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ABSTRACT

Introduction: Alzheimer's disease (AD) is associated with the deterioration of wayfinding abilities that resulted in significant needs of intensive supervision. The report examines the possible wayfinding intervention strategies aimed at assisting orientation deficit in AD patients, predominantly from the aspect of design and technological approaches.

Method: Electronic databases; PubMed/MEDLINE, Scopus, SAGE journals, IEEE and Springer Link were used to find out possible literatures related to any intervention strategy or experimental study by means of design and technological approaches used to facilitate AD patients' wayfinding ability.

Results: Nine relevant literatures were selected and categorized into three intervention groups; (a) virtual reality-based, (b) assistive technology (AT), and (c) environmental enhancement. They were reviewed based on demographic of participants, objectives, methodology and outcomes. The mentioned interventions reported positive results on assisting wayfinding of AD patients after the implementations. The use of appropriate design and technology towards the interventions such as, virtual environment for assessing navigational tasks, basic orientation technology and improvement architectural layout, were fruitfully explored.

Conclusion: There is still a dearth of strong evidence on the associative effects between intervention group and its efficiency, due to the diversity of populations, interventions, comparators and outcomes. However, design and technology do necessarily contribute to the concept of interventions, as it resembles the fundamental approach. Alternative concept of interventions and design guideline based on the limitations and level of wayfinding deteriorations according to AD's severity should be further promoted.

Keywords: Alzheimer's disease, spatial disorientation, orientation intervention strategy, virtual reality, assistive technology, environmental enhancement

INTRODUCTION

Alzheimer's disease (AD), marked by cognitive deterioration, significant alterations in behaviour, and a gradual decline in daily functioning, is the most common type of dementia. As the world population ages, the number of elderly affected by this progressive, degenerative disorder is simultaneously increased. Statically, AD patients are projected to increase to 106.2 million by 2050 from 26.6 million in 2006 [1], which indicates the importance of this subject.

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AD often impairs the patients' spatial representation and is suspected to be related to their cognitive function deficits. This problem is usually referred to as spatial disorientations (SD), with the disability to find one's way in an environment as a result of brain damage or other dementia sub-types [2], [3]. SD is defined as the individual's inability to orient in the environment as a result of focal brain damage. It affects AD patients in terms of impaired linking of landmarks and routes, which in turns resulted in getting lost in both familiar and unfamiliar environments [4]. It is claimed to be one of the major reasons leading to the institutionalization of AD patients [5].

Orientation and wayfinding abilities dramatically change as the disease progresses. In fact, SD occurs early in the development of AD; during the Mild Cognitive Impairment (MCI) stage [6]. Nevertheless, there is still lack of information on the level of wayfinding disabilities due to their severity of AD and the socio-economic impacts towards caregiving. Thus, it is important to reflect the emerging issues as a first step towards finding out the potentials of using design and technological supports to improve AD patients' wayfinding skills. The needs to develop more promising interventions or therapeutic approach on wayfinding deficit are appropriate at present.

The aim of this paper is to find out possible interventions and provide an overview of the existing interventions so far used to help assist this specific deficit of AD patients from the aspect of design and technology, since there is little attention in research works is available in this arena. Discussion on the methodology, effectiveness and practicality of each reviewed interventions were carried out. Recommendations on prospective future study based on this review were then discussed.

METHOD

Computerized search strategies using five major electronics databases; PubMed/MEDLINE (<http://www.ncbi.nlm.nih.gov/pubmed>), Scopus (<http://www.scopus.com>), SAGE journals (<http://online.sagepub.com>), IEEE (<http://www.ieee.org>) and Springer Link (<http://link.springer.com>) were carried out to meet the aims proposed above. Relevant articles were identified through searches using the combinations of the following keywords: (1) Alzheimer's disease, (2) wayfinding or navigation, (3) orientation intervention strategy (4) design and/or technology, and (5) dementia-friendly design.

