How did we get there? Supporting older adults' spatial orientation within the built environment

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Abstract

Older adults exhibit marked declines in navigation skills; these difficulties become worse if individuals are showing early signs of cognitive impairment, which often results in disorientation, particularly in unfamiliar environments. Many of these individuals eventually face the challenge of having to learn their way around new surroundings e.g. with potential increased visits to hospitals or when moving into retirement housing or care-home environments. This PhD thesis aims to develop a clearer understanding of older adults' route learning and route knowledge when learning routes through built environments. To gain a more complete understanding of the experiences typical and early atypical ageing adults encounter, I adopted a mixed-methods approach. Chapters 3, 4 and 8 report on data following a quantitative experimental psychology approach to measure route learning and route knowledge in virtual and real environments, whilst Chapters 6 and 7 report on data using a qualitative approach to data collection and analysis to gain an understanding of the lived orientation experiences people living in and visiting retirement settings encounter. The findings from the data chapters are discussed in relation to existing theory and literature surrounding the effects that typical and early atypical ageing has on the abilities to learn and remember routes. In particular this thesis contributes towards the understanding of how typical and atypical ageing affects route learning and route knowledge, and how the findings can be applied to critically improve the suggestions made in dementia friendly design guidelines. The thesis concludes that simplistic VR environments do reliably capture real world navigation performance, but are additionally beneficial in that they detect the earliest symptoms of early atypical ageing more so than real world navigation. This can have benefits in detecting and diagnosing early atypical ageing in a clinical setting.

Thesis Outline

Disorientation is one of the first symptoms of early atypical ageing and dementia (Pai & Jacobs, 2004). Despite this, some aspects of route knowledge still remain intact during early atypical ageing (Cushman et al., 2008) while other aspects of route knowledge are more severely affected (Benke et al., 2014; Cushman et al., 2008). To date, existing studies have only tested route knowledge after showing participants a route a set number of exposures; which means, that participants may not have necessarily learned the route. An improved understanding of which aspects of the environment are remembered best, as well as the strategies adopted during successful route learning, will shed light on the environmental features/cues that are supportive for successful orientation for typically and early atypically ageing adults. These findings could, in turn, feed into principles of dementia friendly design. Using both qualitative and quantitative measures, this thesis is comprised of five research chapters.

To investigate how typical and early atypical ageing affects route knowledge after successful route learning a new route learning paradigm within virtual environments was developed in Chapter 3. Participants were trained until they could correctly recall short routes. During the test phase, they were asked to recall the sequence in which landmarks were encountered (Landmark Sequence Task), the sequence of turns (Direction Sequence Task), the direction of turn at each landmark (Landmark Direction Task), and to identify the learned routes from a map perspective (Perspective Taking Task). The key findings were that effects of typical ageing were present in learning performance (i.e. number of learning trials required to learn the route) and in the Direction Sequence Task. Early atypically ageing adults were significantly worse at the Landmark Direction and the Perspective Taking Tasks. No differences between groups in the Landmark Sequence Task were found. Given that participants were able to recall routes after training, these results suggest different age-related memory deficits for aspects of route knowledge dependant on the effects of typical or early atypical ageing.

The findings from Chapter 3 highlighted how identifying a learned route from a map perspective was particularly sensitive to the effects of early atypical ageing. A more realistic scenario, however, would be to first study a map, plan a route, and then execute the route. Chapter 4 therefore investigated whether “You Are Here” (YAH) maps are reliable navigation aids for typically ageing adults and those with early signs of atypical ageing. There were two different map styles; maps either had restricted routes from the YAH point to the goal location or allowed participants to plan their own route from the YAH point to the goal. Three groups of participants (young, typically ageing, and early atypically ageing adults) were tested on their abilities to read and use 20 YAH maps to guide navigation within a virtual environment.

The results showed that the older adults showing early signs of atypical ageing were significantly worse than the typically ageing adults and the young adults at reaching the goal location, irrespective of map style. No significant interaction between map style and participant group for performance of correctly reaching the correct goal zone was found. However, for the dependent variable of distance from the goal location, there was a significant interaction between map style and participant group. Post hoc analysis revealed that map style (restricted or free navigation maps) had no significant effect for either of the older participant groups (Old High MoCA and Old Low MoCA), but there was a significant difference for the young group; the young participant group were closer to the goal when using the free navigation maps than when using the restricted maps. Therefore, both typically and early atypically ageing adults did not significantly benefit from having the restricted routes on YAH maps, compared with YAH maps that required participants to make their own route from the YAH point to the goal location (i.e. free navigation maps). The overall findings from Chapter 4 emphasise that older adults showing early signs of atypical ageing perform significantly worse than typically ageing adults when using YAH maps, and YAH maps may not necessarily be suitable navigation aids for atypically ageing adults.

In addition to testing people on their abilities to learn routes, the research approach prioritised talking directly to older adults who had noticed changes to their memory and their orientation abilities within their living environment. To better understand how environments can compensate for decreasing orientation skills, voice was given directly to those experiencing memory difficulties to describe how they find their way around the development where they live, and to understand their design preferences. In Chapter 6, the navigational experiences and design preferences of older adults with memory difficulties were explored. In-depth semi-structured interviews with thirteen older adults experiencing memory difficulties were conducted. All participants were residents of one retirement development in the UK. Questions began broadly, for example, asking participants to describe their experiences of navigating in their living environment, before discussing any specific navigation difficulties in detail. Thematic

Analysis (Braun & Clarke, 2006) was used to identify three main themes: environmental design that causes disorientation, strategies to overcome disorientation, and residents' suggestions to improve the design. The design suggestions were particularly informative, highlighting the importance of having memorable and meaningful spaces which were favoured more than signage as an orientation aid. The findings demonstrate the need to consider environmental design to support orientation for those with memory difficulties. Of particular importance is the use of meaningful and relevant landmarks (i.e. that residents could relate to) as orientation aids which can additionally stimulate conversation and increase wellbeing. Given the range of suggestions in dementia friendly design guidelines aimed to support orientation (often based on proxy views rather than the direct views of older adults), Chapter 6 showed that it is crucial to speak directly to those living in different environments to learn how they find their way around and what design works best in supporting orientation (from the users perspective).

In addition to interviewing residents of a retirement development on their experiences, it was equally important to also ask older adults who were unfamiliar and new to an environment on their experiences on finding their way around it. This is primarily because it is well documented that both typically and early atypically ageing adults exhibit disorientation more frequently in new/unfamiliar environments (Pai & Jacobs, 2004), therefore it may be that different strategies and preferences are present in unfamiliar versus familiar settings. In Chapter 7, older adults were asked to answer four open-ended questions through a questionnaire, focusing on their orientation strategies, reasons for disorientation, and their design preferences. These were given to participants after they had completed a short route learning task through a novel retirement development. The questions were formed based on the themes found in Chapter 6. A Content Analysis (Elo & Kyngäs, 2008) was applied to the participants' responses. It was found that participants relied heavily on visual cues from within the environment (e.g. landmarks, signage), as well as verbal directions of the route learned. Interestingly, there was more focus on participants' abilities to memorise and retrace routes based on their verbal directions rather than purely landmark memory (the opposite was found in Chapter 6). Creating less institutional developments, with unique spaces to assist memory was also reported by the participants and consisted with the previous findings. Chapter 7 demonstrated that older adults are able to articulate their wayfinding experiences after limited exposure to a novel environment. To advance existing age and dementia friendly design guidelines, older adults' wayfinding experiences should be expressed and collected in different settings to ensure the design of environments accompanies the strategies and preferences they report, and should also be drawn on directly in guideline production.

The final data chapter of the thesis (Chapter 8) compared real world navigation to virtual reality (VR) navigation. Most VR experiments have used simplistic VR environments when testing navigation abilities; little is known about how well navigation in these simplistic environments translates to Real World navigation. Two groups of participants (between-subject; typically ageing and early atypically ageing) learned routes and completed route memory tasks for routes in a VR environment (a shortened version of the protocol used in Chapter 3), as well as in a Real World environment (within-subject). We found that the effects of early atypical ageing were more pronounced within the VR condition, than the Real World condition. All measures of route memory were significantly affected by early atypical ageing within the VR condition; these measures were the same as used in Chapter 3. For the Real-World condition though, tasks appeared to be differentially affect by early atypical ageing; Route Learning, Route Recall, Landmark Sequence (decision points) were affected by atypical ageing, but the Decision Point Direction, the Landmark Sequence (non-decision points), the Direction Sequence and the Map Tasks were unaffected. Although there were similarities in performance between the two conditions for each task, the study provides support for using simplistic VR measures to assess navigation abilities, and highlights the potential scope that simplistic VR navigation measures have in detecting and documenting navigation deficits that could support neuropsychological and cognitive assessments for early atypical ageing (i.e. MCI and dementia).

To summarise, this thesis provides a mixed method approach to investigate navigation, orientation and design preferences of older adults with and without early symptoms of atypical ageing. It emphasises the importance of both speaking directly to people about their lived experiences of navigation in different settings, as well as reliably quantifying navigation performance using tasks that assess route learning and memory. It demonstrates the value simplistic VR set-ups have in detecting the earliest symptoms of atypical ageing, highlighting simplistic navigational VR assessments as future tools in diagnostic settings.

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Author Declaration – I hereby declare that the work presented in this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

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Table of Contents

List of Figures

List of Tables

CHAPTER 1: Literature Review

1.1 Introduction to Navigation

The ability to move from one place to another is an essential part of daily life requiring a wide range of cognitive abilities to operate successively. Two principle navigation systems can explain how one navigates in an environment. Firstly, the path integration system refers to the process of updating perceived self-motion information to keep track of position and orientation whilst travelling (Loomis, Klatzky, Golledge, Cicinelli, Pellegrino & Fry, 1993). This includes spatial knowledge derived from internal (i.e. self-motion) and external cues (i.e. sensory stimuli in the surrounding environment) as well as additional cues such as optic flow (Gramann, Müller, Eick & Schönebeck, 2005; Riecke, van Veen & Bülthoff, 2002). The second navigation system is the landmark-based navigation system, which uses landmarks to determine one's location in an environment and to guide successful navigation to a destination. Landmarks are highly informative in that they allow a person to identify places and self-orient. They additionally guide navigation, create targets, provide a frame of reference, and support the acquisition and use of spatial information (see Chan, Baumann, Bellgrove & Mattingley, 2012 for a review). The ability to successfully navigate becomes significantly affected by the effects of cognitive ageing, with changes reflected in the strategies used and spatial representations formed (Cherrier, Mendez, & Perryman, 2001). Atypical cognitive ageing (i.e. mild cognitive impairment and dementia), also affects navigation abilities and results in feelings of disorientation (Cushman, Stein, & Duffy, 2008). This said, there are various strategies atypically ageing adults can use to help support, interpret, organise and retrieve spatial information, (e.g. beacon landmark strategies) and while some aspects of route knowledge are significantly affected by atypical ageing, such as allocentric tasks including landmark location memory (deIpolyi, Rankin, Mucke, Miller, & Gorno-Tempini, 2007; Sjolinder, Hook, Nilsson, & Andersson, 2005; Wilkniss, Jones, Korol, Gold, & Manning, 1997) other aspects, such as landmark recognition (Cherrier et al., 2001; Monacelli, Cushman, Kavcic, & Duffy, 2003), remain minimally affected.

The remainder of this chapter will explore the representations and strategies used to learn new environments followed by a discussion on the effects ageing and early atypical ageing have on navigation abilities and route learning in particular.

1.2 Theory of Navigation

Whilst navigating in an environment, people can employ two types of strategy; an allocentric strategy or an egocentric strategy. Allocentric strategy use involves encoding the spatial relationships between locations and/or landmarks, which results in a cognitive map that supports flexible navigation within an environment (O'Keefe & Nadel, 1978; Tolman, 1948). Therefore, allocentric strategy use depends on an extrinsic, environment-centred frame of reference that is associated with viewpoint-independent spatial knowledge (Klatzky, 1998).

In contrast, during egocentric strategy use, the behavioural responses associated with successful navigation are encoded relative to one’s body, resulting in route knowledge such as “Turn right at decision point X”. As such, egocentric strategy use relies on an intrinsic frame of reference, with spatial knowledge organised with respect to the individual (Klatzky, 1998). Egocentric knowledge is therefore viewpoint-dependent, and only supports accurate navigation when the position and orientation of the navigator in the environment is identical to learning (Hartley, Maguire, Spiers & Burgess, 2003).

Landmark Properties

Both egocentric and allocentric strategy use tend to rely heavily on landmarks. However there are a number of properties that a landmark needs to possess in order to be useful and supportive for successful navigation, such as how informative, unique, salient and stable a landmark is. Landmarks provide information about where we are at a given point, so that we can orientate ourselves within our environment, as well as provide navigational information that allows us to move towards our goal destination (Stankiewicz & Kalia, 2007). Landmarks should be unique to support successful navigation, as identical/repeated landmarks (i.e. if there are two McDonalds along a street) in different locations along a route can cause confusion and disorientation

(Stankiewicz & Kalia 2007; Strickrodt et al., 2015). This is because a non-unique landmark cannot be used on its own to unambiguously identify a location. Additionally, saliency (i.e. how much a landmark stands out from the rest of the environment) affects how easily noticeable and recognisable a landmark is when the navigator repeats or retraces the routes through an environment. Critically, a landmark must remain in the same place over time, so that it is still present when the person returns (Stankiewicz & Kalia, 2007); otherwise, confusion could occur if an object coded as a landmark has been moved since the navigator previously visited that location.

In summary, environmental objects that can serve as landmarks are vital to support successful navigation. In relation to egocentric navigation, particularly route knowledge, having landmarks present that can act as associative-cues or beacons provides navigators with a potential strategy they can adopt when learning or recalling a route through an environment. Importantly, landmark properties can influence how well an object serves as a landmark, which could have implications for the design spaces where flexibility is present.

Egocentric Navigation

Route knowledge is an example of a prototypical egocentric spatial representation. Route knowledge is predominantly studied through unidirectional route learning (i.e. routes learned in one direction over a series of trials). It can be acquired by directly walking through an environment, or through indirect means such as route descriptions and learning specified routes through maps. Route knowledge, like route planning and wayfinding, consists of two parts: firstly one has to identify a goal location, and secondly one needs to move towards the goal.

Egocentric representations refer to self-to-object representations whereby one has calculated the distance and location of objects in relation to their current location (i.e. the church is 50 metres away from my current location). As a result, an object's positioning in space plays an important role when relying on this representation and also affects the navigation strategy adopted (Wiener, de Condappa, Harris, & Wolbers, 2013) and can as a result influence the egocentric response strategy adopted.

Egocentric knowledge; sequence response, associative cue and beacon strategies.

To date, research has identified three different egocentric response strategies that can be employed to learn novel routes. The sequential response strategy involves encoding a series of body movements in temporal order (e.g. “Turn right, then turn left…”; Iglói, Zaoui, Berthoz & Rondi-Reig, 2009). Thus, individuals encode the sequence of directions or direction changes along a route. In landmark-free environments, this strategy is the only available wayfinding strategy navigators can use. However, the use of a sequential response strategy in both landmark-rich and landmark-free environments does not effectively support the acquisition of knowledge for long routes (e.g. Waller & Lippa, 2007), and relies on a fixed starting position and orientation. The use of landmark-based egocentric strategies allows navigators to learn longer routes, and acquire location-specific spatial knowledge (Waller & Lippa, 2007).

Two different landmark-based egocentric strategies make use of environmental objects to support the acquisition of spatial knowledge at individual decision points (see Figure 1.1). The associative cue strategy involves associating a directional response with a landmark located at a wayfinding decision point (e.g. “Turn left at the church”; Tlauka & Wilson, 1994). The recognition of the encoded landmark during subsequent navigation facilitates the recall of the corresponding directional information, which is then used to inform spatial behaviour. In contrast, objects that spatially correspond with a goal location are encoded during beacon strategy use. Subsequent recognition of encoded landmarks triggers a universal behavioural response that results in movement relative to the position of the landmark (e.g. “Turn/move towards the petrol station”; Waller & Lippa, 2007). Although both associative cue and beacon-based knowledge consists of simple stimulus-response pairings, with landmarks serving as a cue for navigation behaviour, it is plausible that the positioning and location of the landmark influences the specific strategy adopted (Wiener et al., 2013). For example, if there is a landmark located in the consistent point to where a directional change needs to be made (i.e. the landmark is on the right and the navigator also needs to turn right), a beacon strategy would be sufficient to recall this route. Therefore, a landmark’s position and location can have an effect on the strategy the navigator adopts.

“Head towards Regent Court”

“Turn Right at Regent Court”

Figure 0.1: Example of Egocentric Response Strategies. The image on the left with its directions “head towards Regent Court” is an example of a beacon landmark, whilst the text on the right is an example of when the landmark acts as an associative cue landmark.

Waller and Lippa (2007) include a detailed account on the differences between these two strategies. In short, whilst the associative cue strategy theory holds that ‘we associate a particular landmark within an environment with an action’, for example, “Turn left at the church”, the beaconing strategy theory holds that a person directs themselves towards a goal landmark, for example, “Go towards the church”. Associative cue strategy use relies on the association between two items – a landmark and the associated directional response – to support navigation at wayfinding decision points. In contrast, beacon strategy use depends solely on the knowledge of landmark identity, as a fixed behavioural response (e.g. “Turn towards”) is performed throughout beacon-based navigation. Beacon landmarks have also been demonstrated to be the quickest to learn and the easiest to use. Therefore, beacon strategy use is more frugal than associative cue strategy use, and consequently better supports spatial learning and navigation in tasks that can be completed with route knowledge (Waller & Lippa, 2007). These findings highlight the importance of landmark positioning in strategy selection (in relation to the direction of turn), and depending on the situation, the usefulness of the landmark in guiding navigation. For example, landmarks at decision points have been consistently highlighted as being useful for navigation (as they relate to associative cue strategies). The importance of landmarks positioned at decision points has been illustrated by Aginsky et al., (1997) who found that participants primarily remember landmarks at decision points when learning a route. Less attention has been spent on landmarks positioned along corridors (or between decision points), which could tap into beacon based strategies though this is yet to be explored. In Aginsky et al., (1997) landmarks positioned between decision points were not visible from the intersection which is why they did not support learning as much as those at decision points. Since Aginsky et al.'s (1997) study, there have been further experiments that have even tested route learning in the real world (Schinazi & Epstein, 2010) reporting better memory for landmarks positioned at decision points rather than non-decision points, highlighting the influence landmarks at decision points have on our memory of a route.

With regards to neural correlates of egocentric response strategies, it has been suggested that the striatal network which is the memory system responsible for procedural/muscle memory, plays a prominent role in route learning (Hartley & Burgess, 2005; Wolbers & Wiener, 2014) particularly stimulus-response learning associated with egocentric response strategies (Featherstone & McDonald, 2004). Future research should look into how striatal dependent strategies (such as beacon and associative cue strategies) are used for those who experience hippocampal atrophy and as a result have difficulties using allocentric and/or early difficulties learning sequences of decisions (which is said to be more hippocampal dependant) (Barnes & McNaughton, 1980; Iaria, Palermo, Committeri, & Barton, 2009).

Allocentric Navigation

Allocentric representations are world-centred rather than observer-centred (Klatzky, 1998). They rely on the formation and use of cognitive maps, which include the location of landmarks within an environment, as well as relationships and distances between landmarks. This reference frame allows efficient and flexible navigation in the environment; for example, it enables a navigator to find a shorter path (from the learned route) to a location, to take detours when the planned path is unavailable and when planning novel routes. A cognitive map (sometimes referred to as mental maps) is the generic term referring to spatial information for various kinds of survey and map knowledge. It was first introduced by Edward Tolman (1948) whose research with rodents linked a specific cognitive map to a certain spatial environment such that the position of an object within the environment could be referred to using at least two other landmarks. This perspective argued against the idea that a rodent's representation of the surrounding environment was based solely on self-referenced (egocentric) sequences of turns, demonstrating that the internal representation of space must be more integrated and comprehensive than previously assumed by behaviourist researchers. Since Tolman, the idea that most species, including humans, possess multiple mechanisms for navigating, including one dependent on information about the position of the self, relative to the environment (egocentric), and another regarding the position of other objects' position relative to each other in the environment (allocentric), is generally well-accepted (Chan, Baumann, Bellgrove, & Mattingley, 2012).

Functional neuroimaging studies have shown that the medial temporal lobe (MTL), particularly the hippocampus, is crucial for spatial learning and for allocentric representations (Bird, Bisby, & Burgess, 2012; Burgess, 2002; O'Keefe, Burgess, Donnett, Jeffery, & Maguire, 1998). The hippocampus contains a variety of different cells such as place cells, cells that fire action potentials when an animal passes through a specific small region of space (O'Keefe et al., 1998) as well as cells in neighbouring cortices such as the enthorhinal cortex which contains grid cells. These cells encode a cognitive representation of Euclidean, 3D space (Killian, Jutras, & Buffalo, 2012; Moser, Kropff, & Moser, 2008). Place cells are also modulated by running speed (i.e. the speed the navigator is walking or running) (O'Keefe et al., 1998), signifying that they have access to distance and direction information. There are multiple other cells such as head direction cells in the postsubiculum (Taube, 1998) and boundary vector cells within the subiculum (Lever, Burton, Jeewajee, O'Keefe, & Burgess, 2009) which support our navigating systems. Together, these cells allow us to form memories of our environment and thus enable us to navigate between locations.

Additionally, fMRI studies have reported that successful navigation can be predicted by activation of the hippocampus (Janzen & Jansen, 2010; Wegman et al., 2013) with differential activation when completing separate tasks in particular environments. For example, hippocampal activation is found to occur during wayfinding when participants are using a mental representation of the spatial layout of an environment (Hartley, Maguire, Spiers, & Burgess, 2003; Maguire et al., 1998; Wolbers & Buchel, 2005) as well as when subjects used a spatial rather than a response strategy to localise target objects (Iaria, Petrides, Dagher, & Pike, 2003). These reports emphasise the role the MTL and in particular, the hippocampus have during allocentric spatial tasks.

Another neural region, shown to be heavily involved in our spatial knowledge, is the retrosplenial cortex (RSC) situated in the posterior neocortical system (see Mitchell et al., 2017 for a review), consisting of Brodmann areas 29 and 30 (Morris, Paxinos & Petrides, 2000). It has been suggested by Iaria et al. (2007) that both the RSC and the hippocampus are equal contributors to the formation and use of cognitive maps. Additionally, the RSC has been shown to support directional information, independent of landmark information. For example, a case study, reported by Ino et al. (2007) found that a patient with RSC damage, who had worked several years as a taxi driver in Kyoto, could recognise buildings and landscapes, and therefore understand where he was, but was unable to extract any directional information from the landmarks. Thus, associative cue (or landmark direction) memory and sequence response memory of directions, were unavailable to support this patient's navigation, whilst landmark and scene memory were available to support his orientation.

Allocentric knowledge; shortcutting, pointing and map reading

Allocentric representations are often referred to as survey knowledge of the environment. Survey knowledge can be used to inform navigators of the direction and the distance to a goal location, independent of knowing the path to get there (for example, the bus stop is 100 metres west from here) and it relies on the inter-relationship between locations. It is acquired from studying maps together with landmark knowledge as well as from active exploration of the environment. Early developmental research suggested that survey representations acquired through direct experience with the environment require time to develop. Siegel and White (1975) put forward a sequence of changes that our mental representations of environmental space go through over time; from knowledge of landmarks, to knowledge of routes, to survey knowledge. Due to its influence in scientific literature, it was suggested that initial forms of spatial knowledge, such as knowledge of routes and landmarks formed in piecemeal fashion, should be named the “dominant framework” (Montello, 1998). However since then, there has been evidence which questions the extent to which survey knowledge follows this framework with some suggesting that survey knowledge can be formed as quickly as during someone’s first exposure to an environment (Holding & Holding, 1989; Montello & Pick, 1993; Ishikawa & Montello, 2006). This highlights how our representations of the environment are flexible and adaptable to change (i.e. the order in which we develop spatial representations can vary) and that survey knowledge can be acquired during early exposures of an environment emphasising the importance of supportive environmental cues to facilitate survey knowledge.

Survey knowledge is commonly measured by looking at shortcutting behaviour (Foo, Warren, & Duchon, 2005), the ability to point to a variety of locations in the environment (Smyth & Kennedy, 1982), or by measuring map-reading abilities (Thorndyke & Hayes-Roth, 1982; Meilinger & Knauf, 2008), mental rotation abilities (i.e. object-based transformations) and perspective taking abilities (i.e. egocentric spatial transformations) (Pazzaglia & De Beni, 2006).

