close contact to the skin. Waistline is one of the most unobstructive areas for wearables, recommended by Gemperle et al[30].

The device consists of (1) the input: GPS receiver, acceleration sensor, and Secure Digital (SD) card module and (2) the output: haptic signals made of mini vibration motors. Technically, the sensors (GPS and accelerator) are used to detect users' location information that comprises of; (1) the real time location and orientation, (2) starting point and the destination, and (3) series of routes that are saved in the SD card. An Arduino microcontroller is used to control the hardware and process these provided information. When the users navigate on the saved routes, the microcontroller uses the input data from the sensors to trigger the haptic signals.
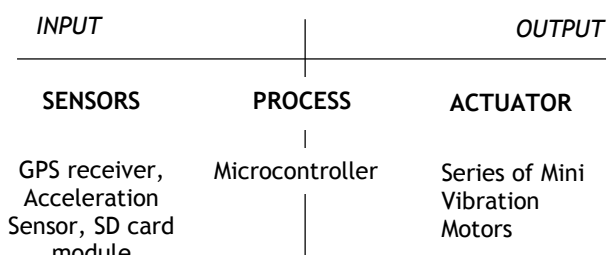
INPUT		OUTPUT
SENSORS	PROCESS	ACTUATOR
GPS receiver, Acceleration Sensor, SD card module	Microcontroller	Series of Mini Vibration Motors

Figure 1: System architecture of the wearable haptic stimuli navigational assistance

Geolocation information based on the positions where the haptic signals should be triggered during navigation is saved in the SD card. These positions are located on the junctions and corners where the users need to turn left/right to reach the designated destination. The series of mini vibration motors which create the haptic signal will be embedded between the two layers of fabrics and sealed together using threads. Figure 1 illustrates the proposed system architecture for the device.

With reference to Figure 2 that visualizes how the proposed navigation system works, to go from point A (home) to point B (local supermarket), there are three routes the user can follow; #1 (Option 1), #2 (Option 2), and #3 (Option 3). In initiating the journey from point A, one may turn left or right and the haptic signals embedded in the navigational assistance will start immediately.

If he/she turns right, #1 will be the choice of route, whereas left is for #2 or #3. In order to go back from B to A, the signal will initiate as soon as the user moves out of the place (B) and directs him/her into the correct route (#1, #2 or #3). During wayfinding, the users need to travel within the estimated range. However (in some inevitable cases), if they happen to accidently go beyond the range, a stronger signal will start immediately to guide them into the correct path.
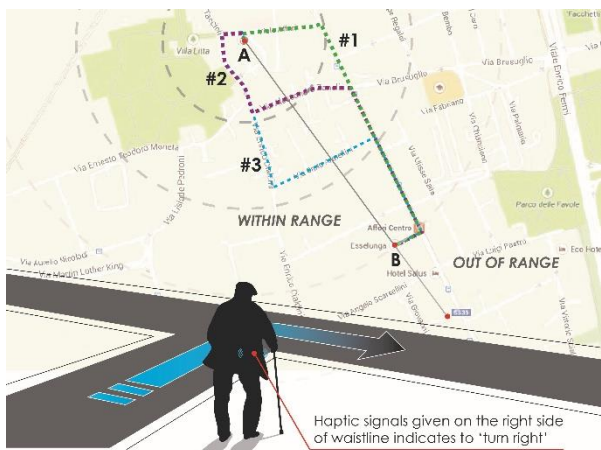

Figure 2: The illustration on how the navigation device works

METHOD

The main evaluation of the proposed concept is the Usability Testing (UT). UT is an essential aspect of user-centred approach that puts the user, at the centre of the development process [31]. Besides, adopting such an approach advocates that the users should be forefront in any design decision. Concisely, this form of assessment is often used to label the method, procedure or strategy used to evaluate a product or system. To be precise, the term UT itself refers to a process that employs people as testing participants who represent the target audience/population to evaluate the degree to which a product meets specific usability criteria[32]. In the test, participants were the older adults with cognitive impairment mainly due to dementia.

The motive behind the selection of this method of assessment is because the main goal of UT itself, which is to identify any usability problems, collect quantitative data on participants' performance[33]. This specific test is typically used to enhance the usability of the product that is being tested, apart of it could probably improve the product design development process by means of reducing the reiterative problems or issues.

EXPERIMENTAL PROCEDURES

In this test, the study used the developed prototype as the apparatus. The device system is designed to be used in a fully outdoor environment, where the GPS receiver functions at its best. The navigation tests were performed in short routes or limited ranges, due to their caregivers' concerns. The aim of this assessment was to investigate how the subjects perceive haptic-feedback as a modality of navigation. The evaluations were divided into three phases: (1) orientation or training, (2) navigation test and (3) further navigation test.