The literatures were selected based on the iterative process and according to the topic's relevancy. Articles were included in the existing review only if they met the generic criteria of inclusions: (1) orientation strategies (or any form of intervention) by means of experimental studies that promotes the application of design and technology, and (2) an intervention to assist SD (or any terms of orientation deficits) who suffered mainly from dementia of Alzheimer's type, and (3) must be peer-reviewed articles in English language only. Recent literatures were prioritized to provide a review on the existing and advance interventions to promote diversity and avoid reiteration of similar approach. Therefore, the search was limited from 1994 onwards.

Furthermore, references listed in the selected articles were also searched using the same computerized strategy, in case of appropriate articles inclusion. Once the additional search was added, articles were once again screened and excluded if; (1) the experimental studies do not involve at least one participant

who suffered from AD, and (2) qualitative or self-reported studies which are not intervention on orientation strategies. The literatures were only selected after they went through the screening procedures. The search strategy to identify and finalized the selected literatures is summarized in Figure 1 below.

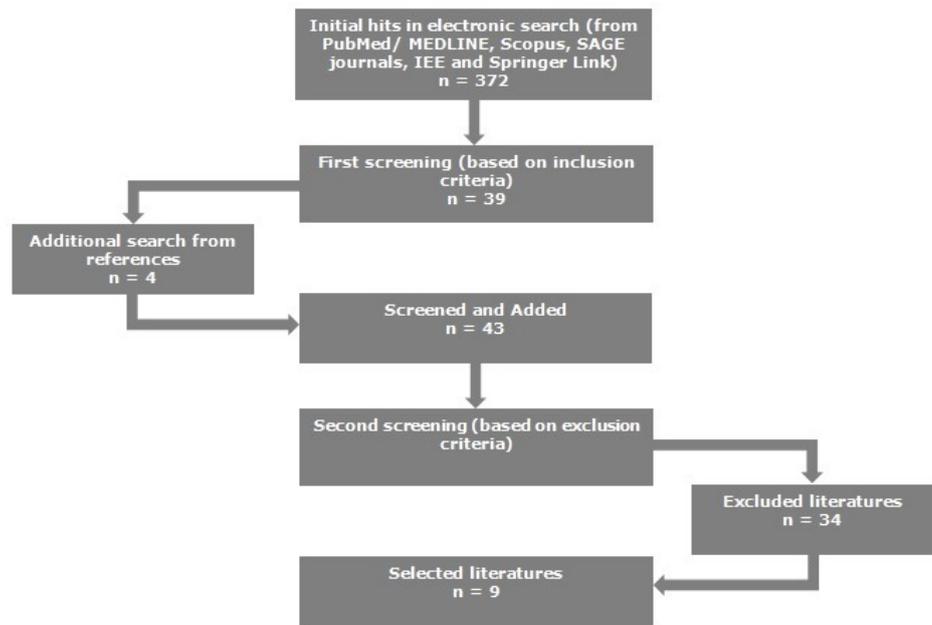


Figure 1 – Search strategy for the selected literatures

FINDINGS FROM THE STUDIES

Nine articles were finally selected concerning intervention strategies to support orientation deficits caused by cognitive impairments of AD. They were categorized into; virtual reality-based (n= 4), assistive technology (n=3), and environmental enhancement (n=2). Table 1 shows these selected literatures according to the main topics of discussion; demographic of participants, aims of the study, intervention strategies or the methods and the outcomes of interventions. At the outset it should be noted that little studies were found relevant and therefore for the purpose of generalization, careful considerations should be taken into account.

The selected literatures were basically current research works with the earliest was in 2000 (n=1) and the latest were in 2014 (n=1) and consequently reveals that this area is still green. Participants of the experimental studies are one of the important topics to be discussed. As mentioned in the criteria of inclusion earlier, recruited participants must consist of at least an individual with AD. All the participants in these literatures varied from young adults (mainly for control population) to elderly with AD which gives the range from 25 to 94 years old. Four studies recruited control group (CG) in their experimental studies basically to compare the efficacy of interventions towards both groups of participants [7], [8], [9] and [10].