Shortcutting

A survey representation allows a person to imagine lines directly connecting points in the environment (Kosslyn, 1980). As-the-crow-flies shortcuts are made through the integration of separately learned routes with some also suggesting that Euclidean maps are constructed on the basis of path integration (Gallistel & Cramer, 1996). Humans and animals can use novel routes to shortcut a route to their goal location. This ability to shortcut in situations when the start and end goal are not visible relies heavily on our allocentric survey representations and can be measured in a variety of ways in humans. Even without metric computations, shortcuts can be estimated when segments of paths are remembered and organised as a configuration. However, errors during shortcutting are far smaller if landmarks are visible from the start and end goal (Foo et al., 2005), and having landmarks present has been able to explain shortcutting behaviour in animals (Chapuis, Durup, & Thinus-Blanc, 1987; Thinus-Blanc & Poucet, 1983).

Pointing

Pointing tasks are often used to assess the quality of the spatial representation, particularly knowledge regarding metric relationship between locations/landmarks in the environment. The ability to point to places which are not visible from your current position can be done using egocentric abilities such as path integration (only requiring an egocentric vector pointing to the start), but can also be supported using survey knowledge. Pointing accuracy is also influenced when presented with a secondary cognitive task (i.e. working memory digit span tasks). An early study by Smyth and Kennedy (1982) found that pointing to landmarks within a university campus, after having walked along a path from the entrance to a room, was significantly negatively affected when participants counted backwards in threes whilst walking to the test room (i.e. they were worse when having to count back in threes). This emphasises the distracting nature secondary cognitive tasks have on path integration as well as the working memory cognitive resources involved (Garden, Cornoldi, & Logie, 2002). There was no difference between participants who were instructed prior to following the path that they would be tested on their pointing, to those who participants were simply instructed to walk with the experimenter to the test room. Interestingly though, all groups performed comparably when asked to describe or draw the path connecting the entrance to the test room, suggesting that path integration or route learning processes were used to retain a representation of the path’s shape, and that it operates independently of a self-to-object updating process using few central processing resources. Path integration, spatial updating and pointing location (in relation to our current position) all affect our abilities to accurately point back to landmarks within the environment.

Map-reading

Maps are tools that facilitate the acquisition of survey knowledge, which consequently rely on hippocampal allocentric processes (Maguire, Woollett, & Spiers, 2006). Whilst supporting navigation in familiar environments, they eliminate the need for familiarity and provide an instant survey representation of the environment. Maps allow spatial relations between places and landmarks to be viewed from a birds-eye perspective. Maps support successful navigation if aligned correctly with the navigators facing direction (Aubrey, Li, & Dobbs, 1994) and, dependent on the type of map, provide sufficient details regarding landmarks and cues within the environment (Klippel, Freksa, & Winter, 2006).

A classic study by Thorndyke and Hayes-Roth (1982) compared spatial learning from maps with spatial learning from direct navigation. Participants learned the layout of a building, either by studying a map or by navigating within the building. Map and navigation learners estimated route distances and straight-line distances (i.e. Euclidean) equally well, whereas navigation learners estimated route distances more accurately than straight-line distances. In addition, the map learners were less accurate in pointing to unseen locations in the building but were more accurate in placing locations on a map, relative to locations in the building. Despite the two groups having different amounts of exposure (from minutes to an hour in the map condition, and from one month to two years in the navigation condition), the authors concluded that after studying a map, people have a survey, or bird's-eye, representation of the environment, from which they can directly estimate straight-line distances. Since Thorndyke and Hayes-Roth's (1982) study, experiments have furthered these findings, showing that map-based route planning may lead to similar performance to receiving verbal directions when retracing routes and completing survey tasks (such as pointing to unseen landmarks; Meilinger & Knauf, 2008).

Map-based route planning and map identification can also be affected by one's general spatial ability. For example, making the change in perspective from birds-eye view to first person view, which is required to act in space, has been found to be influenced by mental rotation (i.e. object-based transformations) and perspective taking (i.e. egocentric spatial transformations) abilities (Pazzaglia & De Beni, 2006), highlighting how individual factors can affect the ability to make perspective changes, as experienced when reading and using a map for navigation.

One of the most commonly encountered types of map, "you-are-here" (YAH) maps, are reference maps that commonly display a rather large scale (i.e. displaying the layout of a shopping centre environment). Most recent YAH maps are designed such to consider the effects of alignment (i.e. designers are aware the effect misaligned maps have on misinterpreting the current/YAH location and route planning) having the map's orientation in line with the navigators facing direction; this is often referred to as forward-up or track-up alignment (Levine, 1982). In addition, a good YAH map also has landmark information and orientation (Montello, 2010), to support the efficiency and reliability of the navigation information they depict. YAH maps are perfect example of how compensations can be made to make navigation information more accessible through careful design and consideration.

1.3 Switching between Strategies

Although allocentric and egocentric strategies involve different processes and environmental input, they can both coexist while navigating through an environment (Li, Karnath, & Rorden, 2014). Similarly, a landmark can have both an allocentric location (e.g. Starbucks is located west of City Hall) and an egocentric location (e.g. Starbucks is located to the left while facing the City Hall). Translation between egocentric and allocentric representations is facilitated by the retrosplenial cortex (Byrne, Becker, & Burgess, 2007), which when damaged, results in heading disorientation, an inability or to estimate spatial relationship between two locations or to acquire directional information from scenes (Aguirre & D'Esposito, 1999). People who navigate well are able to switch from one reference frame to another, depending on what is optimal in a given situation (Epstein, Higgins, & Thompson-Schill, 2006). An example of a group who have difficulties switching between representations are older adults (Harris & Wolbers, 2013), which could consequently result in difficulties translating knowledge acquired from e.g. an allocentric survey representation to an egocentric perspective.

1.4 Active and Passive Navigation

Another factor which has been shown to contribute towards our spatial representation and knowledge of an environment is the extent to which the navigator has actively explored, and navigated within, the environment (Loomis, Da Silva, Fujita, & Fukusima, 1992; Chrastil & Warren, 2012).

Actively exploring an environment can provide greater spatial information, due to several cognitive and physical factors (Wilson, Foreman, Gillett, & Stanton, 1997). For example, idiothetic information, such as efferent motor commands that determine the path of locomotion, and vestibular and proprioceptive information for self-motion (Mittelstaedt & Mittelstaedt, 2001), are components of active navigation. Additionally, the cognitive mechanisms involved in active navigation include attention, decision making, and mental manipulation of spatial information, which supports landmark, route and survey information to be encoded in the relevant units of working memory (Chrastil & Warren, 2012). Without these movement cues to support the learning and exploration of the environment, passive navigation provides navigators primarily with the depth and visual direction of objects (Loomis, Da Silva, Fujita, & Fukusima, 1992).

During passive navigation, a navigator can feel as though they have moved, despite being stationary when a large part of the visual field moves – this is referred to as vection (Palmisano et al., 2015). Studies have even found that illusory motion (i.e. imagining movement) during passive navigation tasks facilitates spatial orientation (Riecke, Feuereissen & Rieser, 2012), therefore the importance of both actual and imagined motion should be noted when interpreting results from such studies and those only involving passive navigation.

Spatial cognition experiments, particularly those using VR, often use procedures that include route learning through watching videos of routes, rather than routes they have been actively navigated through (Strickrodt, O'Malley & Wiener, 2015; Gyselinck et al., 2013). As a result, multiple studies opt for protocols that assess passive navigation. This is often due to the simplicity of the design, the navigation variables of interest to the researchers, and the potential for them to be used alongside neuroimaging techniques.

1.5 How typical cognitive ageing affects navigation

Ageing is associated with functional decline in selective aspects of cognitive performance, brain function and the deterioration of physical ability (for example, reduced mobility). Cognitive skills that are known to decline with age include component processes of executive function, attention, verbal and visual explicit memory, working memory and processing speed (Fjell, Sneve, Grydeland, Storsve, & Walhovd, 2017; Lezak, 1995) while more experienced-based cognitive abilities such as semantic memory as assessed by general knowledge, comprehension, and vocabulary, can remain stable or even improve with age (Salthouse, 2014; Taylor & Burke, 2002).

Cognitive decline is accompanied by substantial neurological changes, most strikingly an overall decrease in brain volume (Scahill et al., 2003). This said, brain regions are differentially affected by ageing-related atrophy. The most substantial volume decreases are evident in prefrontal cortex (PFC), the MTL, and the cerebellum (Kaup, Mirzakhanian, Jeste, & Eyler, 2011; Pfefferbaum, Adalsteinsson, & Sullivan, 2005; Raz et al., 2005). These areas are predominantly associated with tasks involving attention, language, decision making, forward planning and memory and subsequently result in declines these cognitive abilities (MacPherson, Phillips, & Della Sala, 2002).

Deterioration of the hippocampus, and PFC in particular, has been directly associated with a decline in memory and executive functioning individually (Kaup et al., 2011; Yankner, Lu, & Loerch, 2008). Subsequently, as a result of these neurological changes that occur within parts of the MTL during healthy ageing (Raz, Ghisletta, Rodrigue, Kennedy, & Lindenberger, 2010), older adults tend to exhibit difficulties completing spatial memory tasks (Head & Isom, 2010; Moffat, 2009).

Ageing and Route Memory

Healthy older adults generally take longer to learn routes (Barrash, 1994) and perform significantly worse on a range of landmark-based tasks relative to younger adults (Head & Isom, 2010). The age-related declines in navigation abilities are most pronounced in hippocampal-dependent spatial tasks, i.e. tasks that require allocentric processing or cognitive map-like representations (Harris & Wolbers, 2013; Moffat, 2009; Wiener, de Condappa, Harris, & Wolbers, 2013). Typical ageing also affects other navigation tasks that can be solved using egocentric navigation strategies, such as learning an unfamiliar route which is often conceptualised as learning a series of associative cues or recognition-triggered responses ("Turn left at the church", Waller & Lippa, 2007; Wiener et al., 2013).

Given how older adults, particularly those showing early signs of atypical ageing, already exhibit difficulties in route learning and essential/straightforward navigation skills (i.e. route repetition, route retracing), the focus for the remainder of this thesis will be predominantly on egocentric navigation, the strategies used during egocentric navigation, and how route information, particularly environmental cues (i.e. landmarks) are remembered.

To explore the performance on specific measures of route memory, a systematic literature search was conducted to establish a detailed account of route knowledge abilities in older adults.

Search Strategy: Typical Ageing

With regards to studies which have specifically tested route learning and knowledge in real and virtual environments with older adults, a literature search was conducted to ensure all relevant literature was included. The databases used for the search were: PubMed and Web of Science (Web of Knowledge). The following string was used for both databases:

(“Aging" OR “Ageing”) AND ("wayfinding" OR "route learning" OR "orientation" OR "navigation") AND (“landmark”)

The following types of manuscripts were excluded: Meeting abstracts, Notes, Case reports, Letters to the editor, Research protocols, Patents, Editorials and other Editorial materials. Research including animals was also excluded. Additionally, papers that focused predominantly on neuroimaging, or aspects of spatial working memory (e.g. studies focusing explicitly on the Corsi blocks test) were not included. Papers from all years and dates were included (the initial search was carried out on 27th October 2014 and revisited on 31st May 2017).

In total, 24 papers were found through the search. After reading all abstracts to check they met the search criteria, only eight articles were included below. The 16 excluded papers were not explicitly relevant (i.e. did not relate to ageing) or were from another discipline (e.g. road safety). Protocol-driven search strategies were supplemented with snowballing methods to search for additional relevant papers (Greenhalgh & Peacock, 2005). These included reference list and citation searches, author searches and hand searching of key journals.

Table 1.1 below summarises the recent studies that have discussed the effects of typical ageing on navigation.

Table 1.1: Results and studies from the typical ageing and navigation literature review. YA = Young Adults, MA = Middle Aged (50-60 years) and OA = Healthy Ageing.

Author(s) and year of publication	Focus	VR or Real World	Route learning measures	Sample	Key findings
Head and Isom (2010)	Age effects on spatial navigation abilities.	VR	Landmark Free Recall, Temporal Order Memory, Landmark Directional Knowledge, Landmark Location Memory, Landmark Identification Memory:	wayfinding condition: YA (n=16) and OA (n=31). Route learning condition: 13 YA (n=13) and OA (n=32).	Older adults were equivalent younger controls recall of the landmarks and at landmark location, but performed more poorly in naming the landmarks already identified on the map and landmark direction.
Wiener, de Condappa, Harris and Wolbers (2013)	A route learning paradigm that measured beacon, associative cue, and place strategies.	VR	12 test trials. Decision-point direction task	YA (n=23) and OA (n=24).	Age-related deficits in Allocentric processing and an overall bias for response strategies. There was a specific preference for a beacon strategy
Gyselinck et al. (2013)	Mental representation derived from taking a realistic route acquired using virtual	VR	One video of a route (2.14 minutes) through unfamiliar environment. Tested landmark recognition, landmark location and spatial	YA (n=34) and MA (n=30) females with good mental rotation	Age-related differences were reduced when individuals were different in age but similar in spatial ability. Older

	environment and compares individuals different in age but with similar spatial ability.		relations.	ability were chosen on Mental Rotations Test score and their frequency of driving.	participants had difficulty in handling spatial information in a global configuration.
Wilkniss et al. (1997)	Spatial learning assessment in landmark order memory task and a map task in the real world.	Real World	Landmark order: recall relevant route information as well as to recognise and to order temporally landmark information observed along the route. Map task: memorising route on a map and subsequently navigated the route from memory.	YA (n=25) and OA (n=25).	Older participants had relatively greater difficulty retracing the route and temporal spatially ordering landmarks but were equally good at recognition of landmarks occurring on the route. Older participants had greater difficulty memorising the route and navigating it.
Mitolo, Borella, Meneghetti, Carbone and Pazzaglia (2016)	Route-learning training in a group of older adults living in a residential care home.	Real World	Route learning training - route learning from action, route learning from vision and route learning from map.	OA (n=30) living in a residential care home split into training	The trained group performed better than the control group in the route-learning tasks, retaining this benefit 3

			visuo-spatial short-term memory, visuospatial working memory and in self-report measures.	group (n=15) and control group (n=15).	months later. Immediate transfer effects were also seen in visuo-spatial span - benefits were largely maintained at the 3-month follow-up.
Taillade, Sauze´on, Arvind Pala, De´jos, Larrue, Gross and N'Kaoua (2013)	Spatial learning and wayfinding difficulties in large-scale spaces for older adults.	VR	Compared survey knowledge (wayfinding) and route knowledge (spatial memory).	YA (n=30) and OA (n=30)	A significant effect of age was obtained on the wayfinding performances but not on the spatial memory performances.
Marquez, Hunter, Griffith, Bryant, Janicek, and Atherly (2015)	Older Adult Strategies for Community Wayfinding	Real World	Data collection included an interview, map-drawing task, and walk along a previously audited, prescribed route to identify key wayfinding strategies.	OA (n=35) - short- (n = 14) and long-term (n = 21) residents of a neighbour-hood.	Street signs and landmarks were favourites as helpful wayfinding features. When asked to recall the route following the walk, only half of participants gave completely correct directions.
Zhong and Moffat (2016)	Heading direction during navigation.	VR	Route Learning Landmark Direction Landmark Recognition	YA (n=58), MA (n=28), OA (n=27).	OA were significantly worse at processing non-critical landmarks for specifying the directions to reach the goal. OA were also

					worse at Landmark Direction (associative cue).

From this literature review it is evident that aspects of route knowledge are differently affected during healthy ageing. In particular, the memories of where landmarks are located in the environment (landmark location memory), the free recall of landmarks that were along the learned route and the ability to recognise landmarks that were along the learned route against distractors (landmark recognition memory) remained intact and unaffected by the effects of typical ageing (Head & Isom, 2010; Wilkniss et al., 1997), with little, if any, difference in performance between younger adults and typically ageing adults. Particularly, the free recall of landmarks and landmark recognition memories provide less navigational information than some other aspects of memory, but their memories (especially landmark recognition) serve as a prerequisite for other aspects of route knowledge (such as egocentric response strategies). With respect to egocentric response strategies, it is clear from the literature that typically ageing adults show impaired object-direction binding, i.e. they have less accurate knowledge of the direction in which the route continued at particular landmarks (Zhong & Moffat, 2016; Head & Isom, 2010; Wiener et al., 2013). Consequently, typically ageing adults displayed a preference beacon landmark strategies compared to associative cue landmarks strategies (Wiener et al., 2013), which could have implications for where landmarks are positioned in the environment to support older adults' preferred strategy; by positioning landmarks in places which are in the direction of turn (for example, along a corridor), rather than centrally at an intersection, older adults could be supported in their strategy choice and consequently in their ability to learn novel environments and routes through these environments.

Tasks affected by ageing included naming landmarks on a map of the environment, associative cue/landmark direction tasks, memory of the temporal sequence in which landmarks were encountered, repeating the route and verbally recalling the directions of the route. Given the split in tasks affected, compensatory strategies to allow successful recall using the available resources may be supporting healthily ageing adults to continue to navigate successively.

So far, the literature has highlighted situations and tasks where cognitive ageing affects performance in navigation. In particular, deficits in landmark-based route learning tasks (associative cue, temporal sequence memory, and landmark location memory) are seen, with smaller effects in recognition memory and a preference for beacon based landmark memory.

1.6 Atypical Ageing, Dementia and Navigation

Declines in navigation performance become more pronounced if older individuals develop a form of dementia, specifically amnestic Mild Cognitive Impairment (MCI) or Alzheimer's disease (AD; Cushman et al., 2008; Pengas et al., 2010; Monacelli et al., 2003; Cherrier, Mendez, Perryman, 2001; deIpolyi et al., 2007; Benke et al., 2014). The damage that occurs within the hippocampus during the first stages of MCI and AD, leads to difficulties in orientation and navigation (for a review see Lithfous et al., 2013). A recent study by Tu et al. (2017) has also emphasised how damage to the RSC during AD, results poor path integration abilities. In particular, allocentric spatial processing is severely affected (Bird et al., 2010), though the majority of navigation dementia studies have primarily focused on route learning (Pengas et al., 2010).

Mild cognitive impairment (MCI) is an intermediate stage between the expected cognitive decline associated with normal ageing and the more-serious decline of dementia (Petersen & Morris, 2003). The decline of dementia can involve problems with memory, language, thinking and judgment that are greater than normal age-related changes (Freitas, Simões, Alves, & Santana, 2013). MCI can be detected through a full diagnostic assessment, involving functional magnetic resonance imaging (fMRI), cerebral spinal fluids, blood tests, and neuropsychological assessments. This said, initial changes in cognitive abilities can be detected using simple screening tools such as the mini-mental state examination (MMSE), Addensbrook Assessment (ACE-III) and Montreal Cognitive Assessment (MoCA). These tools are able to provide an initial red-flag when scores do not reach the suggested scoring criterion indicative of healthy ageing and provide a benchmark for when further investigations are necessary. It is estimated that between 5 and 20 % of people aged over 65 have MCI. Additionally, whilst MCI is not a type of dementia, a person with MCI, particularly multi-domain MCI, is more likely to go on to develop dementia, though some researchers do stipulate that a diagnosis of MCI marks the early beginnings of AD (Mitchell, Arnold, Dawson, Nestor, & Hodges, 2009; Tabert et al., 2006).

Early atypical ageing and navigation.

Both MCI and AD have been associated with decreases in navigation abilities and orientation (Cushman et al., 2008; deIpolyi et al., 2007). Neuroimaging studies show that this is associated with degeneration of the brain regions, particularly areas within the medial temporal lobe (MTL), as a result of amyloid and tau build-up (Hardy & Allsop, 1991). Vlcek and Laczó (2014) emphasised that spatial disorientation found in people with typical AD reflects neurodegenerative changes in medial and posterior temporal, parietal, frontal lobes, and retrosplenial cortex, while spatial navigation impairments seen in MCI appear connected mainly with changes in medial temporal and parietal areas.

Search Strategy: Atypical Ageing

As early atypical ageing already affects route learning and essential/straightforward navigation skills (i.e. route retracing and route knowledge), the focus for the literature search was predominantly on atypically ageing adults' egocentric navigation, the strategies used during egocentric navigation, and how route information, particularly environmental cues (i.e. landmarks), are remembered.

A literature search was conducted to ensure that all relevant studies that have specifically tested route learning and knowledge in real and virtual environments were included. The databases used for the search were: PubMed and Web of Science (Web of Knowledge).The following string was used for both databases:

("Alzheimer's" OR "AD" OR "Dementia" OR "Mild Cognitive Impairment" OR "MCI") AND ("wayfinding" OR "route learning" OR "orientation" OR "navigation") AND ("landmark")

The following types of manuscripts were excluded: Meeting abstracts, Notes, Case reports, Letters to the Editor, Research protocols, Patents, Editorials and other Editorial materials. Research including animals was also excluded. Additionally, papers that focused predominantly on neuroimaging, or aspects of spatial working memory were not included. Papers from all years and dates were included (initial search was carried out on 27th October 2014 and revisited on 31st May 2017).

In total, 15 papers were found through the search. After reading all abstracts, only three were suitable and relevant. The 12 excluded papers were not explicitly relevant (i.e. did not relate to ageing) or were from another discipline (e.g. road safety). Protocol-driven search strategies were supplemented with snowballing methods to search for additional relevant papers (Greenhalgh & Peacock, 2005). These included reference list and citation searches, author searches and hand searching of key journals. From this, a total of nine papers were found.

Table 1.2 summarises recent studies which have discussed the effects of typical ageing on navigation.

*Table 1.2: R*esults and studies from the early atypical ageing and navigation literature review. YA = Young Adults, MA = Middle Aged (50-60 years), OA = Healthy Ageing, MCI = Mild Cognitive Impairment, AD = Alzheimer's disease and FTD = Frontal temporal lobe dementia.

Author(s) and year of publication	**Focus**	**VR or Real World**	**Route learning measures**	**Sample**	**Key findings**
Benke, Karner, Petermichl, Prantner and Kemmler (2014)	Searched for neuropsychological and demographic predictors of route learning impairment predictors.	Real World	Route Learning Landmark Recognition Route Finding	OA (n=46), MCI, (n=34) and early AD (n=37).	Almost all AD patients and most MCI misidentified landmarks and made errors when following a route without assistance. Poor Landmark knowledge and defective directional guidance.
Widmann, Beinhoff and Riepe (2012)	Compared verbal material and spatial scenery in list format and in VR.	VR	Route Learning (passive) Landmark Recognition Landmark Location Naming Task Free Recall Route Drawing	OA (n=31) and AD (n=15).	Despite learning being up to 90% for both the VE and list learning, whist list learnings recall was 40%, VE recall was 20%.
Kessels, van Doormaal and Janzen (2011)	Investigated memory for objects relevant for navigation in patients with AD	VR	Route Learning (passive) Landmark Recognition	OA (n=20) and AD (n=21)	AD had better memory for the non-toy landmarks. Suggests implicit memory for object information relevant to

					navigation.
Guariglia and Nitrini (2009)	To identify the neuropsychological dysfunctions associated with Topographical disorientation (TD) in AD.	Real World	Landmark Agnosia Test Route Recognition Pointing Localisation Geographical Orientation Mental Imagery Spatial Working Memory House Drawing Landmark Recognition Route Descriptions	OA (n=30), mild AD (n=15), moderate AD (n=15).	Geographical Orientation and House Drawing worse in mild AD than OA. Landmark Recognition and Route Descriptions worse in moderate AD than mild AD. .
Monacelli, Cushman, Kavcic and Duffy (2003)	Route learning abilities in an unfamiliar, hospital environment.	Real World	Route Learning Photo Location Photo Recognition Video Location Route Drawing Self-Orientation Landmark Recall Free Recall	YA (n=47), MA (n=24), OA (n=26), and AD (n=14).	Almost all patients with AD got lost (93%) and some OA subjects (38%).
deIpolyi, Rankin, Mucke, Miller and Gorno-Tempini (2007)	The sensitivity of navigation impairment amongst people with AD and those with MCI	Real World (pushed in a wheel chair)	Map Drawing Landmark Recognition Landmark Location Dead Reckoning Landmark and Place	OA (n=24), MCI (n=21) and mild AD (n=13).	AD and MCI patients recognised landmarks as effectively as controls (OA), but could not find their

	in relation to the atrophy of the specific brain regions.		Ordering (or Sequencing)		locations on maps or recall the order in which they were encountered.
Cherrier, Mendez and Perryman (2001)	Route learning in ageing and AD.	Real World	Route Learning Walking Recall Route Cues Route Map Recognition	OA (n=19) and AD (n=16)	AD group performed best on recognition of landmarks compared with recognition and recall of spatial layout (map task) or landmark location task.
Bellassen, Igloi, Cruz de Souza and Rondi-Reig (2012)	Used a human version of the Star Maze to test temporal components of memory (“when” and “where”).	VR	Temporal navigation tasks: Sequential navigation, route retracing, temporal memory score. These were followed by a what test and a where test	YA (n=20), MA(n=19), OA (n=24), aMCI, (n=14), AD (n=16) and FTD (n= 11)	aMCI and AD were significantly worse at the temporal memory tasks, while OA and FTD performed successfully.
Rusconi, Suardi, Zanelli and Rozzini (2015)	To identify early cognitive markers of MCI conversion to dementia and topographical disorientation	Real-World (Plastic Lego City)	Route Learning: forward test Route Learning: backward test Free Recall Landmark City landmark replacement	OA (n=18) and MCI (n=18; naMCI n=9, aMCI n=9)	aMCI patients performed worse in learning a new route, in replacing landmarks in the city and in drawing a map of the city. NaMCI patients'

	(TD) may help differentiate normal ageing from MCI and AD.		Map Drawing Landmark Photo Recognition Map Replacement Recall Replacement on map Route Planning Shortest Route Planning		performance was not different from that observed in healthy subjects.