Phase 1: Orientation/Training

The orientation/training phase was necessary in order to get the subjects familiarized with the device system as well as the experimental procedures. This familiarization session did not require a large space. It was done in the common area of the therapy centre, where the patients performed their activities or therapy sessions. However, the navigation test for older people with dementia could be difficult, hence the appropriate participants were identified for the experiment. Likewise, subjects were required to wear the device during the actual navigation tests. This justified the necessities of the orientation phase.

This phase was divided into three sessions. (1) The subjects wore the wearable device and their reaction or acceptance were observed. (2) The subjects were asked if they could feel the haptic signals (in form of vibration) on the designated positions. (3) Finally, they were asked to take a short walk inside the provided space and indicate which sides haptic signals they felt by raising and waving hands.

Phase 2: Navigation Test

The experiment continued with the navigation test towards the subjects who succeeded in the orientation/training phase and with the permission of their caregivers. The selection was made based on the subjects' performances in the first phase and was decided after a comprehensive discussion between the experimenters, therapists and the caregivers.

Each subject's walking speed (m/s) was recorded before starting the navigation test. These recorded data were to be compared with the walking speed while navigating with the device. Participants were asked to make the left/right turns (at the junctions) whenever they felt the device's haptic signals from the device.

While navigating, haptic signals were prompted before the subjects reached the junctions and ended after they were in the correct turns. Figure 3 below illustrates when and where the haptic signal was triggered. For example, to go from point 1 to point 2, subjects had to turn left. Hence, the haptic signal was given within this length (of 6 metres). The length for the haptic

signal given to the subjects in every junction was set constant. For comparison, subjects' walking speeds, which were formerly recorded, were calculated as the travelled distance (of 6 metres) divided with the time taken.
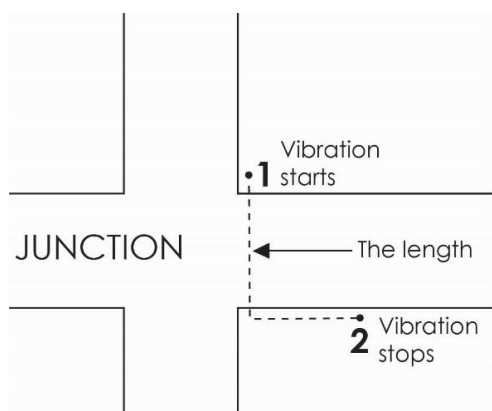

Figure 3: Where the haptic signals take place during the navigation test

The selection of route and its difficulty were based on the accessibility and appropriateness of the settings to the subjects. The route was created not far from the therapy centre they attend. The distance of the route was approximately 300 metres, with 5 (left or right) turns. This is shown in Figure 4 (A).

Phase 3: Further Navigation Test

After the second phase was completed, the experiment continued with the third phase, which was the further navigational test. This particular test was to investigate if there was an improvement of the navigation performance as compared to the previous one. Here, the effect of familiarization in the form of training or constant practice was investigated. As previously mentioned, practicing a task (for example, the navigation task) on regular basis is an example of implicit memories. Also, implicit recollection for haptically-explored objects is preserved especially in the early stages of dementia[18]. Thus, the following navigational test may justify the effect of familiarization in the form of training or continuous practice which may result in positive outcomes of subjects' navigational performance.

This test followed the similar procedures as the second phase, where the subjects needed to navigate in the designated route, but with higher complexities. The distance of this route was around 600 to 700 metres, which was almost doubled from the previous routes. Similarly, the number of turns had also been increased, from five to ten turns. The route of the test is illustrated in Figure 4 (B).

A| Route for the Phase 2

B | Route for Phase 3

Figure 4: The navigation routes for Navigation Test (Phase 2) and Further Navigation Test (Phase 3)

TEST SUBJECTS

As preceded, the test was conducted on subjects with dementia who represented the actual users of the proposed intervention. The experiment was performed with the collaboration of Fondazione di Manuli, a dementia therapy centre in Milan, Italy. In fact, all the subjects involved in this experiment attended the therapy sessions here. Also, the experiment was conducted with the supervision of the subjects' caregivers, therapists or staffs of this therapy centre. Subjects' severity of cognitive impairment were rated using the cognitive-based ratings of Mini Mental State Score (MMSE)[34]. In this experiment, MMSE scores ranged from the minimum of 17 and maximum of 27, with average of 20.9.

In total, ten subjects participated in the first phase. Subjects ranged in age from 74 to 81years old, with the average age being 78.5 years old. Among these subjects, three of them were male. From the total of ten subjects, six of them participated in the second phase (the navigation test). Consequently, for the third phase (the following test), only three subjects were recruited. This was due to subjects' availability, time constraints, and the approval from their caregivers. For easier description, the subjects were identified by their numbers, as shown in the Table 1 below.