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Most of the recruited participants were diagnosed with AD, but vary from preclinical AD, mild cognitive impairment (MCI) and full-blown dementia due to AD; mild, moderate and severe. The severity of AD reported in the studies was mostly based on the assessment of the oft-used Mini Mental State Examination (MMSE) test, which scores ranged from 4 to 24. The other ratings used were Montreal Cognitive Assessment (MOCA), Cognitive Ability Screening Instrument (CASI), Clinical Dementia Rating Scale (CDR), Consortium to Establish for Registration of Alzheimer's Disease (CERAD) and Neuropsychiatric Inventory (NPI).

| STUDY | PARTICIPANTS | AIM | INTERVENTION / METHOD | RESULT |
|-----------------------------------|---|---|--|---|
| Virtual Reality-based | | | | |
| Zakzanis et al. [7] | 8 young adults (mean age: 25.3) and 7 older adults, 2 of them diagnosed as preclinical AD (mean age: 61.6) | To examine age- and AD-related differences in route learning and memory using VR. | Spatial memory task took place in a VE integrated with virtual city. | Young adults more efficient in path navigation than older participants. Whilst, patients with AD made more mistakes on the recognition task, mistaken the elements in the (virtual) city |
| Jheng and Pai [8] | 19 Patients with early AD (mean age: 67.6) and 18 normal control (mean age: 66.4) | To investigate the cognitive maps in early AD patients and their application in a computer-generated arena (CGA). | Hand-drawing tests (for assessing cognitive map of familiar environment) and CGA (new environment learning) | Early AD patients maintain the ability to use a cognitive map and keep pretty good allocentric representation of their familiar environments similar to control group. However, both groups might not properly use their cognitive map to navigate in everyday life |
| Morganti, Stefanini, and Riva [9] | 26 AD patients (mean age 81.0) and 26 (control) healthy, elderly subjects (mean age: 77.2) | To study whether there is a decline in performing the allo- to egocentric translation of spatial knowledge during different types of wayfinding in AD patients | Two virtual reality tasks; the VR-Maze and VR-Road Map tasks | There is a specific reduction in performing allocentric to egocentric spatial tasks in AD. But this reduction is not as obvious in equivalent allocentric spatial tasks |
| Zen et al. [10] | 8 individuals suspected of mild to moderate Alzheimer's (mean age: 71.1) and 11 cognitively healthy controls (mean age: 70.4) | To investigate the orientation ability of individuals with AD using Virtual Reality Navigational (VRN) test by analysing the type of user error such as "side error" and "corner error" | VRN experiment test (a virtual cubic 3 story building, which looks identical from each side) | People suspected of Alzheimer's cannot perceive the VR without the help of a physical model. The required mapping to transfer between virtual and real world settings is deteriorated in AD subjects |
| Assistive Technology | | | | |
| Lancioni et al. [19] | Three patients with mild to moderate AD (73 to 83 years old) | To assess whether AD patients could learn to use basic orientation technology to reach different rooms within their day centre. | Basic AT-based program that provide brief verbal messages (cues) | The orientation system was effective in helping the participants to reach the target destinations within their day centre successfully |
| Lancioni et al. [20] | Five patients with moderate AD (72 to 80 years old) | To investigate the effectiveness of orientation program involving auditory cues and to compare with a program which use light cues | Auditory cues (verbal messages automatically presented from the destination) vs. light cues (strobe lights were used instead of the verbal messages) AT programs | The program with auditory cue system is effective. It gives comparable significant results similar to light cues program in helping all the participants reach the target destination |
| Caffo et al. [21] | Four persons with moderate to severe AD (67 to 89 years old) | To compare between compensatory (AT Program) and restorative strategy (Backward Chaining procedure), in | Comparison between AT program (AT, i.e., remotely controlled sound/light devices) and Backward Chaining procedure (familiar | AT programs can be valuably employed for restoring and maintaining independence indoor traveling in people with moderate to severe AD. Whilst, BC procedure might be preferable in |