This literature review focused on the effects of atypical ageing (MCI or dementia) on navigation abilities, with prominent declines in performance on route memory measures and orientation abilities. For example, Cherrier et al. (2001) compared typically ageing adults and people with early AD on their performance on a series of route learning tasks. When compared with healthy ageing adults, participants with AD showed profound difficulties in identifying a recently navigated route from a map perspective (i.e. a difficulty translating route knowledge from an egocentric perspective to an allocentric map perspective). Older adults with MCI and AD also made significantly more errors than typically ageing adults when following a route without assistance, and additionally misidentified the landmarks along the route (Benke et al., 2014). These results highlight the steep decline in navigation abilities from healthy ageing compared with older adults experiencing the early symptoms of atypical ageing.

Those experiencing AD and MCI are significantly worse at learning longer routes (more than five turns) than those with fronto-temporal dementia (FTD) or typically ageing adults. Using a virtual environment, Pengas et al. (2010) compared young, typically ageing adults, MCI, FTD and AD participants on their ability to learn routes that increased in length/complexity, and found that despite receiving the same amount of exposure to the routes, those with AD and MCI exhibited significant difficulties with routes longer than five turns.

In a similar, but real world study, Monacelli and colleagues (2003) had people with AD and older control participants learn a route through a hospital. Once they had navigated the route, they were tested on a battery of memory tasks related to the navigated route. Interestingly, as well as there being a general decline in the AD group compared with the control group, the strongest deficits were found in photo location and video location. These two tasks required participants to remember the spaces in the environment that the landmark (or segment of the video) filled and be able to translate this memory to a birds-eye view representation of the environment (Monacelli et al., 2003). Both of these tasks firstly required perspective taking abilities as well as being able to correctly connect locations/scenes together, thus making a story (by linking the individual scenes together) which makes use of episodic memory functions. Episodic memory is also heavily reliant on hippocampal functions (Burgess, Maguire, & O'Keefe, 2002), so overlap between memory types affected during atypical ageing can be explained by their neurological correlates.

Using the same paradigm and set of tasks, Cushman et al. (2008) added an additional variable to see whether their navigation performance differed if the route was displayed in virtual reality (VR). The same performance patterns were found between the real world and the virtual replication of the route. Both the findings by Cushman et al. (2008) and Pengas et al. (2010) demonstrate that VR is a valid tool to use both for navigation experiments and to study the effects of dementia on navigation skills. The use of VR can have significant advantages when measuring navigation abilities, in particular, environmental manipulations. It allows for full control over what is displayed in the VR environment and can record additional data points (e.g. route trajectories, exact time spent at decision points). Also, depending on the set-up, it is easily transportable, cost effective and often quick to administrate, which makes VR set-ups a desirable option for testing navigational skills.

Overall, this literature review has highlighted how aspects of route knowledge are affected differentially during ageing and early atypical ageing. Tasks that measure the landmark location memory (stating where landmarks encountered during active navigation were on a map of the environment), map drawing, map identification and temporal memory, have been found to be affected during MCI and early AD (Cherrier et al., 2001; deIpolyi et al., 2007; Rusconi, Suardi, Zanetti, & Rozzini, 2015). However, some aspects of egocentric route knowledge such as landmark recognition have been found to be relatively intact (deIpolyi et al., 2007), particularly those that are relevant for successful navigation (Kessels, van Doormaal, & Janzen, 2011). During atypical ageing, additional aspects of route knowledge are differentially affected with varying levels of abilities depending on the progression. Guariglia and Nitrini (2009) found that whilst landmark recognition was comparable between older adults and those with mild AD, differences in performance occurred when comparing those with mild AD to those with moderate AD. In contrast to the landmark location and map drawing findings discussed above (Cherrier et al., 2001; Rusconi et al., 2015), the findings from these studies emphasise the task-specific deficits that occur during the progression of atypical ageing.

Importantly, the literature review has demonstrated how VR can be used to highlight sensitive changes to navigation abilities during (a)typical ageing (Cushman et al., 2008; Pengas et al., 2010), which should be utilised given its flexibility to present routes in carefully designed environments.

1.7 Qualitative studies surrounding route memory and early atypical ageing.

Disorientation amongst those with AD and older adults with memory difficulties has also been reported in a variety of qualitative studies (Caspi, 2014; Liu, Gauthier, & Gauthier, 1991; Passini, Pigot, Rainville, & Tetreault, 2000; Passini, Rainville, Marchand, & Joanette, 1995). Research by Passini and colleagues (2000) has highlighted, through the use of interviews with care staff and observations of wayfinding behaviour of the residents, the issues that residents living with dementia and early signs of early atypical ageing experience in care environments. In particular, Passini et al., (2000) highlighted that monotonous layouts in care settings, that lacked reference points (e.g. landmarks) in the environment, negatively affect residents living with AD. Ideally settings should have landmarks at each decision point to encourage successful navigation (Passini et al., 2000). These qualitative studies are valuable for two particular reasons: firstly, ecological validity, and secondly, they acknowledge the voice of those affected by dementia, particularly carers and care-workers (Caspi, 2014) by emphasising real-world situations where disorientation is experienced. Such data collected through interviews (Passini et al., 2000) and direct observations (Caspi, 2014) offers a wealth of personal experience which quantitative studies often do not capture. For example, the feelings attached to particular situations as well as attitudes towards behaviours may not be highlighted in purely quantitative studies focused on navigation. Additionally, having people with early symptoms of AD talk about their experiences is especially valuable given the few studies that have directly spoken to people with dementia. Recent studies which have compared care-home residents' versus care-staffs' opinions have demonstrated differences in preferences in design (Godwin, 2014) reinforcing the importance of talking to the user and looking beyond the dementia.

1.8 Summary & Rationale

Early atypical ageing results in drastic declines in navigation performance compared with typical ageing. These declines are explained by the neurological underpinnings supporting successful navigation which are affected during the ageing, and more significantly during the atypical ageing process (Lithfous et al., 2013).

Whilst patterns of decline are similar across the studies reported in the literature search, these studies have all followed a similar methodological protocol, with route memory tested following exposure to a route after a set number of exposures. Given that route forgetting during recall is high during atypical ageing (Pengas et al., 2010), there is potential to create a more rigid protocol which accurately measures route knowledge following successive learning. In order to understand what aspects and strategies are used in successful navigation, it would be beneficial to first ensure participants have learned a route and can accurately retrace it and to then assess potential differences in the route knowledge and in the strategy used.

Additionally, it is important to note that whilst there is overlap between some of the tasks affected during typical and early atypical ageing (e.g. map task performances, egocentric response strategy declines), the vital consideration is the severity of the decline in performance between these two groups. While map-based tasks also appear affected in typical ageing, the decline when comparing them to MCI and AD patients is particularly strong, suggesting that while these effects may already start to decline in healthy ageing, the strongest effects are when signs of atypical ageing are present.

The majority of studies have focused exclusively on typically ageing adults compared with those with a well-defined diagnosis of AD or MCI to establish the changes that occur during early atypical ageing. Little is known about the changes that occur during the earliest stages of atypical ageing (i.e. particularly those with no formal diagnosis and minimal symptoms), and which navigation tasks are effected during this process. Bird et al. (2010) have emphasised how measuring navigation abilities could be used as a diagnostic measure for MCI and AD, with marked decreases in spatial navigation ability being almost exclusive to the early stages of AD related dementia neurodegeneration (Pengas et al., 2010).

Additionally, it is clear from the studies highlighted in the literature review searches that there has been a mix of methodological approaches to test navigation skills. In particular, while some studies have tested navigation skills in real world environments (Cherrier et al., 2001; Monacelli et al., 2003), multiple studies have used virtual models of environments (e.g. town centres, hospitals) (Pengas et al., 2010, Cushman et al., 2008; Gyselinck et al., 2013). There has been increasing evidence supporting the use of VR, with comparative studies (i.e. testing some participants in the real world, and testing others in a virtual model of that environment) that have shown highly similar findings (Cushman et al., 2008). However, given how the majority of earlier spatial cognition research has used rather simplistic VR environments (e.g. Wiener et al., 2013) to test particular manipulations, it would be additionally informative to compare how well such simplistic environments relate to real world navigation.

Finally, in addition to testing participants explicitly on their route memory in an experimental fashion, it would be fruitful to ask them directly about their navigation experiences, in particular their orientation strategies as well as any areas of the environment that cause disorientation. Ageing adults, particularly those displaying signs of cognitive impairment, are an overlooked group in society (Jonas-Simpson, 2003), so giving them a platform to verbalise their experience would provide an additional layer of data which could be used in conjunction with the experimental route memory performance data.

Understanding which aspects of route knowledge are used by typically ageing, and those showing signs of early atypical ageing, will inform us on the strategies used to learn environments, which cues should be available in environments to better support navigation for these individuals, and will have societal benefits through shaping age and dementia friendly design guidelines.

CHAPTER 2: Research Design

To gain a rich understanding of how typically and early atypically ageing adults learn routes through unfamiliar and familiar environments, this thesis used a mixed-method approach.

This thesis bridges the methodologies of quantitative spatial cognition and route learning with qualitative interviews and open-ended questions. Additionally, it provides findings based on participants' performance when tested on their route memory, as well as their own experiences of finding their way through environments through qualitative measures.

2.1 Triangulation and Epistemological Approach

Triangulation within research was first applied by Campbell and Fiske (1959) and developed by Webb and colleagues (1966), who argued that researchers should employ more than one methodology to measure variables. Denzin (1970, 1978) was a major advocate of the use of triangulation by researchers working within the interpretivist paradigm, which focused on research that integrates human interest into a study, often through using naturalistic approaches (such as interviews) to data collection. For this thesis, triangulation of the data sources and theory was critical to the aims of the research. In particular, the inclusion of qualitative exploratory research was done to increase the credibility and validity of older adults' lived experiences when navigating, and to provide them with opportunity to discuss factors that have influenced or affected them when navigating. Consistent with Denzin (1978), different methods were used within the thesis. Quantitative measures to accurately and precisely measure route learning and map route planning abilities, and qualitative methods to gather the lived experiences and opinions of orientation and design from older adults.

2.2 Ethical considerations

Older adults experiencing memory difficulties are one of the most excluded groups in society (Dewing, 2002; Jonas-Simpson, 2003). Keady and Gilliard (1999) found that those with dementia were amazed when someone took interest in them. It is therefore important to ensure researchers design rewarding and suitable studies that are enjoyable for the person with dementia as well as having therapeutic benefits. Throughout the thesis, participants were reminded of their value and importance to the project, by emphasising the potential impact of the study (i.e. their contribution could inform dementia friendly design principles) and provided opportunities to feedback on their experiences of partaking in each study.

Person Centred Approach

Adopting a person-centred approach relates closely to the work of Tom Kitwood who emphasised the importance of seeing the person with dementia beyond the disease (Kitwood, 1997). Kitwood highlighted the ‘malignant social psychology’ used in dementia care, such as ‘treachery’ whereby different forms of deception were adopted to manipulate or gain control over a person with dementia. Kitwood also emphasised ways researchers can explore the subjective lived experiences of people living with dementia, highlighting the importance of direct access of written accounts by people with dementia, as well as directly speaking with them to gain insight into their experiences (Kitwood, 1997).

Although this thesis did not explicitly recruit people living with dementia, a person-centred approach was adopted throughout the thesis to ensure comfort and wellbeing throughout the separate chapters (Cowdell, 2006). For example, research that emphasises that they are researching “with”, rather than “on”, preserves personhood and adopts a more inclusive approach (Cowdell, 2006). Likewise, actively engaging with participants throughout the research study makes the testing environment a less intimidating and more enjoyable experience (Cowdell, 2006). All individual experiments and study sessions included tea, coffee and biscuits, regular breaks and opportunities were provided for the studies (where appropriate) to be completed in an environment familiar to them (such as their home). The importance of conducting the research in a familiar environment for the person with dementia was emphasised by (Hellström, Nolan, Nordenfelt, & Lundh, 2007), who noted the benefits (e.g. being valued, given a voice) of such research far outweighs the risks (such as uncertainty over maximal consent). Having participants choose a suitable testing location was important for this thesis (see Chapter 3 for details).

Using Appropriate Tests

Testing people on tasks which become harder with age and/or cognitive impairment could be potentially upsetting for them and cause challenges. Ensuring participants did not undergo long and/or unnecessary testing was important to avoid any feelings of fatigue and for participants to maintain their sense of pride and dignity. Prior to data collection, care was placed on selecting the most appropriate neuropsychological test for the older adults participating. Specifically, I wanted to ensure the test was sensitive enough to detect cognitive decline, yet still enjoyable for those completing it. Existing short screening tools which are suitable as a pre-test measure of cognition include the Mini Mental State Examination (MMSE), Addenbrooke's Cognitive Examination-III (ACE-III) and the Montreal Cognitive Assessment (MoCA). Nordenfelt (2004) stated that older adults with and without dementia who completed the MMSE in their study felt stupid, humiliated and frustrated when completing this test, emphasising the potential negative impact such screening tools could have on a participant's personhood. The ACE-III, which is more sensitive than the MMSE (Velayudhan, 2014) and frequently used as a tool in the detection of Mild Cognitive Impairment (MCI), proved to be too long a measure to use as a screening tool prior to running experiments.

The MoCA has been deemed superior in comparison to its rivals (Smith, Gildeh, & Holme, 2007), particularly due to its sensitivity in detecting early MCI, and has additionally been reported as an 'enjoyable' screening tool by collaborators who have used the tool with older adults and those with cognitive impairments.

Capacity to Consent

This project predominantly involved younger control participants, typically ageing older adults and older adults showing early signs of cognitive impairment. Given this, those who participated gave consent themselves. According to the Mental Capacity Act

(2005) Section two and three, the criteria set to determine if a person is capable to make a decision or not, is if the person is unable to:

- To understand the information relevant to the decision
- To retain the information
- To use or weigh that information as part of the process of making that decision
- To communicate that decisions

If a participant showed signs that they were unable to do any of these four requirements, they would not have been recruited for the project. Participants were required to demonstrate that they understood the research, and that they were able to retain the information related to the study. Throughout the thesis, no participant showed signs that they were unable to complete the four requirements. This said, mental capacity was assumed until otherwise indicated, based on the criteria stated above.

Gaining Consent and Minimising Risk

Information sheets describing the studies were distributed to participants prior to giving consent. The participant then had time to read through and decide whether they wanted to participate. Consent took place on the day of testing; a consent form was initially provided and required to be signed. In addition, on-going consent occurred throughout all studies; the researcher observed and monitored the behaviour of the person participating for the duration of the study (Dewing, 2008). It was important to observe participants' nonverbal signs of fatigue or anxiety during the studies (Moore & Hollett, 2003). If any indications of discomfort were made evident through body language (i.e. not looking at the material or myself, the subtle diminishing volume) or discomfort, the participants were asked whether they wished to continue (Dewing, 2008).

Moore and Hollett (2003) observed that the diminishing volume of speech, anxiety was portrayed differently by two individuals during their research; one man repetitively rolled paper, whereas a lady constantly shifted weight in her seat. If any non-verbal signs of fatigue or anxiety would have been witnessed during the studies, participants would have been be asked if they would like to stop the study, or have a break before continuing.

Moore and Hollett (2003) also discuss the significance of conducting pilot studies or working with another experienced qualitative researcher has in developing suitable techniques when working with people with dementia; this experience was gained by discussing with fellow members of the Bournemouth University Dementia Institute (BUDI) about suitable research techniques and gaining experience through working on additional dementia related projects. I additionally attended national workshops and conferences where appropriate methodologies, theories and findings were discussed with other researchers.

2.3 Preliminary Preparation Work

Before collecting data, it was important that I sourced appropriate gatekeepers, retirement developments where potential participants lived, and to gain experience talking and working together with older adults and people who are living with dementia.

Experience in care-environments and working with people with dementia

During the first year of my PhD, I spent one morning a week for eight weeks volunteering in a dementia wing of a care-home. This provided me with experience in talking to people with dementia and also allowed me to observe their wayfinding behaviour and how they used their living environment. I also supported additional dementia projects that the Bournemouth University Dementia Institute arranged (such as the Bournemouth Symphony Orchestra project). Additionally, throughout the PhD I familiarised myself with a variety of care-environments and care-providers to see how my research could be implemented into practice. Visiting these developments provided me with a base understanding of which principles of dementia friendly design were most commonly (and less frequently) used, as well as which suggested orientation aids were most frequently implemented. Most noticeably though, visiting the dementia specialist care-homes highlighted that not all care-homes necessarily follow (or are aware of) the suggested dementia friendly design principles, highlighting how more environments should be made aware of their importance and use.

Gatekeepers

I approached and made contact with multiple charities and aged-care housing developers to seek assistance with recruitment for the project. One local group in particular were especially helpful; they advertised the studies in their monthly newsletters and were supportive throughout. I additionally took part in multiple public engagement events (such as coffee mornings at local retirement developments and 'Café Scientifique' Public Engagement Talk in Bournemouth) to source additional participants.

2.4 Research Methods

The individual and specific methodologies are discussed in the respective chapters that are presented in the following chapters.

This thesis used virtual reality (VR) environments to assess which aspects of route learning are most and least susceptible to the effects of cognitive ageing (See Chapters 3, 4 and 8) as well as qualitative methods to gain insight into older adults' design preferences and orientation experiences (See Chapters 6 and 7). The final data chapter in Chapter 8 compares route memory in virtual reality environments with real world navigation.

CHAPTER 3: How do we get there? Effects of cognitive ageing on route memory.

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CHAPTER 3: How do we get there? Effects of cognitive ageing on route memory.

3.1 Overview

Research into the effects of cognitive ageing on route navigation usually focuses on differences in learning performance. In contrast, we investigated age-related differences in route knowledge after successful route learning. One young, and two groups of older adults categorised using different cut-off scores on the Montreal Cognitive Assessment (MoCA), were trained until they could correctly recall short routes. During the test phase, they were asked to recall the sequence in which landmarks were encountered (Landmark Sequence Task), the sequence of turns (Direction Sequence Task), the direction of turn at each landmark (Landmark Direction Task), and to identify the learned routes from a map perspective (Perspective Taking Task). Comparing the young participant group with the older group that scored high on the MoCA, we found effects of typical ageing in learning performance and in the Direction Sequence Task. Comparing the two older groups, we found effects of early signs of atypical ageing in the Landmark Direction and the Perspective Taking Tasks. We found no differences between groups in the Landmark Sequence Task. Given that participants were able to recall routes after training, these results suggest that typical and early signs of atypical ageing result in differential memory deficits for aspects of route knowledge.

3.2 Introduction

Declines in navigation abilities in both typical and atypical ageing are now well established in a variety of tasks (Bellassen, Iglo, Cruz de Souza, Dubois, & Rondi-Reig, 2012; Head & Isom, 2010; Monacelli, Cushman, Kavcic, & Duffy, 2003; Zhong & Moffat, 2016). The vast majority of studies investigating the effects of (a)typical ageing on navigation skills focus on a participant’s ability to learn unfamiliar routes or novel environments (Cherrier, Mendez, & Perryman, 2001; Cushman, Stein, & Duffy, 2008; Pengas et al., 2010). So far, our understanding of whether, and how, spatial representations differ in young and older participants after the successful learning of a novel route is limited. Here we address this question by using a novel route learning paradigm: our participants first learned short routes until they could successfully repeat them. To investigate how route representations are affected by typical ageing and early signs of atypical ageing, we then tested participants on various aspects of route knowledge.

Age-related declines in navigation abilities are most pronounced in hippocampal-dependent spatial tasks, i.e. tasks that require allocentric processing or cognitive map-like representations (Harris & Wolbers, 2013; Moffat, 2009; Wiener, de Condappa, Harris, & Wolbers, 2013). These differences in both typical and atypical ageing are often explained by neurodegeneration of the hippocampus, one of the earliest brain areas affected in both healthy ageing (Raz, Ghisletta, Rodrigue, Kennedy, & Lindenberger, 2010) and in atypical ageing such as Alzheimer's disease (AD) (deIpolyi, Rankin, Mucke, Miller, & Gorno-Tempini, 2007; Hort et al., 2007). Typical and atypical ageing, however, also affects other navigation tasks that can be solved using egocentric navigation strategies, such as learning an unfamiliar route which is often conceptualised as learning a series of associative cues or recognition-triggered responses ("Turn left at the church", Waller & Lippa, 2007).

Healthy older adults generally take longer to learn routes (Barrash, 1994) and perform significantly worse on a range of landmark-based tasks than young adults (Head & Isom, 2010). In experiments where older adults received the same amount of training as the young participants, older adults show impaired performance in locating where objects were encountered along the route (Gyselink et al., 2013) and in stating the sequence in which the objects were encountered (Wilkniss et al., 1997; Head & Isom, 2010, Wiener et al., 2012). Older adults also show impaired object-direction binding, i.e. they have less accurate knowledge of the direction in which the route continued at particular landmarks (Head & Isom, 2010; Wiener et al., 2012; Zhong & Moffat, 2016) and tend to point out salient objects rather than turns or intersections as being navigationally relevant (Lipman, 1991).

Declines in navigation performance become more pronounced if the older individual additionally develops a form of dementia, specifically amnestic Mild Cognitive Impairment (MCI) or Alzheimer's Disease (AD; Cushman et al., 2008; Pengas et al., 2010; Monacelli et al., 2003; Cherrier, Mendez & Perryman, 2001; deIpolyi et al., 2007; Benke et al., 2014). Cherrier et al. (2001) compared typically ageing adults and people with early AD in a series of route learning tasks. In contrast to healthy older adults, participants with AD showed profound difficulties in identifying a recently navigated route from a map perspective. Also, older adults with MCI and AD made significantly more errors than the typically ageing adults when following a route without assistance and additionally misidentified the landmarks along the route (Benke et al., 2014). These results highlight the steep decline in navigation abilities associated with atypical ageing.

While the studies reviewed above clearly demonstrate age-related declines in route learning abilities, in both typically and atypically ageing adults, very little is known about how route memory is affected after the successful learning of a route. This is because different participant groups usually undergo the same training protocol, i.e. they are exposed to the route either for the same amount of time or are presented with the same number of training trials before route knowledge is assessed (Benke, Karner, Petermichl, Prantner, & Kemmler, 2014; Cherrier et al., 2001; Pengas et al., 2010). Assuming slower route learning in older adults (Head & Isom, 2010), they would have learned less about the route than the young participant group when they entered the test phase. While this approach is perfectly suited to study age-related differences in route learning, it may not be sensitive to highlighting differences in the content, format and structure of route knowledge which is sufficiently detailed to support successful navigation of the learned route. Any differences in route knowledge can therefore either result from ageing-related shifts in learning strategy, or could reflect different rates of knowledge acquisition between groups. In other words, it is not clear whether differences in knowledge about the order in which landmarks were encountered (Bellassen et al., 2012), or differences in identifying movement directions associated with landmarks (Head & Isom, 2010; Wiener et al., 2012), highlight specific age-related navigation deficits or instead reflect differences in general route knowledge resulting from slower learning.