Table 1: The test subjects

Subjects	Age	Gender	MMSE Score
1	76	Female	17
2	76	Female	21
3	76	Male	27
4	81	Male	21
5	78	Male	21
6	80	Female	20
7	86	Female	23
8	80	Female	17
9	78	Female	20
10	74	Female	22

RESULTS

The quantitative and qualitative results of this UT are presented according to the three phases: (1) Orientation/Training, (2) Navigation Test, and (3) Further Navigation Test.

Phase 1: Orientation/Training

In the first phase, the evaluation was based on the observations of subjects' reactions. Here, the subjects needed to pass all three sessions to selected for the next phase i.e. navigation test. Results shows only Subject 7 did not get through even the first session out of all the subjects. Based on the observation, she showed the most unenthusiastic attitude in using the device, probably because she got tired after the therapy session. Whilst, Subject 1 and 5 did not pass the second session because they could not recognize the haptic signals. Additionally, Subject 2 could not proceed due to some ethical issues and health condition. For that, the total subjects recruited for the navigation test was only six.

Phase 2: Navigation Test

The recorded control time and walking speeds of each subject were compared in the navigation test. From the observation, subjects were more likely to make directional errors or mistakes at the earlier turns, probably because they did not perfectly understand the function of the device. This is why effective walking was essential to be calculated, as agreed by [35] in their study. The time taken to make every turn and the overall time to complete the route were also recorded. In the Table 2, the entire data shows each subject's speed, control time, average time taken to make the turns and to complete the route.

The average time taken shown above was based on the collective time taken for each turn. Number of mistakes (or direction errors) while navigating with the device in some way effects the scores recorded. Subject 3 had the highest walking speed of 1.08 m/s, and shortest average time taken (6.24 seconds). His average time was also not distinctively different from the control time (5.53 seconds). In fact, he consistently had the highest/best scores for all the recorded data as compared to the rest of the participants.

For the other subjects, their average times (for all the turns) were usually higher when they made more mistakes. This indirectly led to a longer time to finish the routes. Subject 6, 4 and 9 for example had the highest average time to make the turns (18.85, 17.62 and 16.34 seconds respectively) and they demonstrated the longest time to finish the route (776.43, 733.81 and 797.92 seconds respectively). This assumption was also applicable for the other three subjects (8, 3 and 10), who scored the lowest average time (16.23, 6.19 and 11.81 seconds respectively), and shortest time taken (682.27, 321.434 and 512.45seconds) to finish the route.

Nevertheless, average time does not necessarily influence the overall time taken. This is because Subjects 4 and 8 for instance, made the most mistakes (two errors each), but subject 8 with only one error had a longer average time. In addition, Subject 6 had the highest average time (18.85 seconds) after but her overall time taken was not the highest. It was held by Subject 9 with 797.92 seconds, with the third highest average time. This implies that even if the subjects took less time to complete the route than the others, this does not mean that they scored the highest effective walking. It still depends on their walking speeds and hesitations to decide which turns to make.

The best navigational performance was shown in Subject 3 who also scored 27, the highest score of MMSE amongst the participants. The MMSE scores varied from 17 to 23 for the other participants, much lower than the score of Subject 3. Comparing the MMSE score in terms of description and stage, (i) 26-30 could be normal, (ii) 25-20 is mild and in early stage, and (ii) 19-10 is moderate and middle stage[34]. Hence, Subject 4, 6, 9 and 10 had the similar range, which is in the mild condition and only Subject 8 was in the moderate condition. We cannot, however, merely clarify that subjects in early stage have better navigational performance comparing to those in middle stage.

Table 2: The summary of recorded data for the navigation tests (Phase 2)

Subjects	Walking Speed (m/s)	Control time (s)	Time taken to make the turns (s)						Overall time taken (s)
			Turn 1	Turn 2	Turn 3	Turn 4	Turn 5	Average	
6	0.79	7.56	8.69	29.10	28.52	19.71	8.21	18.85	776.43
4	0.78	7.74	7.80	24.22	25.75	21.33	8.98	17.62	733.81
9	0.51	11.08	12.02	11.73	34.45	12.24	11.45	16.34	797.92
8	0.68	8.86	8.92	27.22	26.57	9.43	9.02	16.23	682.27
3	1.08	5.53	5.57	8.41	5.22	6.11	5.63	6.19	321.43
10	0.73	8.15	8.57	21.73	10.11	9.43	9.21	11.81	512.45

Table 3: The summary of recorded data for the further navigation tests (Phase 3)