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| | | | | |
|----------------------------------|---|---|---|---|
| | | reducing wayfinding deficit and promoting indoor travelling in AD | objects of the environment) | conventional teaching strategies |
| Environmental Enhancement | | | | |
| Marquardt and Schmieg [12] | 450 residents with dementia in 30 German nursing homes (mild, n= 91, moderate, n = 183, and severe, n = 176). Age not specified | To implement the results of the study into the design of new or remodelling of the existing facilities, mainly on floor plan typology | 5 wayfinding route tasks in nursing homes which had to be a part of the activities of daily living conducted by skilled nurses. | Most significant supportive factor in floor plan typologies is the straight circulation system. Dependency on supportive environment is increasing as the severity of dementia progresses |
| Passini et al. [22] | 6 patients with moderate to severe AD (76 to 94 year old) | To generate design criteria in order to encourage and facilitate wayfinding for advanced Alzheimer’s patients | Interviews with the staff of a typical urban nursing home, and wayfinding experience with its residents | Supportive environmental information is crucial to help wayfinding. Physical environment may result in either positive or negative impact in wayfinding. |

Table 1 – Selected literatures of intervention strategies to facilitate AD patients with wayfinding deficits

VIRTUAL REALITY-BASED ORIENTATION STRATEGIES

There is a variety of conventional table-top assessment techniques used to measure degenerative of cognitive functioning domains. However, these conventional techniques seem to be lack of important aspect of real-world navigations, namely translocation, or at least the illusion of movement of the body in space [13]. The alternative and advanced technological application that may artificially recreate the real-world [14] is called Virtual Reality (VR) system. It is defined as technology that integrates real-time computer graphics, sounds and other sensory input to create a computer-generated world which the user can interact [15]. The adoption of VR system is meant to be dynamic, interactive and testable via Virtual Testing method [16]. It is suitable for therapeutic and assessment purposes that involve construction of physical environment. This paper revealed four studies [7], [8], [9], and [10] that utilized the distinctive flexibility of VR in their interventions for assessing AD’s wayfinding deficits.

In one study conducted by Zakzanis et al., [7] VR system is used to examine the relationship and differences between age and AD in route learning and memory factors. The spatial memory task was conducted in a Virtual Environment (VE) platform. In order to experience the immersive VE, video unit goggles were placed over their eyes using a Head Mounted device. In this test, they needed to navigate within the virtual city effectively and by the end they were assessed on their level of recognition of the buildings and objects incorporated in the immersive VE. The test module consisted of the real life navigation; walking on sidewalks, and crossing the street. Comparing the results of navigational task, older adults have lower average of distance travelled (effect size of $d=1.17$) and high number of wrong turns (mean effect size of $d=1.04$) as compared to young adults. This suggests that older adults faced more difficulties and took longer time to finish the navigational task, whilst AD patients took the longest and made most mistakes especially in recognizing elements and objects in the VE.

Jheng and Pai, [18] aimed to investigate the cognitive maps of individuals in early stage of AD and its application towards navigational skills in computer-generated arena (CGA). In this experimental study, they assessed at least two orientation strategies using egocentric and allocentric approaches in order to develop specific cognitive map. They posited that the individual’s cognitive map may be developed by reiterating the same navigation in a particular environment. In this intervention, assessment of new environment learning and

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the application of the old map were conducted in CGA. The results of new and old environment learnings verify that normal controls (NCs) did slightly better and took less time than AD group, but there were no significant difference ($t=-0.47$, $p=.641$) detected. They verified that individuals with early AD are still able to use cognitive skills during navigational tasks and maintain their cognitive maps of familiar environments. It suggests that the declining spatial ability in early AD patients might be due to the improper use of cognitive maps in their daily wayfinding.