As earlier studies have reported age-related strategy shifts in spatial learning (Rodgers, Sindone, & Moffat, 2012; Wiener et al., 2013), it is conceivable that such strategy differences could result in (at least partly) different route representations which are best tested after routes have been learned. Ageing also affects executive functions (Fjell et al., 2017; Lezak, 1995) which may in turn affect people's ability to learn different route representations simultaneously or switch between these representation during learning and/or recall. This again would be best assessed after routes have been learned successfully. Finally, age-related differences in memory decay are often not controlled for, which is problematic as forgetting could affect performance in tests of route knowledge that are administered after route learning.

To address these issues, we present a novel paradigm in which participants learned short novel routes through virtual environments. After successful learning, they were then confronted with several tasks assessing different aspects of route knowledge. The tasks we selected have been adopted from previous experiments that have addressed the effects of typical and atypical ageing on route learning (Benke, Karner, Petermichl, Prantner, & Kemmler, 2014; Cherrier et al., 2001; Cushman et al., 2008) and assess knowledge of landmark sequence, sequence of direction changes, landmark-direction associations, as well as participants' ability to recognise the learned route from map-like schematic drawings. After completing these tasks, participants were then asked to navigate the route again, which allowed us to control for potential effects of differential memory decay. To address the effects typical ageing as well as the effects of early atypical ageing, we tested a young participant group and two older participant groups, one of which scored high and the other scored lower on a neuropsychological screening tool for Mild Cognitive Impairment (MCI).

Based on the literature discussed, we anticipated that our typically ageing participants would perform generally worse than our younger participant group, and that our older participant group who showed early signs of atypical ageing would perform generally worse than our healthy ageing older participant group. Having said this, few, if any, studies so far addressed route knowledge after successful route learning. It is therefore possible that all participant groups perform similarly well in those tasks that capture route knowledge that is particularly relevant during navigation. Given that route knowledge is often thought of as a series of stimulus-response associations (Waller & Lippa, 2007), knowledge about movement directions associated with landmarks or knowledge about the sequence in which landmarks are encountered are such candidates. In contrast, we expected effects of typical, as well as atypical, ageing in the map-based task which required mental transformation between the egocentric route perspective and the map perspective, a process that is known to be affected by both typical and atypical ageing (Cushman et al., 2008).

3.3 Methods

Participants

Sixteen Young (mean age = 21.62 years, SD = 3.27; age range = 18-29 years; eight males and eight females) and thirty-three older adults aged 65 and over (American Psychological Association, 2014) took part in this study. All participants were recruited either through the Bournemouth University's participant recruitment system or through opportunity sampling in the community.

Older Participant Group

All older participants completed the Montreal Cognitive Assessment (MoCA), a 30-point test designed to test for healthy ageing and to detect MCI and early stage AD (Nasreddine et al., 2005). This screening tool has been shown to be highly sensitive in detecting early changes in cognition. Moreover, test scores correlate with the severity of cognitive impairment and AD (Freitas et al., 2013). The most commonly used and accepted MoCA cut-off for healthy ageing is 26/30. Lower scores indicate early atypical ageing (Nasreddine et al., 2005). Interestingly though, some studies suggested that cut-offs as low as 22/30 (Lee et al., 2008) and 23/30 (Luis, Keegan, & Mullan, 2009) would also be suitable to separate healthy ageing for atypical ageing (see Julayanont, Phillips, Chertkow & Nasreddine, 2012, for a review). Here we used the suggested higher and lower MoCA cut-offs to split our older participants in two groups. Specifically, participants in the Old High MoCA group scored between 26 and 30 points and participants in the Old Low MoCA group scored between 22 and 25 points. Given that spatial disorientation and declines in navigation abilities are among the earliest symptoms of atypical ageing and early mild cognitive impairments (Pai & Jacobs, 2004), we expected to find differences in navigation performance between the Old High MoCA group and the Old Low MoCA group if MoCA scores below 26 were, in fact, indicative of early atypical ageing.

We had 17 participants in the Old High MoCA group (mean age = 70.06 years, SD = 7.04 years; age range = 65-83 years; twelve females and five males), whilst we had 16 participants in the Old Low MoCA group (mean age = 76.68 years, SD = 6.29 years; age range = 66-93 years; nine females and seven males). One participant scored below the suggested threshold of 22/30 (Luis et al., 2009; Lee et al., 2008). Their data was therefore not included in the final data set. Participants in the Old High MoCA group spend 11.73 years (SD = 2.75) in education and participant in the Old Low MoCA group spend 13.47 years in education (SD = 2.67). There was no significant difference between the Old High MoCA and the Old Low MoCA groups levels of education ($t(31) = 1.474$, $p = 0.151$). Following Nasreddine et al. (2005) criteria, all participants who had less than 13 years of education received an extra point to compensate for the effects of education on the test.

Ethics

Ethical approval for the experiment was obtained from the Bournemouth University ethics panel. The researcher was present throughout the whole experiment, adopting a person-centred approach (Cowdell, 2006) to reduce any possible feelings of discomfort or stress (Dewing, 2008).

Materials

The Virtual Environments

Using Vizard 3.0 (WorldViz) we created 12 different short virtual routes. Each route consisted of four four-way intersections and each route featured one left turn, one right turn and one straight and one additional right turn, left turn or straight movement. Each intersection could be identified by a unique object (landmark) mapped onto a cube that was suspended from the ceiling in the centre of the intersection. All 12 routes were created from the same environment, but each route featured a unique set of four landmarks (i.e. the same landmarks did not appear twice throughout the experiment) and consisted of a different sequence of turns**.** We created a video of each route which showed a passive transportation along the entire route (each video lasted 28 seconds). During the experiment, the videos were presented on a Toshiba Satellite Pro Laptop (22” screen).

Procedure

Participants were first required to read the information sheet, sign the consent form, and were then asked to fill out a brief participant information sheet to collect demographic information (age, gender and years in education). After this, the older participants proceeded to complete the MoCA test, whereas the Young group started with the Experiment.

Before beginning with the actual experiment, participants were shown a demo route and were talked through each of the tasks to ensure that they understood the procedure.

Experiment

The experiment consisted of 12 separate blocks, each composed of a training phase, a test phase, and a route recall phase. Participants learned a different route in each block and the order in which routes were presented was random. Each block took approximately six minutes to complete, and participants were free to take breaks between trials if they wished.

Figure 3.1: The top image shows the viewpoint of one of the routes used during the training phase. The lower image shows the testing room and room set-up during the experiment.

Training Phase

In the training phase, participants first watched a video of a route (see Figure 3.1). After the first presentation, participants were shown the route again, though this time the video was stopped at each intersection and participants were asked to indicate the direction of turn to continue along the route. If they made an error, they were shown the route again and asked for the directions of turn at each intersection. This procedure was repeated until participants were able to accurately indicate the direction of turn at each of the intersections. The number of errors and learning trials required to learn the route were recorded. Once participants successfully learned the route, they moved on to the test phase.

Test Phase

The test phase consisted of four different tasks that assessed different aspects of route knowledge:

<u>Landmark Direction Task</u>**.** Participants were presented with pictures (printed on A4 paper, see Figure 3.2 for an example stimulus) of the landmark objects of the route one at a time and in randomised order. Their task was to indicate in which direction the route continued at the corresponding intersection. The landmark direction task (sometimes also referred to as the associative cue task) required participants to associate a movement direction to the landmarks during route learning. We analysed whether participants could or could not correctly recall the directions for all fours landmarks along a route. For each route, participants' responses were coded as correct or incorrect. Chance level for reporting all four directions correctly was 1.23%.

<u>Landmark Sequence Task</u>**.** Participants were presented with four different arrangements of the four landmark objects of the route printed on an A4 sheet of paper (see Figure 3.2 for an example stimulus). One of the arrangements displayed the correct temporal order

in which the landmarks were encountered along a route, the other three arrangements were variations of the correct order (e.g. the second and third object were swapped). The participants' task was to indicate which row of landmarks displayed the correct order of landmarks from start to finish on the route. For each route, participants' responses were coded as correct or incorrect. Given four possible choices, chance level for this task was 25%.

Direction Sequence Task**.** In the Direction Sequence Task, participants were asked to verbally report the sequence of direction changes or movements along the route (e.g. "left, right, straight, right"). We analysed whether participants could or could not correctly recall all four directions changes along a route. For each route participants' responses were coded as correct or incorrect. Chance level for reporting all four direction changes correctly was 1.23%.

Perspective Taking Task**.** Participants were presented with three different schematic map-like drawings of routes through a regular grid like environment (see Figure 3.2 for an example stimulus). One of these schematised routes depicted the route they had just learned, while the other schematised routes were variations of the correct route (e.g. one turn was mirrored). The routes were printed on a sheet of A4 paper. Participants' task was to indicate which route depicts the route they have just learned. The Perspective Taking task required participants to recognise the route from a top-down map-like perspective. For each route, participants' responses were coded as correct or incorrect. Given three possible choices, chance level for this task was 33.3%.

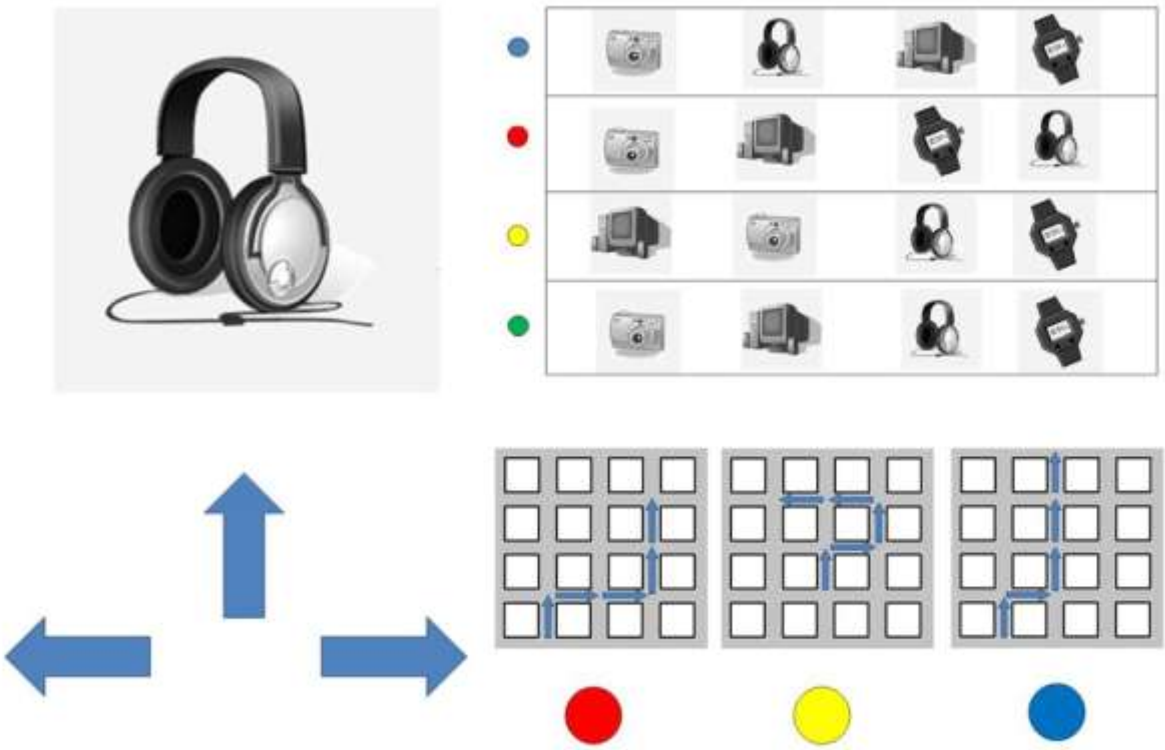


Figure 3.2: Stimuli used during the test phase. Left shows the Landmark Direction Task, upper right shows the Landmark Sequence Task, and the lower right shows the Perspective Taking Task.

Route Recall Phase

Once participants had completed the Test Phase, they were again presented with the video of the route to test whether they could still accurately recall the route. This was done to ensure that potential differences in Test Phase performance were not due to general memory decay. As in the learning phase, the video was stopped at each of the four intersections along the route, and participants were required to state the correct direction at each intersection.

Task Order in the Test Phase

The tasks in the test phase were presented in two different orders. Order 1 was: Perspective Taking, Direction Sequence, Landmark Sequence and Landmark Direction. Order 2 was: Landmark Sequence, Perspective Taking, Direction Sequence and Landmark Direction. After 6 routes, the order switched from Order 1 to Order 2 or vice versa (counterbalanced between participants).

Analysis

To investigate the effects of typical and early atypical ageing on performance we ran linear mixed effect (LME) models for accuracy for each of the tasks (using R and the lme4 package; Bates, Maechler, Bolker, & Walker, 2014). We defined two a priori contrasts: First, between the Young group and the Old High MoCA group to study the effect of typical ageing, and second, between the Old High MoCA group and Old Low MoCA group to study the effect of early atypical ageing.

The analysis included participant group as a fixed effect with the individual participants and the routes as random intercepts. We report the coefficient and standard error estimates (SE) and interpreted effects with a value of $t > 2$ as reliable, although we also report estimated p values.

3.4 Results

Learning & Recall

The analysis of route learning and route recall performance encompassed all 12 trials per participants.

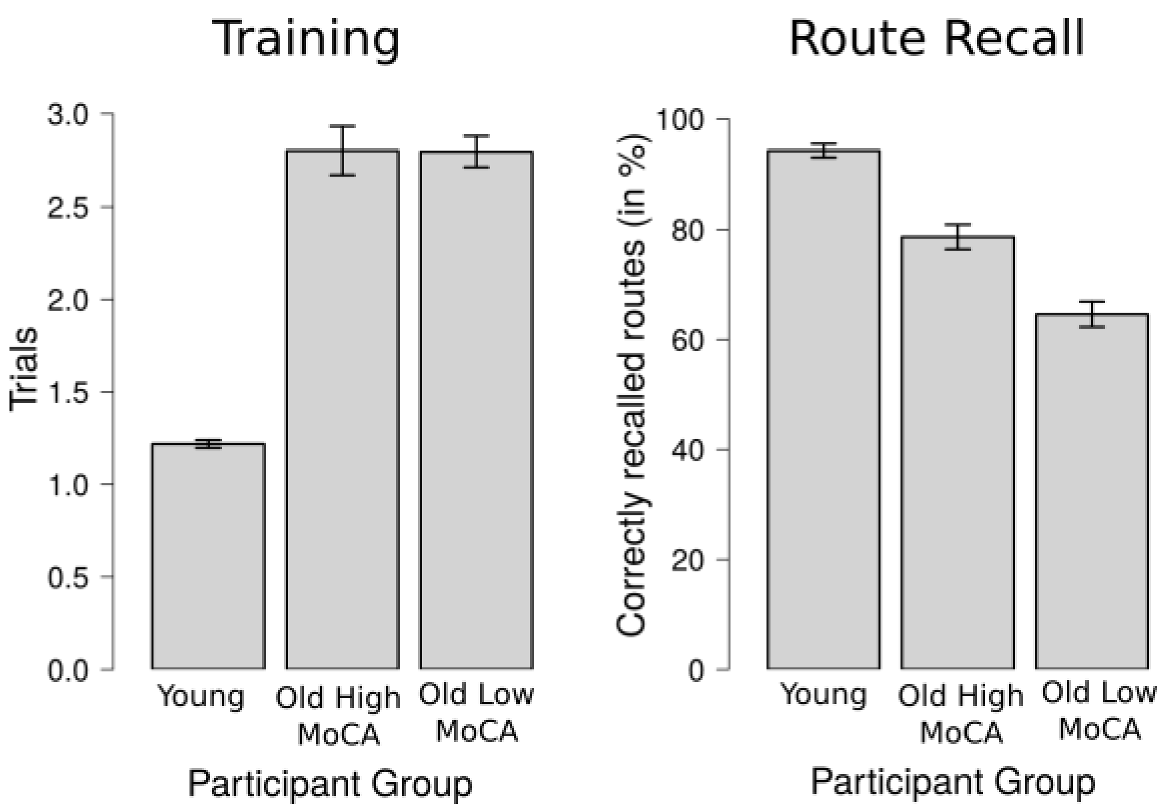


Figure 3.3: learning performance (number of trials to watch the route) during the training phase for the Young group, the Old High MoCA group, and the Old Low MoCA group; right: recall performance (%) for the Young group, the Old High MoCA group, and the Old Low MoCA group.

Training Phase

On average the Young group viewed routes 1.22 times during the training phase, whilst both the Old High MoCA group and the Old Low MoCA group viewed the routes 2.80 times. The LME analysis revealed significant differences between the Young and Old High MoCA (typically ageing) participant group (b = 1.58, SE = 0.22, t = 7.15) but no differences between both the two older participant groups (b = -0.01, SE = 0.22, t = -0.02).

Route Recall

On average the Young participants recalled 94.3% of the routes correctly, the Old High MoCA group recalled 78.7% of the routes correctly and the Old Low MoCA group recalled 64.6% of the route correctly. The LME analysis revealed significant differences for both a priori contrast, i.e. between the Young and Old High MoCA participants ($b = -1.54$, $SE = 0.40$, $z = -3.82$, $p < 0.001$) and between the two older participant groups ($b = -0.74$, $SE = 0.30$, $z = -2.51$, $p = 0.01$).

While Young participants showed better performance in the training phase and the route recall, these results demonstrate a dissociation between learning and recall in our older participant groups. Specifically, the route learning during the training phase was not affected in the Old Low MoCA group, while route recall was affected.

Association between acquisition and forgetting

To investigate whether the number of learning trials had an influence on recall performance, we compared the number of training trials for correctly and incorrectly recalled routes for each of the participant groups. None of these comparisons were statistically significant, suggesting that the there was no association between acquisition and forgetting in this study (note that the majority of the younger participants did recall all routes correctly, so that we could run this analysis only on a subset of the younger participants: Young $t(6) = 0.379$, $p = 0.718$; Old High MoCA $t(15) = -0.103$, $p = 0.909$; Old Low MoCA $t(15) = 0.346$, $p = 0.734$.

Test Tasks

The analysis of the four test tasks only included the data from routes that were correctly recalled after the test phase.

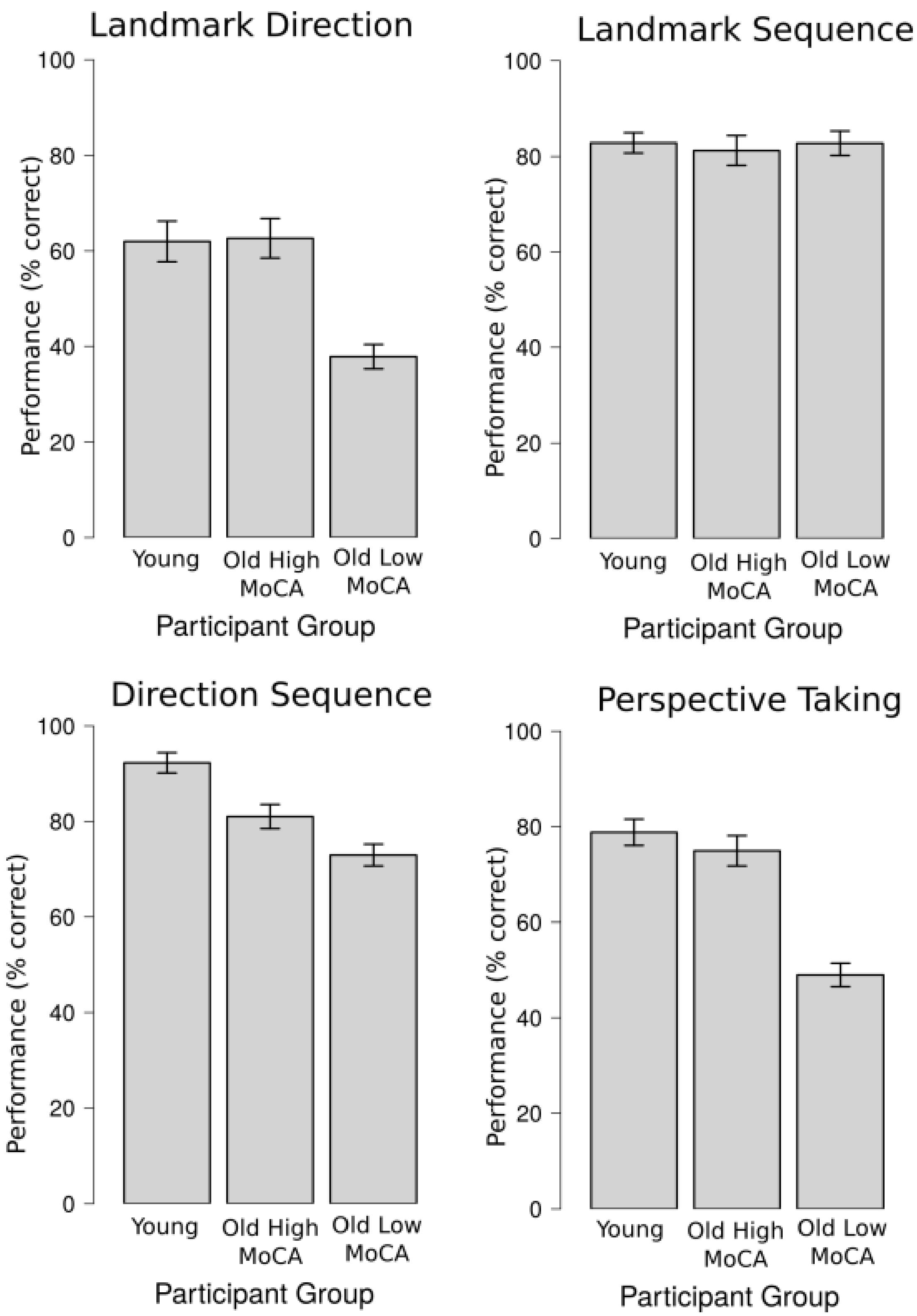


Figure 3.4: Upper Left: Landmark Direction Task performance for the Young group, the Old High MoCA group, and the Old Low MoCA group; Lower Left: Direction Sequence Task performance for the Young group, the Old High MoCA group, and the Old Low MoCA group; Upper Right: Landmark Sequence Task performance (%) for the Young group, the Old High MoCA group, and the Old Low MoCA group Lower Right: Perspective Taking Task performance (%) for the Young group, the Old High MoCA group, and the Old Low MoCA group.

Landmark Direction Task

On average, Young participants remembered the directions for all landmarks for 62.00% of the routes, the typically ageing group achieved similar scores (62.55%), while the Old Low MoCA group remembered the directions for all landmarks for only 37.84% of the routes. An LME did not reveal significant differences between the Young and Old High MoCA group (b = -0.10, SE = 0.46, z = -0.21, p = 0.83). The comparison between the two older participant groups, however, was significant (b = -1.28, SE = 0.47, z = -2.68, p < 0.01).

Landmark Sequence Task

Performance in remembering the sequence in which the four landmarks were encountered along the route were very similar between participant, with 82.81% accuracy in the Young participant group, 81.23% accuracy in the Old High MoCA group and 82.74% accuracy in the Old High MoCA group. An LME did not reveal significant differences between the Young and Old High MoCA group (b = -0.04, SE = 0.43, z = -0.09, p = 0.93), or between the Old High MoCA group and Old Low MoCA group (b = 0.15, SE = 0.46, z = 0.33, p = 0.75).

Direction Sequence Task

On average, Young participants successfully remembered the sequence of direction changes for 92.26% of the routes, our Old High MoCA group achieved 81.01%, while our Old Low MoCA group remembered the sequence of direction changes for 72.93% of the routes. An LME did reveal significant differences between the Young and Old High MoCA group (b = -1.14, SE = 0.49, z = -2.36, p = 0.02). The comparison between the two older participant groups, however, did not reveal a statistically significant difference (b = -0.52, SE = 0.43, z = -1.21, p = 0.23).

Perspective Taking Task

On average, our Young participants chose the correct map in 78.8% of the trials, the Old High MoCA group in 74.8% of the trials and the Old Low MoCA group recalled 49.0% of the trials. An LME did not reveal significant differences between the Young and Old High MoCA group ($b = -0.17$, $SE = 0.38$, $z = -0.43$, $p = 0.67$). The comparison between the two older participant groups, however, was highly significant ($b = -1.44$, $SE = 0.39$, $z = -3.74$, $p < 0.001$).

Table 3.1: Summary of the results per task, which highlights the effects of typical ageing (comparisons between Young and Old High MoCA group) and the effects of early atypical ageing (comparisons between Old High MoCA group and Old Low MoCA group).