Subjects	Time taken to make the turns (s)											Overall time taken (s)
	Turn 1	Turn 2	Turn 3	Turn 4	Turn 5	Turn 6	Turn 7	Turn 8	Turn 9	Turn 10	Average	
6	9.06	14.84	7.58	9.72	8.40	17.72	17.40	9.54	7.69	8.01	11.00	1082.70
8	8.98	9.60	18.90	9.56	9.64	9.65	23.69	20.77	35.21	8.90	15.49	1420.46
10	8.57	10.73	15.11	8.43	19.21	9.97	19.57	8.62	9.12	8.16	10.88	1101.39

Table 4: Comparison of average time in making the turns between Phase 2 and Phase 3

Subjects	Average Time			Average overall time			
	Phase 2 (Seconds)	Phase 3 (Seconds)	Reduction (%)	Phase 2 (Seconds)	Expected Phase 3 (Seconds)	Actual Phase 3 (Seconds)	Percentage of reduction (%)
6	18.85	11.00	41.64	776.43	1552.86	1082.70	30.28
8	16.23	15.49	4.56	682.27	1364.54	1420.46	4.10
10	11.81	10.88	7.87	512.45	1024.90	1101.39	7.46

Subject 6 for instance, with the MMSE score of 20 did the same number of directional errors with subject 8 with the MMSE score of 17. Having said that, other participants with mild condition indicated an average or moderate navigational performance.

Phase 3: Further Navigation Test

The recorded data for this phase were similar to the previous navigation test (Phase 2). The variables used for the assessment of data were identical, the only difference was the increased complexity of the route. As previously mentioned, only three subjects (Subject 6, 8 and 10) participated in this phase, thus their walking speeds and control times were the same. Table 3 summarized the recorded data for this phase.

DISCUSSION

The first indication in terms of the improvement of subjects' navigational performances was on the average time of all the turns as shown in Table 4. All the three subjects indicated lower average time taken to make the turns as compared to both phases. For example, Subject 6 scored 18.85 seconds average time in Phase 2. This average score was compared to her average time taken in the Phase 3, which was 11.00 seconds. Thus, the time difference was 7.85 seconds, making the percentage of average time reduction in both phases as 41.64% (calculated as [7.85 ÷ 18.85] x 100%). The percentage of average time reduction is also shown by the other subjects, though it is not so significant.

The second indication of improvement is on the overall time taken to finish the Phase 3 route. While the overall time taken was not necessarily influenced by the average time, as reported in the previous results, but when comparing both phases, there were apparently decreased in the ratio of the average time to the overall time taken. For example, the Subject 6 took 776.43 seconds to complete the route in Phase 2. If this average time was doubled (taking the length in Phase 3 was doubled), she should finish the route in 1552.86 seconds. Instead, she completed the route in only 1082.7 seconds instead, fewer 470.16 seconds than expected, which is 30.28% reduced. Subject 6 again had the highest percentage of time reduction of 30.28%, as compared to the other two subjects; Subject 8 with 4.10% and subject 10 with 7.46% respectively.

Table 3 summarizes the comparison of average time and average overall time for all the subjects in Phase 3. The percentage of reductions could or could not have been due to the number of errors made. For instance, Subject 8 had lower ratio than Subject 6 probably because she made more mistakes. But this did not explain why Subject 8 had the lowest ratio since she did the same number of mistakes as Subject 10. Again, this is due to each subject' control time (and walking speed), as presented in Table 1 from Phase 2.

CONCLUSIONS

A system of navigational assistance was developed to verify on the potential of haptic as a modality of navigation. The developed system was used in a pilot test that was performed towards the actual group of the intervention, which is the elderly with different severity of dementia. The assessment aimed to investigate if sense of touch through the haptic signals could be helpful for elderly with dementia in the course of navigation.

Results of the conducted navigational test demonstrate the potential of haptic modality to support the wayfinding of the participants. These encouraging findings were based primarily on the decreasing of (i) overall time taken and (ii) the numbers of errors, especially when comparing subjects' navigational performances in both routes accordingly. In addition to this, to prevent confusion and for the purpose of familiarization, a new intervention should be appropriately introduced to its targeted audience[28]. The proposed concept of wearable and non-visual form of assistive navigation device are completely new for the participants. Accordingly, getting familiar with the device's functions by means of proper training and continuous use is very crucial. This is noticeable when subjects demonstrated better navigational performance in the further navigation test.

The findings were also supported by the subjective evaluation analysis, where the participants required sufficient time in learning the device's functions and operations. Responds from the subjects as well as their caregivers and therapists also recommend us to consider improving the physical design of the device since it caused the wearability issues.

In our future works, an improved version of the navigational assistance prototype will be developed mainly from its wearable aspects. Once the improved prototype is ready, another Usability Test will be conducted towards the same population, using the similar experimental procedures in this study, but with bigger samples. The further development is important in determining the wearable aspect of haptic-feedback navigational assistance to be more practical, acceptable and convenient for the target users

COMPETING INTERESTS
There is no conflict of interest.

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