VR system is also adopted by Morganti et al., [9] investigated whether there was a decline in performing the allocentric (object-to-object) to egocentric (self-to-object) translations of spatial knowledge during different types of wayfinding in AD patients. Two virtual reality tasks; VR-Maze spatial task (VR-MT) and VR-Road Map task (VR-RMT) were used to evaluate their ability to explore complex environments using allocentric map but applying egocentric wayfinding technique instead. The results of the correlation between neuro-psychological tests (MMSE) and (1) VR-MT (Pearson's .678, $p < .001$), and (2) VR-RMT (Pearson's .371, $p < .018$) demonstrate that VR tasks may assess general cognitive functionality and specific ego- and allocentric spatial cognitions. This indicates that AD patients portray a decreasing ability in performing allocentric to egocentric spatial tasks, but it is not as obvious in equivalent allocentric spatial tasks. In comparison, most of the participants from CG show the ability to plan a path in the VE when provided the same perspective.

Zen et al., [10] in their study investigated the orientation ability of individuals with AD using Virtual Reality Navigational (VRN) test by analysing the type of users' errors, such as "side error" and "corner error". This test made use of virtual cubic 3-storey building. They hypothesized that even in the early stage of AD the ability to orient using egocentric information decreased, while general orientations might be preserved by using allocentric perspective in mild AD patients. During the VRN experiment, all AD subjects were unable to find the target room as contrast to CG with the maximum error score of 80. Results of statistical analysis showed that there is significant difference between AD subjects and CG ($p=2.5e-5$). Thus, they suggested that individuals suspected with AD were unable to perceive VR without the help of a physical model. AD subjects are able to perceive VR after practicing with the physical model that imitates VE. From this study, it can be concluded that depreciation of cognitive mapping which transfer from virtual to real world setting is obviously shown in AD patients.

ASSISTIVE TECHNOLOGY FOR PROMOTING WAYFINDING

The term assistive technology may refer to device, system or tool that allows individual to perform a task that they would otherwise be unable to do, or increases the ease and safety with which the task can be performed [17]. Available technologies for assisting AD patients can be classified into screening, memory aids, monitoring health or safety, information sharing or tele-care, and also communication support and therapy [18]. AT in promoting navigation or wayfinding due to spatial orientation deficits are yet to be explored and this might be significantly beneficial mainly for individuals with cognitive impairments. Studies by [19], [20], and [21] implement AT program in the orientation strategies. The general aim is to assist wayfinding and allow independency towards this segmented population.

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Lancioni et al., [19] for instance, assessed if individuals with AD could learn to use AT in the form of basic orientation technology to find different rooms in their nursing home. In their study, orientation system which included a sound source at each of the destinations and a portable control system to activate and deactivate each of those sources were set. Brief verbal messages (cues) from targeted destinations were also provided during the test. From the results, the orientation system provided was effectively used by the participants to reach different room destinations within their day centre. The percentage of travel accuracy was improved to almost 100% from 30% to 40% during the baseline sessions. This credibly demonstrates the efficiency of this form of basic orientation technology to inexperience populations and provides the promising alternatives for maintaining minimal orientation ability within individuals with cognitive impairment.

In a different study by Lancioni et al., [20], they investigated the effectiveness of orientation program involving auditory cues and compared this with a program which used light cues. In this study, auditory cues used the verbal messages automatically presented from strategic destinations, while in the light cues procedure strobe lights were used instead of the verbal messages. Results showed that the program with auditory cue system was effective and gave equally strong impact of the program with light cues in helping all participants reaching the target destinations within their day centre. There was a significant increase in mean percentages of correct travels (up to 95%) by most of the participants during the intervention phase, as compared to (10% to 30%) during the baseline sessions. In addition, results from the social validation assessment recommended that program using light cues is more practical and preferable by the social raters although both cues were equally worthy.