Task	Young Group vs Old High MoCA group (typical ageing)	Old High vs. Old Low MoCA group (early atypical ageing)
Training Phase	Yes	No
Route Recall	Yes	Yes
Landmark Direction Task	No	Yes
Landmark Sequence Task	No	No
Direction Sequence Task	Yes	No
Perspective Taking Task	No	Yes

Performance over the course of the experiment

Learning several routes in similar environments could lead to interference which could result in declining performance over the course of the experiment. To test whether performance was affected by interference we calculated correlations between our different measures of route learning and knowledge (Route Learning, Route Recall, Direction Sequence Task, Perspective Taking Task) and the block of the experiment (1-12) for each participant. Only two correlations were significant: for the Landmark Sequence Task for the Old High MoCA group ($r = 0.671$, $n = 12$, $p = 0.017$) and for the Landmark Direction Task for the Young group ($r = 0.660$, $n = 12$, $p = 0.019$). Note that both correlations were positive, suggesting increasing performance over the course of the experiment. These results suggest that interference was not an issue in this study.

Controlling for Age

As mentioned in the participants section, participants in the Old Low MoCA group were older than participants in the Old High MoCA group (t (31) = -3.027, p < 0.005). It could therefore be argued that this age difference, rather than differences in cognitive abilities as assessed by the MoCA between the two older groups, explains the described effects. To test this, we matched pairs of older participants based on their MoCA score. We then assigned the older participant of the pair to the older participant group ("Old-Old group") and the younger of the pair to the younger participant group ("Old-Young group"). We could match 28 out of the 33 participants (in cases in which there was an unequal number of participants with the same MoCA score, we were left with one participant – the one in the middle - who could not be matched). By matching participants in this way, we created two participant groups that were perfectly matched on MoCA score, but that differed in age (mean age Old-Young group: 68.43, SD = 3.87; mean age Old-Old group: 77.93, SD = 7.63, t (26) = -4.153, p < 0.001). We then compared performance in the different tasks between these groups. The results are presented in Table 3.2. Importantly, none of the comparisons revealed a significant difference between the Old-Old and the Young-Old group. This suggests that declines in cognitive abilities rather than differences in age between the two older participant groups drove the effects we reported in the original analyses above.

Table 3.2: The Table show's t-test comparisons between the Old-Young and Old-Old groups, who were matched specifically on MoCA score (degrees of freedom=26). The results show that none of the comparisons was statistically significant; only one task, the Training Phase, was close to being significant. We take this as strong evidence that the differences in performance between the two older participant groups in our original analysis resulted from differences in cognitive abilities (as assessed by the MoCA) and not from differences in age.

Condition and Task	Old-Young Mean	Old-Young SD	Old-Old Mean	Old-Old SD	T	P value
Training Phase	2.54	0.71	3.11	0.87	-1.895	0.07
Route Recall	75.60	12.43	67.26	20.53	1.299	0.21
Landmark Direction	72.19	18.37	76.49	15.13	-0.676	0.51
Landmark Sequence	79.98	17.92	78.96	21.59	0.14	0.89
Direction Sequence	91.27	7.96	85.63	13.22	1.368	0.18
Perspective Taking	63.72	19.92	58.97	27.00	0.53	0.60

Controlling for Gender

The Old High MoCA group sample had more female than male participants (Old High MoCA = 17, female = 12, male = 5). To ensure our results were not influenced by this unequal gender ratio, t-test comparisons between the female and male Old High MoCA participants were conducted on all measures of route memory (see Table 3.3). There were no significant performance differences between genders performance for any of the measures of route memory.

Table 3.3: Summary of t-test comparisons between the female and male Old High MoCA participants on the measures of route memory.

Condition and Task	**High MoCA Female Participants Mean (SD)**	**High MoCA Male Participants Mean (SD)**	**T**	**Degrees of freedom (df)**	**P value**
Route Learning	3.0637 (SD= .89808)	2.2345 (SD= .95721)	1.704	15	0.109
Route Recall	75.69% (SD=16.839)	83.33% (SD= 10.21)	-0.935	15	0.365
Landmark Direction Task	84.10% (SD=13.44)	77.67% (SD= 17.83)	0.819	15	0.425
Landmark Sequence Task	86.19% (SD=16.63)	68.09% (SD= 25.898)	1.740	15	0.102
Direction Sequence Task	88.07% (SD=13.33)	92.59% (SD= 08.69)	-0.693	15	0.499
Perspective Shift Task	76.11% (SD= 24.00)	77.09% (SD= 19.52)	-0.819	15	0.425

3.5 Discussion

In this study, we presented a novel route learning paradigm to investigate how ageing affects route knowledge after the successfully learning novel short routes. To do so, participants were first trained until they could replicate the routes without errors. In the subsequent test phase, they were then asked to complete several tests assessing their knowledge of the route. Afterwards, participants were asked to recall the route once more to ensure any differences between groups during the test phase did not results from different rates of memory decay.

Comparing performance between our Young participants and the Old High MoCA group scores allowed us to investigate the effects of healthy ageing on route learning and memory. By comparing performance between the Old High MoCA and the Old Low MoCA groups, we aimed to investigate the effect of early signs of atypical ageing on route learning and memory. The findings highlight clear differences between the two older groups in a number of tasks. This supports the argument that (1) the MoCA is a sensitive measure to screen for early atypical ageing (Nasreddine et al., 2005) and (2) that declines in navigation abilities are among the earliest sign of atypical ageing (Pengas et al., 2010). In the following, we will therefore discuss differences between the two older participant groups in context of early atypical ageing.

Before discussing the results in more detail, it is important to highlight that the result pattern of the six tasks was complex. We found significant effects of typical as well as early atypical ageing in only one task (Route Recall Task). We found effects of typical ageing but not of early atypical ageing in two tasks (Training Phase and Direction Sequence Task), and effects of early atypical ageing but not of typical ageing in two other tasks (Landmark Direction Task and Perspective Taking Task). Finally, one task (Landmark Sequence Task) was neither affected by typical ageing nor the effects of early atypical ageing (for an overview, see Table 3.1). This heterogeneous result pattern strongly suggests that declining navigation abilities in both typical and early atypical ageing are not the result of general declines in learning and memory abilities. Rather, typical ageing, and early atypical ageing, affect specific mechanisms and components of navigation.

Additionally, whilst there was a slightly unequal gender balance for the Old High MoCA, we have been able to demonstrate no differences on route memory performance dependent on gender for this sample. These findings are consistent with existing age and dementia research that has explored the effects of gender on navigation skills (Cushman & Duffy, 2007), suggesting that no extensive gender differences in navigation ability are present.

4. 1. Training Phase and Route Recall

In line with earlier research (Head & Isom, 2010), older participants showed slower rates of route learning, requiring more than twice as many training trials to learn the routes as compared to the Young participant group. While the two older participant groups did not differ in their learning performance, they differed in their recall performance. Specifically, the Old Low MoCA group recalled less than 2/3 of the routes after the test phase. In fact, performance in the route recall task differed between all three participant groups with the *Young* group showing best performance followed by the Old High MoCA group and then the Old Low MoCA group. While forgetting is rarely studied in the context of spatial cognition and navigation, it has been studied in other cognitive domains and accelerated forgetting has been associated with both healthy ageing (Huppert & Kopelman, 1989) and with mild cognitive impairments (Geurts, van der Werf, & Kessels, 2015; Walsh et al., 2014). Taken together, these results suggest (1) that typical ageing is associated with slower route learning, (2) that early atypical ageing does not affect route learning, and (3) that ageing as well as early atypical ageing are associated with faster forgetting of route knowledge. While these findings are in line with earlier research, we did not find that slower rate of acquisition or learning to criterion was associated with accelerated forgetting in our study (Macdonald, Stigsdotter-Neely, Derwinger, & Bäckman, 2006).

Given the different rates of forgetting between participant groups, we included only data in the test phase analyses from routes that participants recalled correctly. This ensured that participants still knew the routes in the actual test phase, and any group differences in that phase therefore did not result from different rates of forgetting.

4. 2. Test Phase

Interestingly, we did not find any differences between groups in the Landmark Sequence Task. We did not find differences between our Young participants and the typically ageing adults in the Perspective Taking Task and Landmark Direction Task, but we found differences in the Direction Sequence task. Comparisons between the two older participant groups revealed significant differences for the Perspective Taking and the Landmark Direction tasks, but not for the Landmark Sequence or Direction Sequence tasks.

Some of these results are surprising at first glance given that several earlier studies reported that typical ageing was associated with declines in perspective taking abilities (De Beni, Pazzaglia, & Gardini, 2006; Puglisi & Morrell, 1986), declines in the knowledge of the sequence in which landmarks were encountered during route learning (Head & Isom, 2010; Wiener et al., 2012; Bellassen et al., 2012), and declines in ability to bind directional knowledge to landmarks (Head & Isom, 2010; Wiener et al., 2012). It is likely that these differences between our study and these earlier studies can be explained by the fact that we tested participants’ route knowledge only after they had successfully learned the routes, which took our older participant groups twice as long to learn as the Young group. In other words, our older participant groups had more exposure to the routes which was - at least for the higher MoCA group - sufficient to encode the route knowledge required to solve the test phase tasks.

The performance differences between the two older participant groups in the Perspective Taking and the Landmark Direction tasks are in line with earlier studies: Cherrier et al. (2001) used a task similar to our Perspective Taking Task and found significant differences between healthy older adults and those with AD. Similarly, Cushman et al. (2008) found that participants with MCI and early AD had particular problems when asked to indicate the positions at which they encountered landmarks along a route in a schematic drawing of the route (see also deIpolyi et al., 2007). Recognising a route, experienced and encoded in an egocentric reference frame, from a map, requires either the construction of an allocentric representation or a mental transformation. Both of these processes have been closely associated with the hippocampal circuit (King, Burgess, Hartley, Vargha-Khadem, & O'Keefe, 2002), an area that is among the earliest affected by MCI and AD (Fjell, McEvoy, Holland, Dale, & Walhovd, 2013; Raz et al., 2010). The performance differences between the older participant groups in the Landmark Direction Task, which is essentially an associative learning task assessing people’s ability to bind directional information to specific landmark object, is not surprising as earlier studies highlighted impaired associative learning in early atypical ageing (Boespflug, Eliassen, Welge, & Krikorian, 2014). Additionally, damage to the RSC has been found to result in declining abilities in associative cue and direction memory (Ino et al., 2007) while landmark or scene memory remains intact. The RSC area has been found to be one of the brain regions affected by AD (Lithfous et al., 2013), which could explain performance differences between the tasks requiring directional information and those required purely landmark information - in the present chapter, the Landmark Direction Task and the Landmark Sequence Task.

Surprisingly, we did not find performance differences between the two older participant groups in the Landmark Sequence or the Direction Sequence tasks. Earlier navigation studies have described that the learning of sequences of turns relies on the hippocampal circuit (Igloi, Doeller, Berthoz, Rondi-Reig, & Burgess, 2010), which undergoes substantial functional and structural changes during the typical ageing, and early atypical ageing process (Fjell et al., 2013). Moreover, earlier studies explicitly demonstrated that people with MCI and AD have profound deficits in ordering objects encountered along a route (deIpolyi et al., 2007) and when learning a sequence of direction changes (Bellassen et al., 2012).

We believe that these differences in the paradigms used to measure sequence and order memory may explain these differences between our and earlier studies (e.g., Monacelli et al., 2003; Pengas et al., 2010). Specifically, we used relatively short routes, assessed route knowledge only after participants successfully learned the routes and we focused on routes that participants were able to correctly recall later in order to investigate the effects of (a)typical ageing on the content of route knowledge rather than on route learning performance.

Further studies are needed to investigate the impact of these methodological differences on route learning and route knowledge in more detail. It would, for example, be important to investigate how the different aspects of route knowledge (sequence knowledge, associative cue knowledge, etc) develop as people learn to navigate the route. Moreover, our Landmark Direction Task and the Landmark Sequence Task are cued recall tasks, while the Direction Sequence Task represents a free recall task. Earlier learning studies using non-spatial stimulus material demonstrated that free recall is more strongly affected by early atypical ageing than cued recall (Grober & Buschke, 1987; Grober, Veroff, & Lipton, 2016). Further research is needed to understand the effects that (a)typical ageing has on free and cued recall in the context of navigation and route learning in particular. To develop a better understanding of the variability in route learning between groups, future studies should also consider individual difference in spatial abilities such as visuo-spatial working memory or mental rotation which have been suggested to be closely related to age-related differences in navigation abilities (Gyselinck et al., 2013).

When comparing overall performance levels of the test phase tasks, it is striking that performance was very good in the Direction Sequence Task (over 90% correct in the Young participant group). In contrast, performance in the Landmark Direction Task, often used as a measure of route knowledge in other studies (Head & Isom, 2010; Waller & Lippa, 2007; Wiener et al., 2013; Mallot & Gilner, 2000), was considerably lower. Given that participants were able to recall the learned routes shortly after completing these tasks, these results suggest that participants primarily relied on memorising sequences of turns rather than using an associative cue strategy (Waller & Lippa, 2007). This could be due to the fact that we used short routes with only four decision points in this study. Note however, that none of the route knowledge tasks in the test phase in isolation captured participants' route knowledge perfectly. If that was the case, we expected participants to perform perfectly, reaching 100% performance on at least one of the test phase tasks. This suggests either that (1) participants relied on the various aspects of route knowledge tested, (2) or that none of our tasks fully captured the information participants used to learn the routes.

It is also important to note that the Old Low MoCA group performed considerably worse than the Young and/or the Old High MoCA group in three of the four test phase tasks even though they were able to recall the learned routes in the subsequent route recall phase. This may suggest that they have used different strategies than the Young and Old High MoCA participants to memorise the routes and that these strategies are not captured well by our test phase tasks. Additionally, declining cognitive abilities may have forced the Old Low MoCA participants to focus all their efforts on learning and recalling the routes, which leaves fewer resources that could contribute to memorising aspects of the route that were required to solve all the test phase tasks. While our current data does not allow us to test these explanations, we currently run further experiments to address these issues. Our study also has implications for other studies that use, or have used, the MoCA to screen for cognitive impairments**.** Some studies have suggested scoring criteria as low as 21/30 (Freitas et al., 2013) or 22/30 (Lee et al., 2008) for differentiating healthy ageing from MCI. Here, we demonstrated that the participant group for which we used a cut-off of 22/30 has shown substantial deficits in several spatial tasks when compared to the participant group with the higher cut-off of 26/30

(Nasreddine et al., 2005). Studies that use the lower cut-off may have, as a result, overestimated the effects of typical ageing (Harris & Wolbers, 2013; Wiener et al., 2013) and future studies addressing the effects of typical ageing should use the more conservative higher cut-off of 26/30 (Nasreddine et al., 2005).

It must be noted that this chapter has explored route learning through passively learning a route, as opposed to participants actively learning a route. Whilst passive navigation restricts certain cognitive and physical factors that contribute towards our knowledge of a route and environment (Chastril & Warren, 2012; Wilson, Foreman, Gillett, & Stanton, 1997), the patterns of performance for the route memory tasks in the present study, mostly replicate, earlier research into this area. Importantly, most of the earlier studies investigating the effects of typical and early atypical ageing, have used passive route learning protocols (Cushman et al., 2008; Monacelli et al., 2003; deIpolyi et al., 2007). In order to prevent these findings being taken out of context, future research that uses an active navigation condition should be considered to investigate how ecologically valid these results are during real world navigation.

Conclusion

In this chapter, we developed a new paradigm to investigate the effects of typical and early atypical ageing on route learning performance and on route knowledge after successful learning of short unfamiliar routes. Results suggest that typical ageing affected route learning performance, participants’ knowledge of the sequence of turns along the route as well as their ability to recall the routes later. Early signs of atypical ageing did not affect route learning, but participants’ ability to recognise the route on a map, their ability to associate landmark to directions and their ability to recall the routes later. Importantly, differences between groups in the test phase did not reflect general age-related differences in learning rates or memory decay, as we only included data from routes that participants could successfully replicate later.

CHAPTER 4: The effects of Cognitive Ageing on Route Planning Abilities using "You Are Here" Maps

4.1 Overview

Chapter 3 demonstrated that typically ageing adults require more time to learn a route than young adults, but perform well when tested on aspects of route knowledge (in particular the landmark direction/associative cue and map tasks). Early atypically ageing adults though also required more time to learn the routes (similar to the typically ageing adults), but performed significantly worse on aspects of route memory, in particular the map task. This is consistent with previous studies have also highlighted how map reading abilities are particularly sensitive to the effects of early atypical ageing and cognitive impairment (Cherrier et al., 2001).

Most experiments addressing map-based navigation test participants in unrealistic environments, and have not tested how people with cognitive difficulties use YAH maps and whether they are a supportive navigation aids for this population. Additionally, maps are not typically studied after a route has been successfully learned (as tested in Chapter 3), so a new map-based paradigm, using "You Are Here" (YAH) maps, was designed in Chapter 4 to create a more realistic and ecologically valid scenario to test the effects of early atypical ageing on map usage.

The objectives of Chapter 4 were to investigate whether YAH maps are reliable navigation aids for older adults with and without early signs of atypical ageing, and to compare maps highlighting specific routes to the goal location, versus maps where navigators have to plan their own route to the goal location.

Nineteen young, 23 typically ageing, and 14 early atypically ageing adults were tested on their abilities to read and use 20 YAH maps to guide navigation within a virtual environment. There were two different map styles; maps either had predefined lines from the YAH point to the goal location (restricted routes) or allowed participants to plan their own route from the YAH point to the goal location (free routes).

We found that the early atypically ageing adults performed significantly worse at reaching the goal location using the YAH map than the typically ageing and young participant groups, irrespective of map type suggesting that the restricted routes provided no additional benefit in alleviating the amount of route planning required to interpret the routes. These findings are in line with earlier research (Cherrier et al.

2001; Chapter 3). How well aligned (i.e. degree of alignment of the route with the map; when the goal location is south of the starting point this would be High Route Alignment) the routes were on the restricted maps also affected participants' performance.

The findings demonstrated that the older adults showing early signs of atypical ageing were significantly worse than the typically ageing adults and young controls. Restricted routes on YAH maps provided little benefit for early atypically ageing adults suggesting that the declines in performance may not be as a result of route planning deficits. As the maps depicted a small-scale environment, it may have been that the routes were too simple and future experiments should investigate planning of longer routes of maps depicting larger scale environments. The findings and implications will be discussed in relation to age and dementia friendly design guidelines and how to improve suggestions surrounding map design.

4.2 Introduction

"You-Are-Here" (YAH) maps are frequently used navigation aids in cities, towns and buildings. Common in environments used by visitors or tourists, they provide geographical and navigational information to help you localise where you are, and plan where you are going (Montello, 2010). However, despite their frequent use, there is relatively little research investigating how useful YAH maps are as navigation aids, and in particular, how useful they are to the ageing community. Map reading abilities are particularly sensitive to the effects of early atypical ageing and cognitive impairment (Cherrier et al., 2001). This said, most of the existing research has not tested older adults' map reading abilities under ecologically valid and realistic scenarios (e.g. in cities, care home environments or hospital settings), or using realistic (and ecologically valid) map styles (Sjolinder et al., 2005). Additionally, studies investigating ageing and map reading abilities have frequently used unrealistic protocols (i.e. first traveling along a route and then having to identify the taken route on a map) (Cherrier et al., 2001; Chapter 3). The current experiment explicitly investigated the use of YAH maps in a population of young, typically ageing adults and older adults showing early signs of atypical ageing.

Using a map to provide navigation support can be both perceptually and cognitively costly (Klippel, Freksa, & Winter, 2006), as there are multiple tasks required in order to successfully use a map to guide navigation. To begin with the navigator (1) needs to localise themselves in the map, (2) align the map with their current orientation (through mental transformation or by rotating the map), (3) find the goal location, (4) plan a route to that location, and (5) memorise the route and track the process during navigation (Klippel, 2010). Failure to follow this series of tasks and successfully execute them would lead to disorientation. For example, if navigators are unable to correctly align the map to their current orientation, they may misinterpret the route to the goal location and become lost.

“You Are Here” maps are one of the most commonly encountered types of map when visiting a new city or new building (e.g. a hospital). They act as reference maps and typically depict small areas of the environment (often in rather large scale) and are positioned within the surrounding area they depict (Montello, 2010). See Figure 4.1 for an example of YAH maps.

Figure 4.1: Above are two examples of different YAH maps. The left map is of London (Applied Wayfinding, 2013) and is correctly aligned to the navigators facing orientation (as seen by the line above the arrow), while the right map is of York, UK (City of York Council, 2011), shows the location on the map but is not aligned to their orientation, highlighting the differences in informativeness different YAH maps have.

YAH maps are often used as they address the first two processes that standard maps require: they support initial localisation (i.e. they provide a YAH point) and are often correctly aligned (or orientated) with your current orientation. Research into principles of well-designed YAH maps have highlighted key design principles (Klippel, Freksa & Winter, 2006) with many reiterating the importance of having the map correctly aligned with one’s current position and orientation to reduce the amount of route alignment required to interpret the map (Montello, 2010; Klippel et al., 2010) and how key areas of interest (e.g. first exits and landmarks) should be clearly posted to support route planning.

Healthy older adults display similar performance to young adults in interpreting maps when they are correctly aligned (Yamamoto and DeGirolamo, 2012; Borella et al., 2014). Although some studies have reported some differences between young and typically ageing adults (Wilkniss et al., 1997; Moffat, 2009; Sjolinder, Hook, Nilsson and Anderson, 2005), difficulties using maps are more prevalent when maps are misaligned with their correct position (Borella et al., 2014; Muffato et al., 2015).

This can be explained by the effects of cognitive ageing on mental rotation and perspective-taking, processes which are essential to translate information displayed on the map to the egocentric perspective of the navigator (Gaylord & Marsh, 1975; Kirasic, 1990).

Few experiments have tested people with Mild Cognitive Impairment (MCI) and Alzheimer’s disease (AD) on their map reading abilities (Cherrier et al., 2001). Those that have used map-like representations to assess spatial knowledge that was acquired through navigation, have found that people with AD were significantly impaired when asked to locate landmarks on a 2D map of the environment, and when drawing their route on a map (Cherrier et al., 2001; Cushman et al., 2008; deIpolyi et al., 2007; Monacelli et al., 2003). In a recent experiment, we have shown (Chapter 3; O’Malley, Innes & Wiener, 2018) clear differences in map reading abilities between typically ageing and early atypically ageing adults. Specifically, early atypical ageing adults performed significantly worse than typically ageing adults, as well as younger controls, when asked to identify the route they had previously learned on a map.

However, it is not the typical case to first learn a route and then identify the route or landmarks of the route on a map. It is much more common that we use a map to plan a route and then navigate it, or that we use YAH maps to find our way through complex unfamiliar environments. At present, there are few studies that have investigated how typical ageing affects the use of YAH maps (Aubrey et al., 1994), highlighting how maps that are not correctly aligned with older participants' current orientation, take longer to study, and result in less accurate direction decisions. However, no study has yet investigated how YAH are used and interpreted by older adults showing signs of atypical ageing or dementia. Given that maps are a familiar navigation aid for older adults and frequently used navigation aids in hospitals, residential developments and care homes, it is important to first understand how they are used, and secondly how they can be improved. Understanding the situations (both environmentally, and in terms of map design), in which these difficulties with interpreting and using maps occur, could lead to a better approach in how we design YAH maps for older adults. This in turn could feed into dementia friendly design principles. Existing research has not yet examined how YAH map design can be implemented into everyday practice to better support orientation and successful navigation of older adults living with cognitive impairments.

One example of how YAH maps could be made easier to use for people with cognitive impairments, is by reducing cognitive effort by providing predefined/restricted routes on YAH maps. Route planning is typically comprised of three distinct phases: firstly, reviewing the spatial relationship between an origin and a destination; secondly, identifying and comparing possible route options; and thirdly, selecting the most viable path (Bovy & Stern, 1990; Brunye´ et al., 2012; Grison, Gyselinck, Burkhardt, & Wiener, 2016). Providing users with a pre-planned/pre-defined route (a line from the YAH point to the goal location on the map; from now on defined a "restricted routes"), would eliminate the need to carry out at least the second and third phase of route planning. This could alleviate some of the map reading difficulties experienced by older adults displaying cognitive impairment.