Caffo et al., [21], in their study aimed to compare between a compensatory; AT Program and a restorative strategy; Backward Chaining (BC) procedure, in supporting wayfinding in an indoor environment of persons with moderate to severe AD. AT programs include remotely controlled sound and light devices, while BC procedure included familiar indoor objects as landmarks for each section of the route like chairs, large pictures, small furniture, coloured pillars and automated doors. The results demonstrated that mean percentages of travel/route sections in participants is above 90 during the intervention with the AT, whilst only 37 to 54 in BC program. This suggests that AT programs were more adoptable in maintaining autonomy of indoor traveling for AD patients, and highly efficient in reducing their wayfinding deficits. BC procedure on the other hand, is more preferable for conventional teaching strategies. In the social validation assessment, higher results were given to AT program in terms of comfort, competence and self-determination, whilst BC has higher score in the aspect of environment.

ENVIRONMENTAL ENHANCEMENT

Improvement of physical and social environments in supporting individuals with AD has gained a significant attention and carries weight in dementia care research works. However, AD patients usually show difficulties to adapt to the provided environment and less capable to control the environmental factor due to their cognitive and behavioural deficits [12]. Therefore, it is crucial to consider that their environment is designed to meet their needs. This somehow allows the autonomy to take place by maintaining an active everyday practice. Environmental factors like lighting, acoustic, climate, colour, furnishing,

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materials and flooring are able to be modified, manipulate and combined to meet the needs and supporting the inabilities of AD patients, which include SD, as we referred to dementia-friendly design.

Marquardt and Schmieg [12], aimed to implement the results of their study into the design of new or remodelling of the existing facilities and the development of design criteria. They reported that architectural design of the environment may support the wayfinding skills in dementia and there were two aspects discussed; flooring and environmental cues. They posited that the level of resident's wayfinding abilities influenced by characteristics of architectural structure may be measured by the destinations reached independently by the residents in the nursing homes. Five distinctive routes were chosen within the living areas of the nursing home in supporting the residents' autonomy. Three major floor plan typologies were then identified through an empiric-qualitative exploration and were subdivided into (1) straight circulation systems, (2) layouts that featured one shift in direction and (3) continuous paths around an inside courtyard. Statistical evaluation demonstrated that the most significant supportive factor in the case of floor plan typologies is the straight circulation system, with $P = .001^c$ (as c is extremely significant). This study confirms that the dependency on supportive environment increases as the severity of dementia progresses.

In a research conducted by Passini et al., [22], they aimed to generate design guideline in encouraging and assisting navigation for AD patient with advanced severity. This study used interviews (with 10 staff members of the nursing home) and wayfinding experience (with patients) as the complementary methods of data collections. The selected staff members consist of the director of the nursing home, a security agent, an occupational therapist, a physiotherapist, a recreation guide, 2 orderlies, and 3 nurses. Performance in wayfinding tasks were varied among participants and no further statistical analysis is reported. However, results suggest that even patients with severe cognitive deterioration are able to reach certain destinations provided that the environmental information is accessible and well programmed. This study concludes that the physical environment determines the efficiency in wayfinding and also able to create problems and solution for the wayfinding issues.

DISCUSSION

This review has identified a growing body of research that aimed to assist spatial orientation deficits in individuals with AD to navigate, orientation or finding their ways to reach certain destination within their environments. Apparently, all the mentioned intervention strategies reported positive results on AD patients' spatial representation after the implementation of the interventions. The adoption of design and technological knowledge were brilliantly utilized and feasible in the reviewed experimental studies.

In virtual reality-based orientation strategies, VR system seems to be an appropriate tool of assessment in identifying the declining spatial orientation ability in AD patients. This review has revealed various acceptations by AD patients towards perceiving VR system in the interventions. For instance, [7] explained that AD patients took longest and made most mistakes in recognizing elements in VE as compared to the other participants. Additionally, AD patients show declining wayfinding ability due to the confusion in their cognitive and spatial domains.