In this study, we explored how effectively younger adults, typically ageing adults and older adults showing early signs of atypical ageing use YAH maps to guide navigation. Participants were required to first study a YAH map and then navigate to the indicated goal location within a virtual care environment. For some of these maps, routes to the destination were pre-planned and defined (which should reduce cognitive effort associated with route planning), while others required participants to plan their own route from the YAH point to the goal location. Once participants reached the goal location, they were required to state how confident they were that they had reached the goal, and were then required to point back to the start location. Our predictions were that the older adults would take longer than younger controls to study the maps (Aubrey et al., 1994), and that the older adults displaying early signs of atypical ageing would be worse than the typically ageing adults and younger controls at reaching the goal location (Cherrier et al., 2001). Additionally, we predicted that older adults would perform better using maps that had predefined/restricted routes that require less cognitive effort associated with route planning compared with maps that require them to make their own routes.

4.3 Method

Participants

Nineteen younger (mean age = 21.10 years, SD = 3.26 years; eleven females and eight males) and thirty-seven older adults aged 65 and over (mean age = 71.68 years, SD = 4.24 years) took part in the experiment. The older participants were split into two groups depending on their score on the Montreal Cognitive Assessment (MoCA), in accordance with suggested thresholds in the literature (Lee et al., 2008; Nasreddine et al., 2005). All participants were recruited either through the Bournemouth University's participant recruitment system or through opportunity sampling in the community.

Older Participants

All older participants completed the Montreal Cognitive Assessment (MoCA), a 30 point test designed to test for healthy ageing and to detect MCI and early stage AD (Nasreddine et al., 2005). The most commonly used and accepted MoCA cut-off for healthy aging is 26/30. Lower scores indicate early atypical ageing (Nasreddine et al., 2005). Interestingly though, some studies suggested that cut-offs as low as 22/30 (Lee et al., 2008) and 23/30 (Luis, Keegan, & Mullan, 2009) would also be suitable to separate healthy aging for atypical ageing. We used the suggested higher and lower MoCA cut-offs to split our older participants in two groups. Specifically, participants in the Old High MoCA group scored between 26 and 30 points and participants in the Old Low MoCA group scored between 22 and 25 points. If the MoCA scores below 26 were, in fact, indicative of early atypical ageing, we expected to find differences in navigation performance between the Old High MoCA group and the Old Low MoCA group

The Old High MoCA group (mean age = 71.13 years, SD = 3.26 years; twenty-three participants, ten females and thirteen males), whilst the Old Low MoCA group (mean age = 72.64 years, SD = 4.55 years; fourteen participants, six females and eight males). Participants in the Old High MoCA group spend 13.46 years (SD = 2.51 years) in education and participant in the Old Low MoCA group spend 14.92 years in education (SD = 5.28 years). There was no significant difference in age between the two older groups (independent samples t-test: $t(35) = -1.065$, $p = 0.296$), and no significant difference in years in education ($t(35) = -1.169$, $p = 0.253$).

Material

The experiment made use of a three screen set-up (each screen: Width: 88.8cm, Height: 55cm; Resolution: 1920px x 1080px; Side screens angled at 120-deg) to give the participant a more immersive experience of the environment (see Figure 4.5 for the set-up). The virtual environment used was of a virtual care environments (see Figure 4.2 for selection of snapshots from within the virtual environment), which consisted of several corridors and communal spaces (see Figure 4.3 for a birds eye-view of the floor plan). Participants were instructed to sit on a chair which was positioned one-metre away from the central screen. A keyboard was used to indicate directions at decision points, when participants felt the goal was reached, and when they had completed the pointing task.

Figure 4.2: These four images are snapshots taken from within the virtual care environment, displaying the corridor style and communal spaces participants would have navigated through.

Design of Maps

A total of 20 different maps were designed. Each map featured a start point (a red circle saying "You-Are-Here") and a goal location (a finish flag logo; see Figure 4.3 for example maps). All maps were designed such that they were aligned (i.e. up/north on the map is straight ahead), with the participants' current orientation within the virtual care environment. Given the previous research on alignment (Borella et al., 2014; Muffato et al., 2015), and existing design suggestions of YAH maps (Montello, 2010), it was important that the maps created were as realistic as possible (i.e. including a clear and realistic YAH symbol).

Design of Routes on Maps

Of the 20 maps included in the study, 12 featured lines from the YAH point to the goal location (to measure the ability to memorise and track the shown routes; they were referred to as restricted routes; see Figure 4.3 for an example) and eight had no lines (to measure the ability to plan, memorise and track the participants' chosen route; these were called free routes; see Figure 4.3 for an example). For the eight maps that had no line (free routes), the shortest possible routes between the YAH point and the goal were plotted, to identify the number of turns and decision points along the shortest route. For all 20 maps there was an equal balance of routes with two, three and four turns, as well as an equal selection of routes with three or four intersections (the number of intersections differed from the number of turns in the cases where there was a straight-ahead at an intersection). For the 12 maps with restricted routes, the starting direction of the routes from the YAH point was also balanced (i.e. six maps started with a left turn, and six maps started with a right turn). We additionally ensured that there was an equal number of maps that required low and high route alignment (i.e. degree of alignment of the route with the map; when the goal location is south of the starting point this would be High Route Alignment) when executing the route. Route alignment refers to the cumulative degree of misalignment between the map orientation (forward is up) and the direction of travel along the route. For example, in Figure 4.4 the right image shows a route that would require more mental rotation as the movements are misaligned by 180 degrees from the maps orientation (e.g. a turn left or right turn is harder if movement is towards south and would affect the route descriptions/memory used to navigate the route) than the left image in Figure 4.4 which requires the route to be planned in the forward direction.

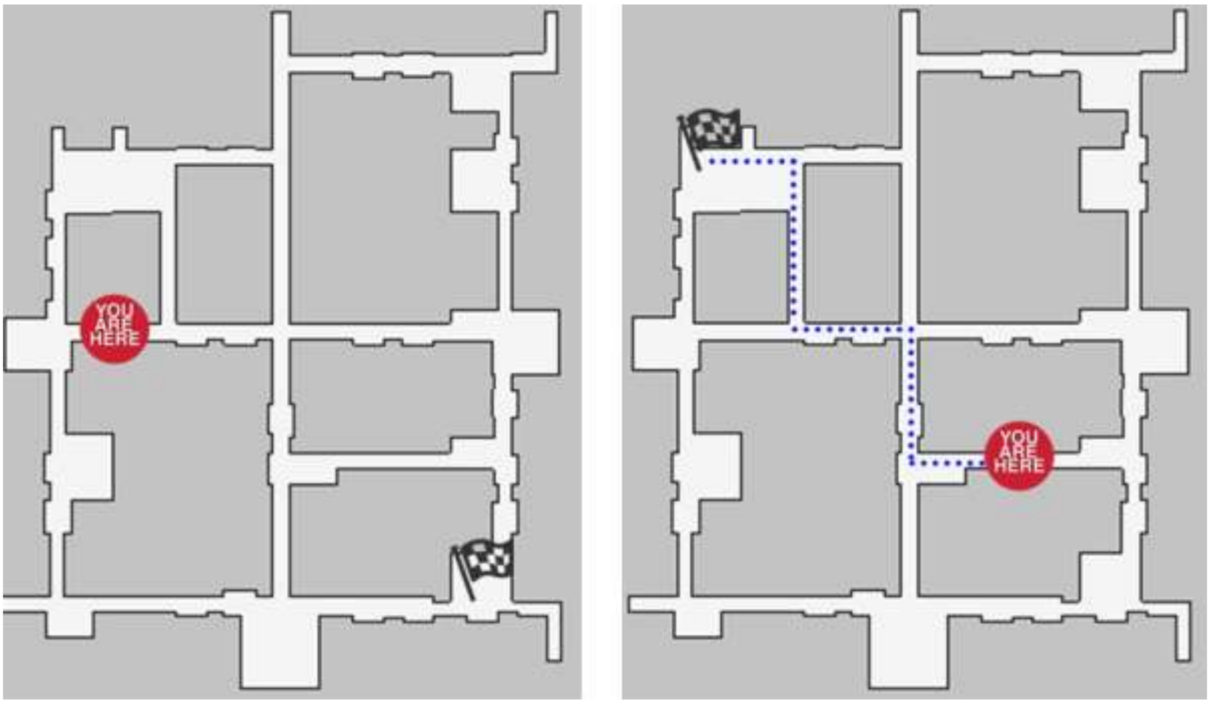
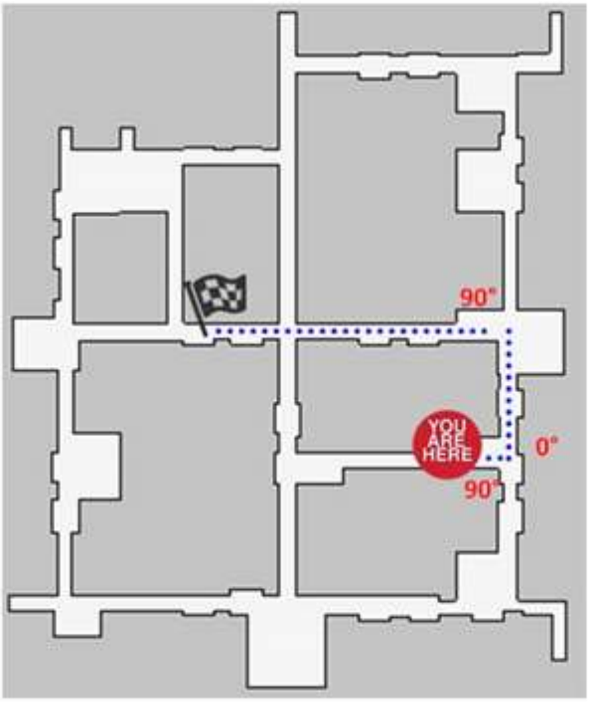
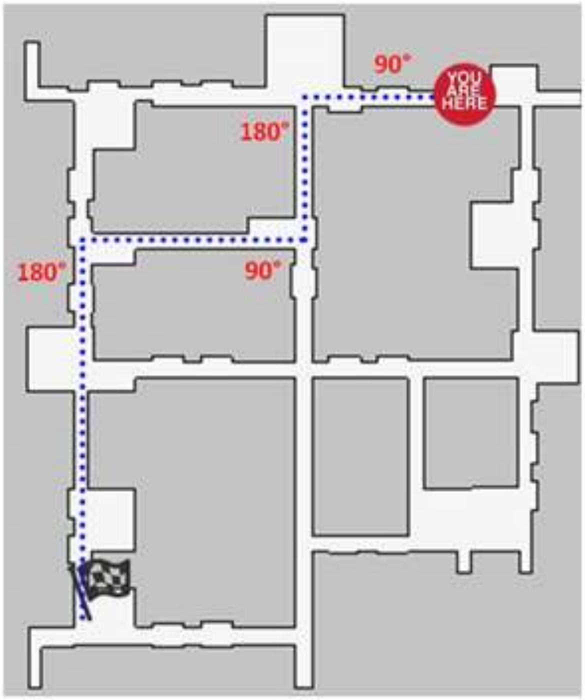


Figure 4.3: Here is an example of two of the twenty maps that were used in the experiment. Left: example of a free navigation map where participants were required to plan their own routes from the YAH points to the goal location (bottom of the flag). Right: An example of a map with a restricted route indicated – participants were instructed to follow the specific route between the "You are here" point and the goal location. These two are both examples of "north facing" maps; we had equal balance of maps having initial facing points from all four directions.





Low Route Alignment

High Route Alignment

Figure 4.4: Route alignment refers to the cumulative degree of misalignment between the map orientation (forward is up) and the direction of travel along the route. Left is an example of a Low Route Alignment map (total route alignment =180 degrees), Right is an example of a High Route Alignment map (total route alignment = 540 degrees).

Procedure

The experiment consisted of twenty trials. For each trial, participants were shown a different map (in randomised order). At the beginning of the trial, the participants were positioned in the VR such that the map was aligned with the position and orientation in the virtual environment. Each trial consisted of three distinct phases:

1. Map-Study Phase: A clear map stand was placed in front of where the participant was sitting; at the start of each trial the experimenter placed a new map on this stand for the participant to study until they felt they could execute the route from the YAH point to the goal location. Participants indicated to the researcher when they were ready to start the navigation. The map was then removed, and they were instructed to navigate to the goal location in the virtual care environment.

2. Navigation Phase: All participants had the option to navigate in the environment themselves (using the arrow keys on the keyboard), or have the researcher navigate using the keyboard for them under their instruction (i.e. the participant provided the directions). All young controls opted to navigate themselves to the goal location, whilst only two older adults decided to navigate themselves (both from the Old High MoCA group). Once participants believed they had reached the goal location, they stopped or told the researcher to stop. They were then asked to indicate how confident they were that they had actually reached the goal location on a 7 point Likert Scale (1 indicating not very confident and 7 being very confident).

3. Pointing Phase: Participants were asked to point back to the starting point from their ending position by turning within the virtual environment such that the central point of the central screen was aligned with the start location. Participants were instructed as follows: "I would like you to imagine all the walls are invisible, and turn so that you are facing where you think you started off and studied the map in the environment". Once the centre of the central screen was aligned with where they thought the starting point was, they instructed the experimenter.

Each trial took approximately four minutes to complete. Participants were free to have breaks between trials if they wished. All participants additionally completed the Santa Barbara Sense of Direction Scale (SBSOD) (Hegarty et al., 2002) at the start of the study.

Figure 4.5: Experimental set-up showing a participant (right) studying the YAH before commencing the route to the goal (flag) location in the virtual care environment.

Data analysis

To measure performance, we calculated the distance between the actual goal location and the participant's location at the end of each trial. In addition, we calculated whether participants had accurately reached the "goal zone" area. Goal zones were defined by segmenting the floorplan of the virtual care environment into individual corridors between intersections as well as intersections and communal living spaces (see Figure 4.6). This was done to separate situations in which participants reached the correct room or corridor in the virtual environment (but may have been a few metres from the actual goal location), from situations where participants were in a different part of the virtual environment but were still close in proximity to the goal location (see Figure 4.6 for an overview of the goal zone areas). If the participant ended up within the correct goal zone, they were scored as having correctly reached the goal zone (this will be referred to as "reached goal zone" throughout the rest of this chapter). The percentage of trials in which participants reached the goal zone was computed. Other variables recorded were the confidence ratings after each trial (i.e. to capture how confident participants were that they had reached the goal) and pointing error from the ending position to the start (YAH) point for each trial (to measure path integration). The duration of time spent studying maps was also recorded (to measure latency of map learning).

Route Alignment

Restricted navigation routes additionally captured differing levels of route alignment (see Figure 4.4 for an overview of how route alignment was calculated). Route alignment refers to the cumulative degree of misalignment between the map orientation (forward is up) and the direction of travel along the route. To calculate route alignment, the degree of the alignment (or misalignment) from the original facing orientation was calculated for each segment (i.e. after each turn) of the route. Following this, all the values of route alignment for the different segments along the route up were added up for an overall route alignment value for the entire route. For example, when one initiates navigation after studying the route by turning 90 degrees to the left and then walking down the corridor, then this segment of the route would be misaligned by 90 degrees. If the second turn would be 90 degrees to the left, the following segment would then be misaligned by 180 degrees. However, if the second turn was a 90 degree turn to the right, the following corridor would be aligned with the orientation of the map during the study phase, i.e. the alignment would be 90 degrees.

In total, there were six maps categorised as Low Route Alignment (up to 270 degrees), and six categorised as High Route Alignment (360 degrees and over). To explore the effect of route alignment on map usage, we focused on the data from 'restricted navigation' as these maps had pre-defined routes that allowed us to calculate route alignment. Data from the 'free navigation' routes were not included in this analysis as we could not know which routes participants planned to navigate while studying the maps.

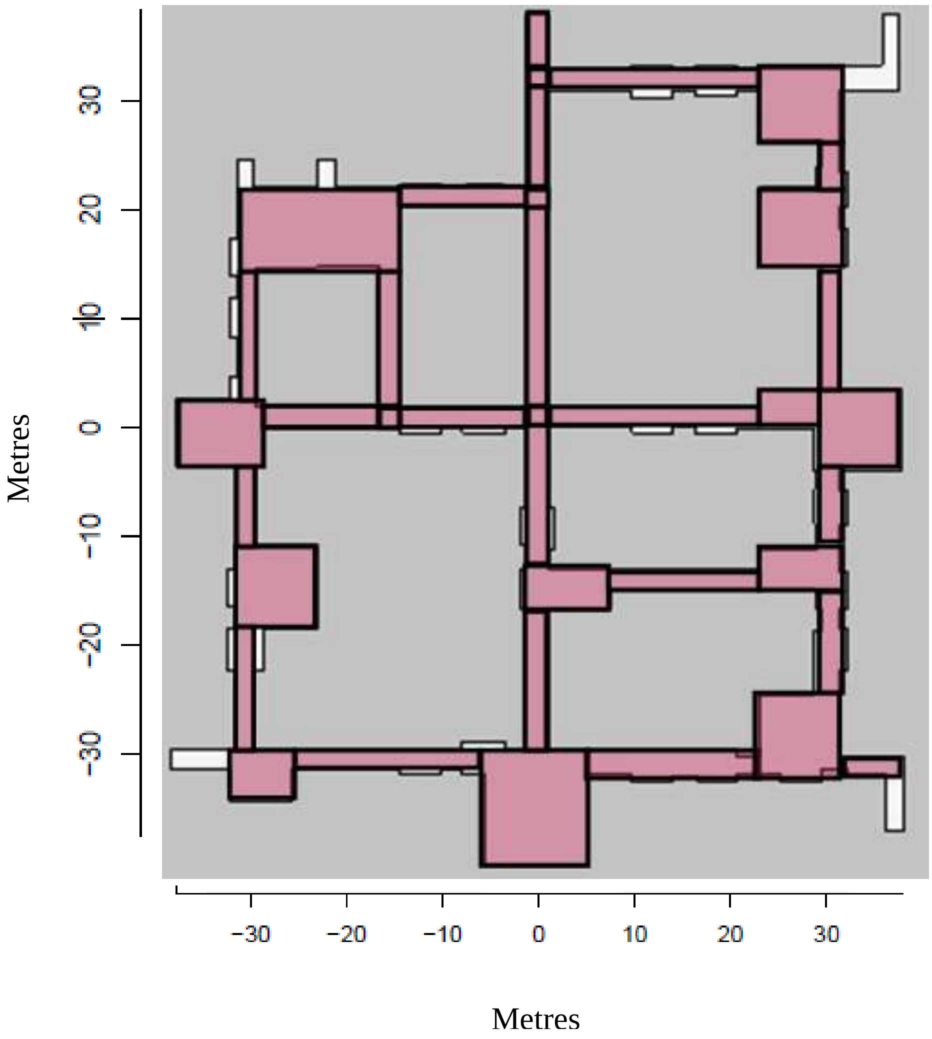


Figure 4.6: Getting to the goal reference system. The individual zones are indicated here in the separate pink boxes.

4.4 Results

Free Navigation Maps: Route Trajectories

Below we have included two of the free navigation maps, to demonstrate the types of routes taken by participants (i.e. which were most and least popular), as well as the ending position for each of the participants. The two maps selected both had average performance across the eight map trials.

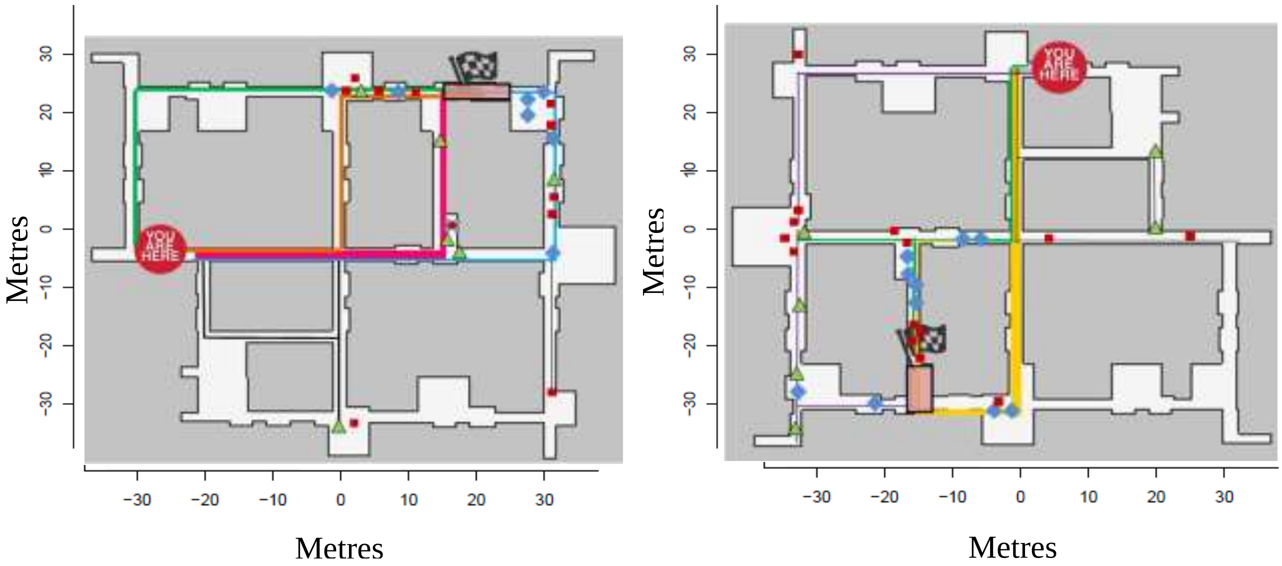


Figure 4.7: Above are maps from two free navigation maps depicting the route trajectories participants took highlighted in different colours as well as the ending positions (i.e. when participants declared that they had reached the goal) for all participants. The blue diamond represents the young participants, the red squares represent the Old High MoCA participants and green triangles represent the Old Low MoCA participants. For the left map, the most commonly taken route was the pink route (19 participants took this), followed by the green route (10 participants took this) and the orange route (10 participants took this). For the right map the most common route was the orange route (24 participants took this route) followed by the green route (14 participants took this route).

Figure 4.7 shows the superimposed trajectories and the final destination for two of the free navigation maps in the experiment. This shows that most participants ended up in the correct quadrant off the environment, especially for the left map (which is a Low

Route Alignment Map), and that participants used different routes to reach the goal which are described in the Figure title.

Time Studying Maps

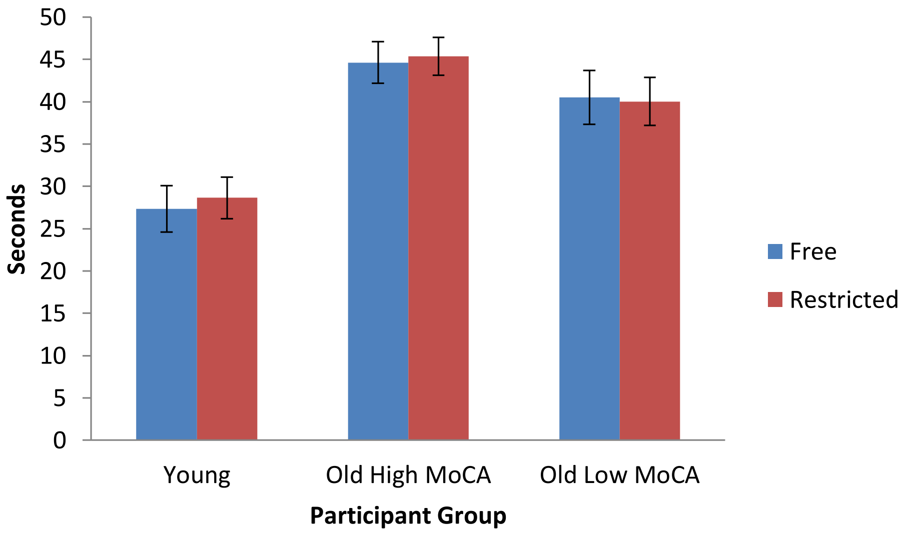


Figure 4.8: time spent studying the maps (seconds; y axis) for each of the three participant groups (x axis) both of the two map styles (free navigation map data are indicated in blue, while data from maps with restricted routes are shown in red).

A mixed effects ANOVA with the between factor participant group (Young, Old High MoCA and Old Low MoCA) and the within factor map style (free or restricted route) did reveal a main effect of participant group ($F(2,53) = 13.831$, $p < 0.001$; $\eta_p^2 = 0.333$) on the time studying the maps, while neither the main effect of map style ($F(1,53) = 0.028$, $p = 0.868$; $\eta_p^2 = 0.001$) nor the interaction were significant ($F(2,53) = 1.529$, $p = 0.226$; $\eta_p^2 = 0.055$).

Post hoc analyses (An adjusted Fisher's LSD) revealed that the Young group spent significantly less time studying the maps than both the Old High MoCA group ($p < 0.001$) and Old Low MoCA ($p < 0.001$). There was no significant difference between the Old High MoCA and the Old Low MoCA groups ($p = 0.734$).