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As agreed by [10], these problems challenged their ability to orientate in the VR tasks and are unable to perceive VR without the help of a physical model. This is due to the depreciation of cognitive mapping from virtual to real world setting. In contrast, [8] suggested that AD patients in the early stage are able to maintain their cognitive maps in both VE and real-world, but claimed that the decrease in orientation skills possibly caused by improper use of cognitive in everyday practice. Despite the different perceptions indicated in individuals with AD, the use of VR system for assessment is still acceptable. For training purposes, although conservation of such route learning ability is not assured, but it might give encouraging effects in constant practice.

For the interventions using AT, all the discussed results from the reviewed literature show promising results. The ATs used in the orientation strategies were not too complex and were easy to implement. This suggests that basic orientation technology is still effective even for inexperienced people and people with mild to moderate AD. This is recognized by more recent study by [20] that confirms the orientation program using auditory cues is also as efficient as light cues in assisting the participants with moderate AD to reach the task destinations.

In addition, [21] who also used auditory and light cues as AT programs claim that orientation strategies using AT program was highly efficient as compared to BC procedure which use familiar objects in reducing wayfinding deficit in patients with moderate to severe AD. However, all the reported interventions took place in nursing homes which cover limited area of the environment the AD patients live in. AT program using uncomplicated system might be significantly helpful for indoor navigation within the nursing homes; however there is lack of evidence that it might have compatible positive effect on outdoor wayfinding.

Similar to AT program, interventions with environmental enhancement involve the use of physical environment as the apparatus of assessment. As claimed by [9], the dependency on supportive environment is increasing as the severity of dementia progresses and proven that uncomplicated floor plan typologies (straight circulation system) is the best to avoid in indoor travelling. The importance of providing appropriate environment to support wayfinding is also agreed by [22] as they claim that a well-designed physical environment with the appropriate environmental information could be useful even for more severed AD patients. The improvement of existing physical environment plays a significant role to defining the effectiveness of wayfinding, where it also may provide the solution to the existing wayfinding problems.

In general, pertaining to therapy perspective, AT programs and virtual reality-based orientation strategies seem to be best employed towards less impaired patients, (mild to moderate stage of AD, and the stages before fully-blown AD i. e. preclinical AD and MCI), who are more capable to adopt and practice the remaining learning skills. Whilst environmental enhancement can be a good way in maintaining most of motor skills left in AD patients including SD, good knowledge in their specific and demanding needs is a must before a real physical environment can be constructed.

CONCLUSION

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This review demonstrates that at present, a precise direction and magnitude of the effectiveness of one group of intervention towards significantly reducing the SD, is yet to be conclusive considering the extraneous variability of population, intervention, comparators and outcomes. Nevertheless, the knowledge of design and technology has been adopted in the mentioned literatures, demonstrating its significant contribution as the domain of intervention concepts. For instance, creating the computer-generated environment as referred to VE that almost accurately resemble the real-world environment, requires both technical and aesthetic skills. In addition, designing the appropriate technological devices to be used for these cognitively impaired individuals is quite a challenge. Besides understanding the exhaustive needs from gerontology and neuroscience point of view, ergonomics, functionality and aesthetic perspective carries the same weight. Similar to the construction of enhanced physical environment to cater these specific needs, the conceptual design went through several assessments before it can be approved to be built.

The whole process of designing the intervention concepts apparently resembles this fundamental approach; design and technology, regardless of the diversity of implementers' field backgrounds; science streams, social sciences or in between. While this approach can at least carry a valuable supplement in conceptualizing the orientation intervention strategy, imperative study on identifying the limitations of this specific group due to their changes and impairments in cognitive and motor function as well as the sensory and physiology is highly recommended. This information in particular could benefit greatly in helping implementers and researchers in finding better alternative solutions, or design guidelines in terms of design and technological applications towards reducing SD and promoting wayfinding abilities.

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