Time Studying Maps and Route Alignment

The restricted navigation maps allowed the effects of Route Alignment as a factor to be addressed, which is why an additional ANOVA on this subset is included. Only data from the 12 restricted navigation map trials were included as they provide an accurate account of the routes people took. There was a significant difference between High and Low Route Alignment Maps for Time Studying the Maps (F (1,53) = 12.362, p <0.001; η_p^2 = 0.189), with the High Route Alignment maps requiring more time, as well as a significant difference between dependent on participant group (Young, Old High MoCA and Old Low MoCA; (F (2,53) = 13.263, p <0.001; η_p^2 = 0.334). No significant interaction was found between the map’s Route Alignment and the participant group (F (2,53) = 0.090, p = 0.914; η_p^2 = 0.003).

Post hoc analyses (An adjusted Fisher’s LSD) revealed that the Young group took significantly less time studying the maps than the Old High MoCA groups (p < 0.001) as well as the Old Low MoCA (p < 0.05) dependent on route alignment. However, the Old High MoCA spent significantly more time than the Old Low MoCA groups (p < 0.05) studying maps dependent on route alignment.

Reaching the Goal Zone

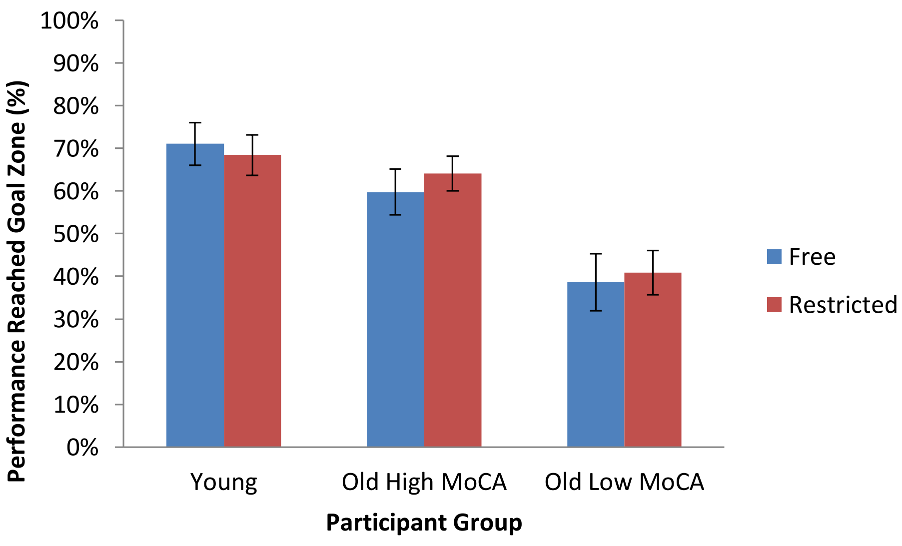


Figure 4.9: Performance for reaching the goal zone (percentage trials correct; y axis) for each of the three participant groups (x axis) for both of the two map styles (free navigation map data are indicated in blue, while data from maps with restricted routes are shown in red).

A mixed effects ANOVA with the between factor participant group (Young, Old High MoCA and Old Low MoCA) and the within factor map style (free or restricted route) did reveal a main effect of participant group ($F(2,53) = 9.542$, $p < 0.001$; $\eta_p^2 = 0.265$) on the percentage of getting to the goal zone, while neither the effect of map style ($F(2,53) = 0.260$, $p = 0.612$; $\eta_p^2 = 0.005$) nor the interaction were significant ($F(2,53) = 0.696$, $p = 0.503$; $\eta_p^2 = 0.026$).

Post hoc analyses (An adjusted Fisher's LSD) revealed that the Young group were significantly better at reaching the goal zone than the Old Low MoCA ($p < 0.001$), and that the Old High MoCA group were also significantly better at reaching the goal zone than the Old Low MoCA groups ($p < 0.005$). There was no significant difference between the Young and Old High MoCA groups ($p = 0.426$).

Getting to the Goal Zone and Route Alignment

There was a significant difference between High and Low Route Alignment Maps for Getting to the Goal Zone ($F(1,53) = 14.497$, $p < 0.001$; $\eta_p^2 = 0.215$), as well as for participant group (young, Old High MoCA and Old Low MoCA) ($F(2,53) = 8.612$, $p < 0.001$; $\eta_p^2 = 0.215$). No significant interaction between the map's Route Alignment and the participant group was found ($F(2,53) = 0.097$, $p = 0.907$; $\eta_p^2 = 0.004$).

Post hoc analyses (An adjusted Fisher's LSD) additionally revealed no significant differences between the Young and Old High MoCA ($p = 0.982$), however the Young group were significantly better than the Old Low MoCA group ($p < 0.001$) at reaching the goal zone dependent on route alignment. The Old High MoCA group were also significantly better than the Old Low MoCA group ($p < 0.001$).

Distance from the Goal

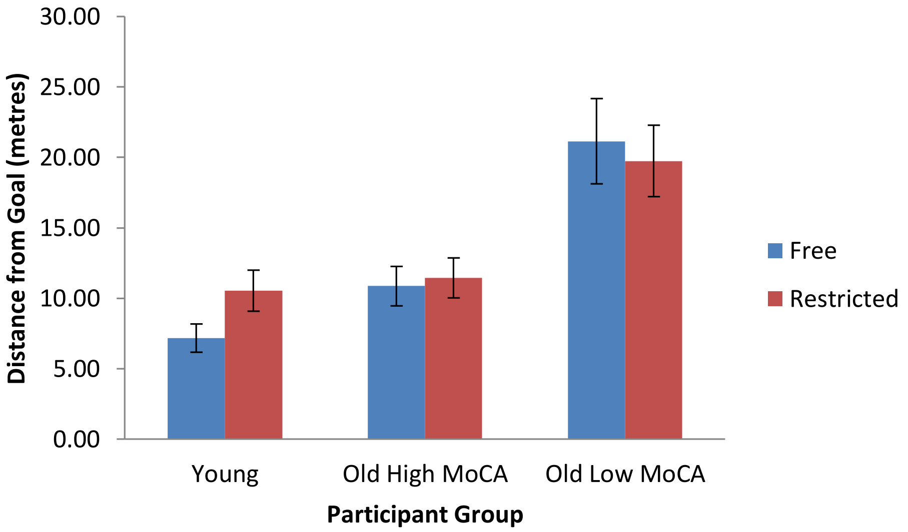


Figure 4.10: The graph above shows the mean distance from the goal data (metres; y axis) for each of the three participant groups (x axis) for both of the two map styles (free navigation map data are indicated in blue, while data from maps with restricted routes are shown in red).

A mixed effects ANOVA with the between factor participant group (Young, Old High MoCA and Old Low MoCA) and the within factor map style (free or restricted route) did reveal a main effect of participant group ($F (2,53) = 11.686$, $p < 0.001$; $\eta_p^2 = 0.306$) on the distance from the goal, while there was no significant effect of map style ($F (2,53) = 1.630$, $p = 0.207$; $\eta_p^2 = 0.030$). There was a significant interaction ($F (2,53) = 3.990$, $p < 0.05$); $\eta_p^2 = 0.131$).

Post hoc analyses (An adjusted Fisher's LSD) revealed that the young group was significantly closer (distance in metres) to goal location than the Old Low MoCA ($p < 0.001$). The Old High MoCA group was also significantly closer (distance in metres) than the Old Low MoCA group ($p < 0.001$). There was no difference between the Young and Old High MoCA group ($p = 0.602$). The significant interaction was driven by a significant difference between map styles (free and restricted) in the Young group ($p < 0.05$), which was not significant for either of the older participant groups (Old High MoCA group: $p = 0.572$; Old Low MoCA group: $p = 0.291$). Focusing specifically on the free navigation routes, there was no significant difference between the Young and

Old High MoCA group ($p = 0.120$), but there was a significant difference between the Young and the Old Low MoCA group ($p < 0.001$) with the Young group getting closer to the goal location on the free navigation routes, while the Old Low MoCA group performed worse (i.e. were further away from the goal location) with free navigation maps. There was also a significant difference between the Old High MoCA group and the Old Low MoCA group for the free navigation routes ($p <0.001$), with the Old Low MoCA group performing worse with these maps than the Old High MoCA group. For the restricted routes, there was no significant difference between the Young and the Old High MoCA group ($p = 0.697$), but there was a significant difference between the young and Old Low MoCA group ($p < 0.005$), with the Young group performing better than the Old Low MoCA. Also, the Old High MoCA were significantly closer with the restricted routes than the Old Low MoCA groups ($p < 0.005$).

Distance from the Goal and Route Alignment

No significant difference between High and Low Route Alignment Maps for distance from the goal zone was found ($F (1,53) = 2.062$, $p = 0.157$; $\eta_p^2 = 0.037$). However, a significant difference was found for participant group (Young, Old High MoCA and Old Low MoCA) ($F (2,53) = 7.195$, $p <0.005$; $\eta_p^2 = 0.214$). No significant interaction between the maps' Route Alignment and the participant group (Young, Old High MoCA and Old Low MoCA) was found ($F (2,53) = 0.001$, $p = 0.999$; $\eta_p^2 = 0.001$).

Post hoc analyses (An adjusted Fisher's LSD) additionally revealed no significant differences between the young and the Old High MoCA groups ($p = 0.699$) for distance from the goal dependent on route alignment, however, significant differences were found between the Young and Old Low MoCA groups ($p < 0.001$) as well as between the Old High MoCA and the Old Low MoCA groups ($p < 0.005$), with the Old Low MoCA group further away from the goal location than the Young group, and the Old High MoCA group.

Pointing Task

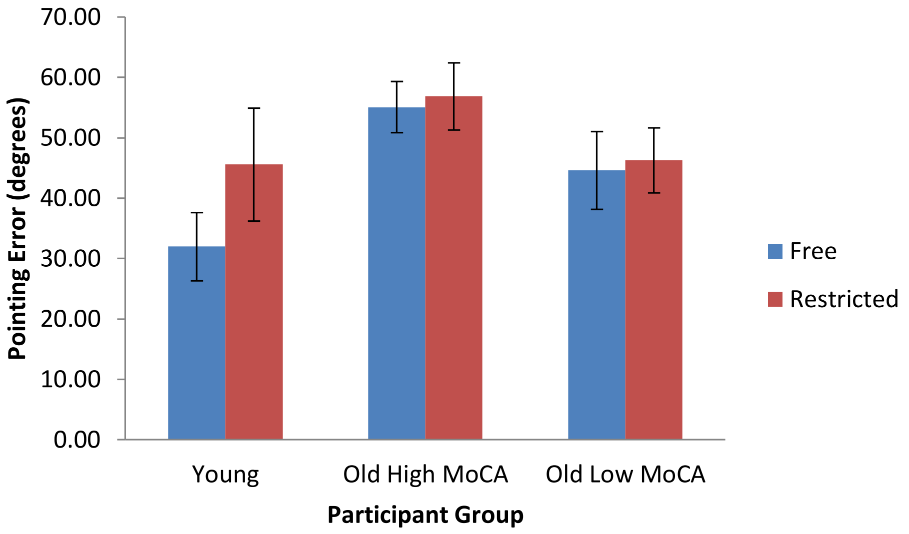


Figure 4.11: The graph above shows the mean pointing error (degrees; y axis) for each of the three participant groups (x axis) for both of the two map styles (free navigation map data are indicated in blue, while data from maps with restricted routes are shown in red).

A mixed effects ANOVA with the between factor participant group (Young, Old High MoCA and Old Low MoCA) and the within factor map style (free or restricted route) did not reveal a main effect of participant group ($F(2,53) = 2.540$, $p = 0.088$; $\eta_p^2 = 0.087$) for the pointing task. Additionally, neither the effect of map style ($F(2,53) = 3.678$, $p = 0.061$; $\eta_p^2 = 0.065$) nor the interaction were significant ($F(2,53) = 1.860$, $p = 0.164$; $\eta_p^2 = .066$).

Pointing Error and Route Alignment

No significant difference between High and Low Route Alignment Maps for pointing error was found ($F(1,53) = 1.657$, $p <= 0.204$; $\eta_p^2 = 0.030$). Additionally, no significant difference was found for participant group (Young, Old High MoCA and Old Low MoCA) ($F(2,53) = 0.859$, $p = 0.429$; $\eta_p^2 = 0.031$) A significant interaction between the maps' Route Alignment and the participant group was found ($F(2,53) = 5.377$, $p < 0.05$; $\eta_p^2 = 0.169$).

As there was a significant interaction between participant groups for pointing performance dependent on the maps' Route Alignment, a post hoc analysis of the interaction was conducted. An adjusted Fisher's LSD analysis revealed no significant difference in route alignment for the young group ($p = 0.069$) or for the Old High MoCA ($p = 0.226$). However, a significant difference was found between Route Alignment Maps for the Old Low MoCA group pointing performance ($p < 0.05$), with them performing significantly better on the Low Route Alignment maps than the High Route Alignment maps.

Pointing performance for routes where goal zone was reached

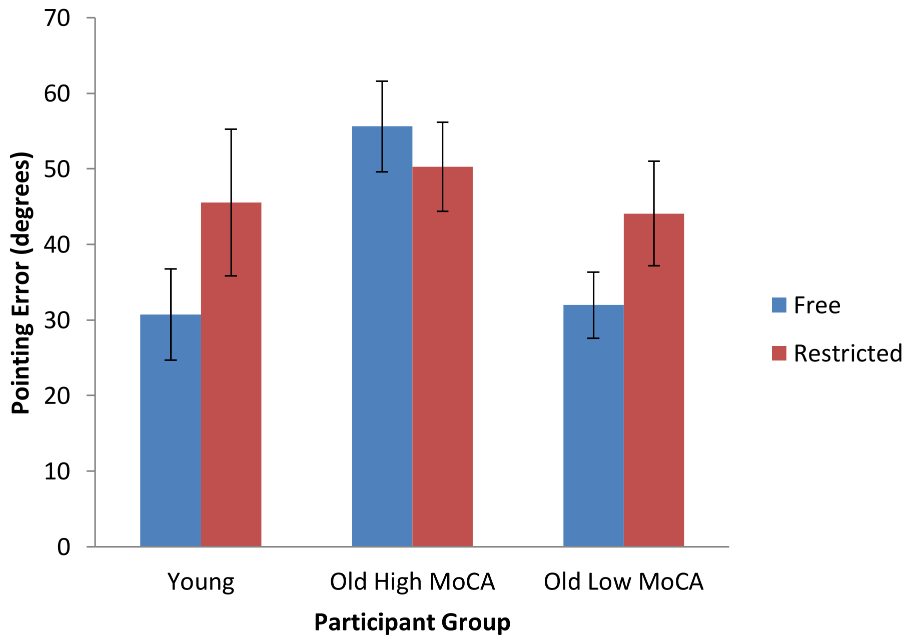


Figure 4.12: Mean pointing error (degrees; y axis) for each of the three participant groups (x axis) for both of the two map styles (free navigation map data are indicated in blue, while data from maps with restricted routes are shown in red) for trials where participants could reach the goal zone.

As errors in the pointing data could have been explained by participants' pointing as though they were at the correct goal (for the incorrect trials), we included an additional analysis with routes where participants correctly reached the goal location to investigate pointing performance for correct trials only. For routes where participants correctly reached the goal zone, a mixed effects ANOVA with the within factor map style (free or restricted route) and the between factor participant group (young, Old High MoCA, Low MoCA) did not reveal a main effect of participant group ($F (2,53) = 3.026$, $p = 0.057$; $\eta_p^2 = 0.104$) for the pointing task nor was there an effect of map style ($F (2,53) = 3.463$, $p = 0.068$; $\eta_p^2 = 0.062$). There was a significant interaction ($F (2,53) = 3.232$, $p < .05$; $\eta_p^2 = 0.111$).

As there was a significant interaction between participant group and map style for pointing performance for routes where the goal zone was reached, a post hoc analysis of the interaction was conducted. An adjusted Fisher's LSD analysis revealed a significant difference in map style for the Young group ($p < 0.05$), with the Young group displaying better pointing accuracy for free navigation routes, but no significant difference for the Old High MoCA ($p = 0.363$) or for the Old Low MoCA group ($p = 0.127$). Also, for the free navigation routes, the young group had significantly better pointing accuracy than the Old High MoCA group ($p < 0.005$), while the Old High MoCA were significantly worse pointing accuracy than the Old Low MoCA group ($p < 0.05$). There were no significant differences between the Young group and the Low MoCA group ($p = 0.895$). For the restricted routes, there were no significant differences between any of groups; Young and Old High MoCA ($p = 0.652$), Young and Old Low MoCA ($p = 0.899$) and Old High MoCA and Old Low MoCA groups ($p = 0.595$).

Confidence Ratings

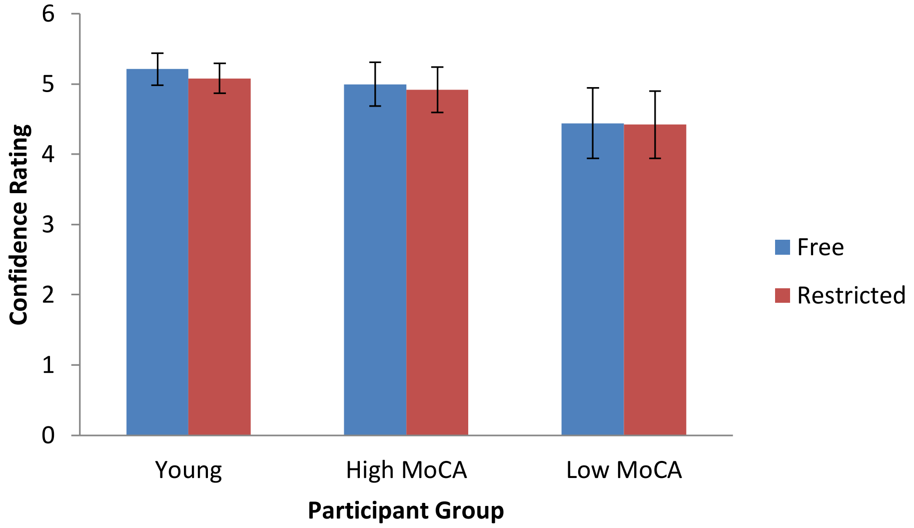


Figure 4.13: Mean confidence ratings (y axis) for each of the three participant groups (x axis) for both of the two map styles (free navigation map data are indicated in blue, while data from maps with restricted routes are shown in red).

A mixed effects ANOVA with the between factor participant group (Young, Old High MoCA and Old Low MoCA) and the within factor map style (free or restricted route) did not reveal a main effect of participant group ($F(2,53)=1.98$, $p=.233$; $\eta_p^2= .054$). However, there was a significant effect of map style ($F(1,53) = 4.009$, $p < 0.05$; $\eta_p^2 = 0.070$). Specifically, participants were more confident using the free navigation maps. No interaction was found ($F(2,53) = 0.654$, $p = 0.524$; $\eta_p^2 = 0.024$).

Performance and Confidence ratings

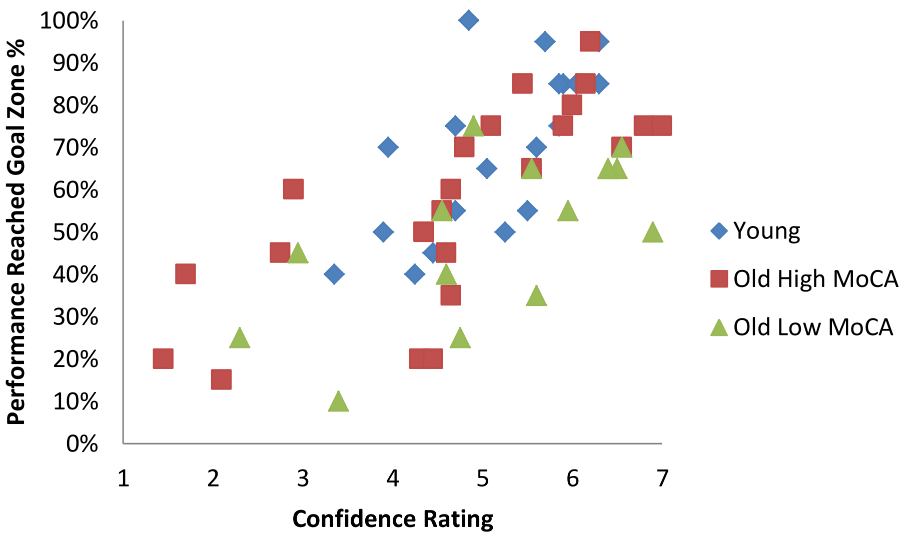


Figure 4.14: Performance data (Reached the goal zone mean) confidence ratings (mean) for all participants. Young (mean = 5.13, SD = 0.87), Old High MoCA (mean = 4.69, SD = 1.59) and Old Low MoCA (mean = 5.06, SD = 1.42)

To investigate the association between confidence ratings on performance on getting to the goal, we calculated a mean performance score as well as a mean confidence rating score per participant. A linear regression was calculated to quantify the association between confidence ratings and the performance on getting to the goal. Confidence ratings significantly predicted performance for getting to the goal, $B = 0.111$ $t(55) = 6.433$, $p < 0.001$. Performance (getting to the goal) also explained a significant proportion of variance in confidence rating scores, $R2 = 0.453$ $F(1,55) = 41.378$, $p < 0.001$. Individual Pearson's R correlations were carried out for each of the participant groups to see whether associations between performance and the confidence ratings specific to each of the groups were present. A strong positive correlation was observed between performance and confidence ratings for the Young group ($r = 0.691$, $n = 19$, $p < 0.001$), as well as the Old High MoCA group ($r = 0.642$, $n = 23$, $p < 0.001$) and the Old Low MoCA group ($r = 0.683$, $n = 14$, $p < 0.05$).

Performance and SBSOD

All Participants were required to complete the SBSOD scale which gives an indication of participants' self-ratings of their sense of direction. The following analysis was included to investigate whether MoCA group had any effect on participants' MoCA scores.

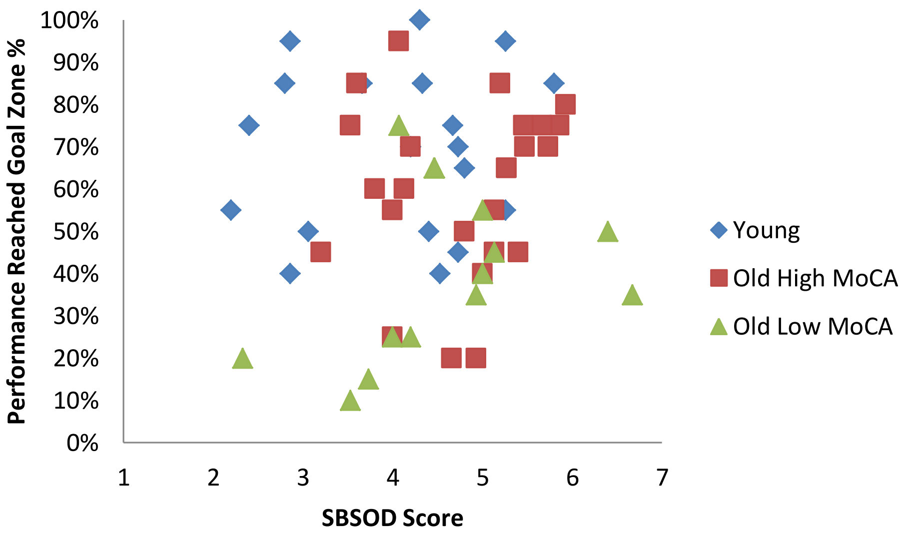


Figure 4.15: Scatter graph showing participants' performance data (Reached the goal zone mean) in relation to their SBSOD ratings. Young (mean = 4.04, SD = 1.05), Old High MoCA (mean = 4.79, SD = 0.816) and Old Low MoCA (mean = 4.56, SD = 1.11).

A one-way between subjects ANOVA did not reach a significant difference between the Young, Old High MoCA and Old Low MoCA groups scores on SBSOD (F (1,52) = 3.129, p= 0.052), but did show a trend. Moreover, SBSOD scores did not correlate with performance on reaching the goal zone (r = 0.060, n = 56, p = 0.659).

Individual Pearson's R correlations were carried out for each of the participant groups to see whether associations between performance and the SBSOD specific to each of the groups. No significant correlations were observed between performance and confidence ratings for the Young group (r = 0.086, n = 19, p = 0.728), the Old High MoCA group (r = 0.076, n = 23, p = 0.740) or the Old Low MoCA group (r = 0.355, n = 14, p = 0.212).

4.5 Discussion

In this study we tested young adults, typically ageing adults and older adults showing early signs of atypical ageing, on their abilities to use YAH maps in a virtual care environment setting. For this, participants studied YAH maps which highlighted current position and the goal destination until they felt comfortable that they could find their way to the goal location. Some of these maps required participants to plan their own route (thus testing their route planning abilities), whilst others already depicted restricted routes to follow (therefore focusing predominantly on participants' abilities to memorise and track the progress of the route).

In line with our predictions, we found that the older participants, who displayed early signs of atypical ageing (Old Low MoCA group), performed significantly worse than young controls and typically ageing adults (Old High MoCA group) at getting to the goal (both in terms of reaching goal zone and distance). Interestingly, performance was similar between young participants and the Old High MoCA group. For both the typically ageing adults, and the older adults showing early signs of atypical ageing, map style (free or restricted maps) did not influence any of the performance variables: getting to the goal zone, distance from the goal, time studying the maps, or performance in the pointing task. This suggests that the cognitive processes involved with route planning on free navigation YAH maps that would be alleviated by having restricted routes displayed, are not especially affected by the effects of typical and early atypical ageing.

The main finding from this study was that the Old Low MoCA group were significantly worse at getting to the goal location than both the Young participant group and the Old High MoCA group, while the latter two groups performed similarly. These results suggest that the abilities required to read and use YAH maps for navigation are not affected by typical ageing, but are affected already by the earliest signs of atypical ageing (as assessed by the MoCA). These results are consistent with studies addressing the effects of typical and atypical ageing on other map-based spatial tasks (Cherrier, 2001; Chapter 4). For example, Cherrier et al. (2001) found a significant difference between typically ageing adults and those with AD when participants were required to identify a previously travelled route from a map perspective amongst distractor maps depicting other routes (map identification task); they found performance dropped from 80% to below 20%, which, alongside the verbal recall of landmarks task, saw the biggest drop in performance between the two participant groups (Cherrier et al., 2001). Although the performance declines in the current experiment were subtler when compared with Cherrier et al.'s (2001), findings from these studies, as well as from Chapter 3 of this thesis, suggests that this map usage and successful navigation using maps is affected during early atypical ageing.

In the current experiment, map style (free or restricted maps) did not affect performance which suggests that route planning abilities that were needed to solve the task in the study remain unaffected or less affected by the effects of typical and early atypical ageing. Bovy and Stern (1990) highlighted that route planning typically comprises of three phases: firstly, reviewing the spatial relationship between an origin and a destination; secondly, identifying and comparing possible route options; and thirdly, selecting the most viable path. Our findings suggest that the second and third phases that Bovy and Stern (1990) highlighted (the first process was not addressed in the present study) are not affected by early atypical ageing as similar performance was found for both map style factors, and that they also do not play a significant role in the overall ability to reach the correct goal zone (when comparing conditions per participant group). This is particularly interesting as forward planning and prefrontal decision making tasks are said to be affected during ageing and especially during early atypical ageing (MacPherson et al., 2002), and cognitive mapping of an environment has been shown to take longer for older adults compared with young controls (Iaria et al., 2009).

Some discrepancies were found during the analyses for distance from the goal and reaching the goal zone variables, dependent on the map style. Whilst no interaction between participant group and map style was found for the reaching goal zone, there was an interaction between participant group and map style for how close participants were to the goal location (i.e. the distance from the goal). Post hoc analysis of this interaction revealed that map style (free or restricted maps) had no significant effect for either of the older participant groups (Old High MoCA and Old Low MoCA) with distance from goal approximately equal irrespective of map style, but there was a significant difference for the young group; the young participant group ended up closer to the goal when using the free navigation maps than when using the restricted maps

Contrasting this, the map style had no significant effect for the typically ageing adults (Old High MoCA) or older adults showing early signs of atypical ageing (Old Low MoCA) suggesting that the restricted maps, in this scenario, do not alleviate the cognitive workload involved when planning routes from one location to another for typically and early atypically ageing adults.

Despite reducing the cognitive effort associated with route planning required, the maps which aimed to reduce the load of planning required (by providing a visible path between the origin and destination), did not seem to have an effect on reaching the goal location. One explanation for our findings is that, as the maps were simple, these results may relate specifically to planning simple routes from maps rather than with maps depicting larger scale environments. Therefore, planning simple routes from maps may be less affected than the planning longer and more complex routes, particularly if these were planned from memory, which would require cognitive mapping of the environment and has been shown to be affected by ageing (Iaria et al., 2009).

To explore the effects of route alignment and mental rotation involved in interpreting maps, the restricted routes were further analysed on the ability to reach the goal zone. Route alignment had a significant effect on time spent studying the maps, and performance of getting to the goal zone as well as for the pointing task. All groups spent significantly longer studying the High Route Alignment maps (i.e. the maps which required 450 degrees or more alignment from the current orientation). Route alignment also had a significant effect on getting to the goal zone, with all participants reaching the goal zone more frequently for the low route alignment maps (maps which required 360 degrees or less alignment from their current orientation). Also, the Old Low MoCA (early atypically ageing) group reached the goal zone significantly less often than the Young and Old High MoCA (typically ageing) groups on High Route Alignment maps.

Route alignment also affected performance for distance from the goal, with the Old Low MoCA (early atypically ageing) group ending up significantly further away from the goal location than both the Young and Old High MoCA groups. This suggests that the processes involved in mentally translating a route depicted on a map from an allocentric to an egocentric representation, are affected during early atypical ageing, most likely due to the mental rotation abilities associated with this task which have been demonstrated to be affected by ageing (De Beni, Pazzaglia, & Gardini, 2006; Puglisi & Morrell, 1986). Whilst all maps in this study were correctly aligned with the participants' starting orientation, these findings do highlight the importance of where the goal is situated on the map when considering map design, as mental rotation abilities are required in interpreting the correct route trajectory. All three groups performed better on all variables (e.g. studying maps, reaching the goal zone and pointing) for maps that required less route alignment with the map. Previous studies have illustrated the effect that map alignment has on the ability to reliably use maps to support orientation, with minimal differences between young and old participants when maps were correctly aligned (Borella et al., 2014). This study furthers this, emphasising route alignment as an important consideration to improve map design.

Why are maps especially difficult to use for early atypically ageing adults?

All participants indicated when they felt comfortable to execute the routes, and if they experienced any issues initially localising where they were. Despite this, there were still declines in performance per participant group, which could be explained by a reduction in short term memory (STM) available to remember and execute the routes (Allain et al., 2005). It may be that participants simply forgot the route whilst executing it, which was also reflected in the confidence rating scores (i.e. participants rated being more confident when they reached the goal position or came close to the goal location, and less confident when they did not come close to the goal location).

Studying Maps

Both the Old High MoCA and the Old Low MoCA group spent much longer studying the maps than the Young controls. These findings can be explained by the age-associated declines in working memory processes (Salthouse & Babcock, 1991). Slower processing primarily influences the time required to achieve stable encoding of the information rather than the rate at which information is lost across time or subsequent processing (Salthouse, 1994; Salthouse & Babcock, 1991). Additionally, we know from this study and Chapter 3 that typically ageing adults do perform similar to young adults if given enough time to encode the route, either by spending more time to study the route or by having more exposures to the given route (Chapter 3) which would support the argument that slower processing may be the cause the increased study time.

An alternative explanation for why typically ageing adults took significantly longer to encode and plan the route could relate to how ageing adults affects the initial localisation with the environment. The analysis on the effects of route alignment for restricted navigation maps, revealed that the Old High MoCA group and the Old Low MoCA groups both required significantly more time to plan routes than the young group. Mental rotation and perspective taking performance have previously been shown to reduce with age (Inagaki et al 2002), which could explain why the Old High MoCA group required more time to study the maps (required more time to interpret and make sense of the given route) despite performance levels being comparable to the Young group.

Pointing Task

The ability to point back to the starting position was not affected by typical or early atypical ageing, as the three groups all performed similarly. The map style did render a significant interaction between participant group and map style for performance on the pointing task for trials in which participants have successfully reached the goal. Post hoc analysis revealed that this interaction was driven by a performance difference between map styles in the young participant group; the young group showed better pointing accuracy for the free navigation maps than for the restricted maps. Both of the older participant groups did not significantly differ in their pointing accuracy dependent on map style, therefore the map style did not appear to support neither of the older groups' pointing accuracy. Whilst we did predict that restricted maps would potentially eliminate the amount of route planning associated with getting to the goal, these findings highlight that the route planning associated with the task, had little to influence the older adults' survey knowledge (as measured by the pointing task) of the environment. This finding is novel especially as free navigation maps would provide navigators more opportunity to explore alternative routes during the map studying phase (Bovy & Stern, 1990; Brunye et al., 2012), which could lead to better knowledge of the environment and therefore better pointing performance when using the free navigation maps. Given that this was found only with the young participant group, suggests that survey knowledge may be less dependent on learning condition (i.e. map style) for typical and early atypical ageing adults. Together with the distance from goal findings, the findings highlight that younger adults, compared with older adults, perform better on route memory measures after studying free navigation maps rather than restricted maps.

Additionally, despite not reaching the goal locations on multiple trials, participants were not completely lost in the environment, as their performance on the pointing task was similar to the young controls. These findings also highlight that path integration was little affected by typical and early atypical ageing, which is consistent with earlier findings that indicate that path integration is relatively spared following hippocampal damage, which is known to occur during the ageing process (Kim, Sapiurka, Clark, & Squire, 2013; Tu, Spiers, Hodges, Piguet, & Hornberger, 2017). A recent study by Tu et al. (2017) reported that judgements of heading direction which relies on path integration, was spared in people with behavioural FTD but affected for those with AD. Tu et al., (2017) suggest that the inability for people with AD to path integrate could be as a result of damage to the retrosplenial cortex (RSC), which is not affected during behavioural FTD or typical ageing. As the present study only focused on participants displaying the earliest symptoms of atypical ageing, it is therefore unlikely that this group shows RSC damage. Furthermore, it would be informative to include a well-diagnosed cohort of participants with AD to explore how they would perform in the task presented in this study, particularly given the recent findings by Tu et al (2017).

The findings by Tu et al., (2017) are in line with the present study's contrasting age-related effects found between some tasks and not others (e.g. the getting to the goal zone data and the pointing data). These findings are in line with theoretical accounts stating that these allocentric tasks (e.g. map reading and pointing tasks) utilise different mechanisms (depending on the task) to support execution, which are differentially affected by typical and atypical ageing (Smyth & Kennedy, 1982).

However, in contrast to previous studies that have measured pointing performance (Meilinger & Bülthoff, 2010), participants did not have to infer the spatial relationship solely on basis of their ego-motion information (i.e. path integration) as they could see the spatial relations from the map during the map studying phase. Importantly, with regards to the pointing task, participants in this study did see the spatial relationship between start and goal when they studied the map, which could have had some influence on participants' pointing behaviour.

Self-ratings of navigation ability

In addition to actively testing behavioural route knowledge, participants were also asked to give self-ratings of their abilities; firstly through the SBSOD, and then through confidence ratings after each trial. Although the SBSOD task was not designed to investigate the effects of ageing, the SBSOD scores did not reflect performance for reaching the goal zone in any of the three participants groups, with similar scores between groups. These findings are consistent with Taillade, N'Kaoua, and Sauzéon (2016) who found that older adults had similar SBSOD scores to young adults, whilst navigation performance was affected by ageing. Taillade et al. (2016) argued that if age-related changes in navigation are minor in everyday situations, they could be more difficult to detect, rendering their monitoring and self-awareness more difficult. However, the present study also found that young adults SBSOD ratings were similar to the ratings reported by the older adults displaying early signs of atypical ageing (Old Low MoCA group). Although, the suggestion made by Taillade et al. (2016) that older adults are less aware and able to detect the overall gradual changes to their navigation skills could still be an explanation, the analysis on goal zone performance together with confidence ratings (see Figure 4.12) suggest that participants were able to monitor whether they have successfully reached the goal zone. This suggests that the Old Low MoCA group were less able to monitor their navigation abilities overall (as measured here using the SBSOD), whilst immediate scoring through confidence ratings appeared more reliable.

Although multiple studies have used various self-reporting measures for navigation ability (Kirasic et al., 1992; Baroni & De Beni, 1995; Burns, 1999; De Beni et al., 2006; Taillade et al., 2012, 2013; Borella et al., 2014; Taillade et al., 2016), care should be taken when choosing an appropriate measure in experiments that involve testing typically ageing adults and older adults displaying early signs of atypical ageing. Philips et al. (2013) highlighted that although older people may feel confident within familiar environments, there are different types of barriers (for example physical, economic, cultural and social) that are a concern for older people, particularly when they experience new environments. Making sure that these factors are considered in the questions given to older navigators, may result in a more reflective account of their skills. For example, including additional questions based on specific events rather than more generally (e.g. "I felt comfortable finding my way around the last hospital I visited", "I could easily find my way from the car park/bus stop to this University reception"). Also, asking people to rate (e.g. by using confidence ratings or other measures) their navigation ability directly during navigation, or shortly after navigating a route or completing a navigation task, may prove more reliable and capture the persons true perception of their navigation ability.

Where do these overall findings sit in relation to the existing ageing map research and what do the findings contribute to the field?

It is important to note that this study is the first YAH map study to include an early atypical ageing group, highlighting that older adults displaying early signs of atypical ageing are significantly worse at YAH map usage than typically ageing adults. Existing research in this field has focused predominantly on perspective taking abilities, pointing ability after participants studied maps (Meneghetti et al 2011; Borella et al 2014; Yamamoto and DeGirolamo 2012), or have included associated tasks such as map drawing and landmark location (using a map). This study has demonstrated a clear decline in YAH map usage between typically ageing adults, and older adults displaying early signs of atypical ageing, highlighting how sensitive this task is to the changes associated with atypical ageing.

YAH maps are often used in large environments to support navigation. In this study, we explored how YAH map design could be improved by reducing the amount of associated route planning required from YAH point to goal location. We found no difference in performance dependent on map style, with the older adults displaying early signs of atypical ageing performing poorly on both map styles. This firstly suggests that the cognitive resources for route planning required to complete a free navigation route are not necessarily affected by the effects or early atypical ageing and secondly that early atypical ageing causes difficulties that cannot be explained by route planning. It is important to note here that a pre-defined route would only ever direct a navigator to one particular location. YAH maps without predefined routes, in contrast, allow a navigator to travel to all the locations depicted so could be a more beneficial style of YAH map (as opposed to the restricted routes) in the long term. Overall, our results highlight that YAH maps may not be overly useful for people who show early signs of atypical ageing, therefore other navigation aids should be implemented to support successful navigation for this group.

One must make note though, that our maps (deliberately) did not include any landmark information, which we know is vital in successful YAH map design (Montello 2010). Future studies should therefore address how the suggested components of YAH map design (Montello, 2010) could better support early atypically ageing adults in using YAH maps.

A point to consider is the participants' preferred way of navigating to the goal. As highlighted in the methods section, participants were given the choice to use the keyboard to navigate, or to provide directions, and the researcher would then operate the keyboard. This was done in order to reduce the participants' cognitive effort that would be involved in learning to operate the controls and to familiarise them with the equipment during the navigation phase of the procedure. All of the young participants chose to navigate themselves, whilst only two of the older adults chose to navigate themselves. Note that this difference in procedure between age groups is not the same as comparing passive with active navigation (Loomis, Da Silva, Fujita, & Fukusima, 1992; Chrastil & Warren, 2012), as all participants, even those who did not operate the controls themselves, were making the decisions about turns along the route themselves. However, those participants who operated the keyboard/controls may have had additional proprioceptive information (pressing left, right, or straight button) - participants who asked the researcher to control movements, would not have not experienced this. The impact of this difference is difficult to assess without further experiments. This said, the patterns of performance between young adults, typically ageing adults, and older adults showing early signs of atypically ageing, does closely mirror the patterns of performance found in Chapter 3, where all groups underwent the same, passive navigation route learning condition prior to assessing route memory. This suggests that differences in physically controlling motion, while important to note, were not the cause of the performance differences between groups.

In turn, these findings could have implications for age (and particularly dementia) friendly environments and the suggestions made in the associated design guidelines. At present, the evidence base for successful navigation in the community and built environment, still requires underpinnings, which future studies could provide.

Together with the findings from Chapter 3, where multiple aspects of route memory were measured after route learning, one could argue that measuring map reading abilities could serve as an early indicator of atypical ageing, and should be considered during neuropsychological assessments.

4.6 Conclusion

In this experiment, we tested young, typically ageing adults and older adults displaying early signs of atypical ageing on their ability to use and interpret YAH maps and accurately get to the shown goal location in a virtual care environment. We found that older adults who showed early signs of atypical ageing were significantly worse at getting to the goal location shown on the maps based on distance away from the goal location. Map style (restricted or free navigation) did not influence performance of researching the correct goal zone, suggesting that the declines seen by the older adults displaying early signs of atypical ageing are not associated with route planning. These findings demonstrate that YAH maps as navigation aids may not be suitable for environments used by people with memory difficulties.

4.7 Interim Summary

The first two studies (Chapter 3 and Chapter 4) have highlighted the differences in performance on different sub-types of route knowledge between young adults, typically ageing adults and older adults displaying early signs of atypical ageing. In particular, typically ageing adults compared with young controls require more time to learn and study a route (either by viewing a video of the route in Chapter 3 or by studying a map in Chapter 4), but performed relatively well on measures of route memory (particularly, associative cue/landmark direction tasks and map-tasks). By contrast, older adults showing early signs of atypical ageing, while requiring a similar amount of time to study/learn a route as typically ageing adults, showed significant performance declines in several route memory tasks. In particular, the older adults showing early signs of atypical ageing were significantly worse at map-based tasks than typically ageing and young controls, which could have implications for the use of maps as navigation aids for people with cognitive impairments (i.e. MCI and/or dementia).

For example, if maps are to be implemented in an environment, they should be correctly aligned to the navigators’ position and orientation; as we found in Chapter 4 that this had a significant effect on performance. Additionally, the free navigation routes highlight that nearly all participants were able to reach the correct quadrant of the environment, which could suggest that having additional maps more frequently visible in the environment could support navigators in reaching their goal. The findings from Chapter 3 though, do emphasise that, compared with other measures of route memory, map-based tasks are most affected by the effects of early atypical ageing, so further exploration should be focused on the representations least affected to understand how to better support older adults displaying early signs of atypical ageing. The next three chapters focus in more detail on how disorientation is experienced in real world settings, both for typically ageing adults and older adults displaying early signs of atypical ageing. Moreover, these chapters address possible environmental changes that could compensate for declines in navigation abilities and therefore support navigation. While existing dementia friendly design guidelines highlight possible environmental improvements to better support navigation, these guidelines are not well integrated with psychological theory. A review of existing dementia friendly design guidelines and how they relate to theories of navigation will therefore be discussed in Chapter 5. To gain a richer understanding of the mechanisms involved in supporting successful real world navigation, Chapters 6 and 7 adopted qualitative approaches to explore the lived experiential accounts of orientation and navigation (as well as design preferences) of typically and early atypically ageing adults within familiar and unfamiliar environments.

CHAPTER 5: Decreasing spatial disorientation in care-home settings: How psychology can guide the development of dementia friendly design guidelines

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CHAPTER 5: Decreasing spatial disorientation in care-home settings: How psychology can guide the development of dementia friendly design guidelines

5.1 Overview

Atypical ageing, especially Alzheimer's disease (AD), results in marked declines in navigation skills that are particularly pronounced in unfamiliar environments. However, many people with AD eventually face the challenge of having to learn their way around unfamiliar environments when moving into assisted living or care-homes. People with AD would have an easier transition moving to new residences if these larger, and often more institutional, environments were designed to compensate for decreasing orientation skills. However, few existing dementia friendly design guidelines specifically address orientation and wayfinding. Those that do are often based on custom, practice, or intuition and not well integrated with psychological and neuroscientific knowledge or navigation research, therefore often remaining unspecific. This chapter discusses current dementia friendly design guidelines, reports findings from psychological and neuropsychological experiments on navigation, and evaluates their potential for informing design guidelines that decrease spatial disorientation for people with dementia.

5.2 Introduction

There are currently 820,000 individuals with dementia in the UK and with increased life expectancy, this figure is expected to rise to more than one million by 2025 (alzheimers.org.uk). 60-80% of all dementia cases are of the Alzheimer's disease (AD) type (Alzheimer's Association, 2014). Declines in navigation and orientation skills are among the first symptoms of AD, and appear to be quite stereotypical in people with AD (Pai & Jacobs, 2004). Whilst people who experience the milder symptoms of AD can often remember familiar environments, learning new environments becomes especially difficult (Lithfous, Dufour, & Despres, 2013). It is therefore unfortunate that 80% of people living with dementia eventually move from their well-known environment into assisted living or care-home environments (Alzheimer's Society, 2013). Environments need to be designed such that they support spatial orientation, to enable care-home layouts to be learnt with ease. Improvements in design layout could compensate for impaired abilities and reduce disorientation for those with dementia.

This would also improve quality of life and wellbeing, allow for the highest possible degree of independence to be maintained, reduce the work load of the carers and ease the transition of moving into care-homes (Marquardt & Schmieg, 2009).

Despite multiple dementia friendly design guidelines being readily available (Yates-Bolton, Yates, Williamson, Newton, & Codinhoto, 2012), only a minority discuss the importance of alleviating disorientation and design-led improvements; these often come from professional practice, and are rarely backed by empirical or experimental evidence.

We will argue that design guidelines could be improved if informed by the in-depth understanding of the (neuro-) psychology of navigation and the effects that AD has on cognition; we will discuss how future research can contribute to this process. Improvements to care-home design could compensate for impaired navigation abilities and support residual orientation skills which would alleviate the disorientation experienced by those with AD.

We will begin by reviewing current dementia friendly design guidelines that relate to navigation and orientation.

Dementia friendly design guidelines

It has been argued that designing an environment for people with dementia will result in well-designed environments for all (Marshall, 2001). Whilst it is not obligatory for care-homes to be "dementia friendly" in their design, many organisations are trying to adopt designs that increase wellbeing for the resident, reduce work load for the carer, and to meet (and often beat) the standards of competing care-homes. Some guidelines and frameworks that refer to what constitutes dementia friendly environments are readily available via the web and in print form. The majority of these focus on ways to enhance person-hood, visual appearance and ways to aid memory, as these factors have been found to increase wellbeing in the residents (Kitwood, 1995; Lynch, 1960).

Only a handful of these guidelines though, report issues surrounding spatial (dis-)orientation in detail (Dementia Services Development Centre, 2011; Lewis et al., 2010;

Mitchell, Burton, & Raman, 2004; The King's Fund, 2013a); Few take into account the specific impairments in orientation and navigation reported in (neuro-)psychological research.

Design tools that discuss ways to alleviate disorientation will be reviewed in turn. (See Table 5.1 for an overview of the tools discussed and their contributions towards orientation facilitation).

The Dementia Audit Tool (DAT)

The DAT contains a series of resources aimed at carrying out self-assessments in environments used by people with dementia. Both for refurbishments and new builds, users can identify areas for improvement which can then be formally assessed by a member of the DAT team (Dementia Services Development Centre, 2011). The professionals who devised this tool have also contributed towards similar tools addressing “Improving the design of housing for people with dementia” and “Design for people with dementia: an overview of building design regulators” (Dementia Services Development Centre, 2013a, 2013b); they also have a “Dementia Design Checklist”, together with *Health Facilities Scotland* , that comprises of both internal (e.g. bedroom, communal areas) and external (e.g. garden) environment features that they raise as being important design aspects for people with dementia (Health Facilities Scotland, 2007a). When using the Dementia Design Checklist, an accreditation scheme is offered whereby complying care-homes receive gold, silver or bronze “stars” recognising their efforts in being dementia friendly. Whilst this tool identifies many key environmental aspects (e.g. colour contrast, lighting), there is little direction on how environmental design could improve orientation and wayfinding for residents. The Dementia Design Checklist states “There should be landmarks to assist people with finding their way to areas e.g. their bedroom, such as furniture, plants, wall hangings, artwork and generally items that are attractive and interesting” (Health Facilities Scotland, 2007, p.11). Landmarks are only mentioned once and referred to in a broad sense; more specificity and research is needed to know which specific landmark qualities are most helpful in guiding navigation.

EVOLVE

The EVOLVE design toolkit, initially created to facilitate extra care housing design, is a recent and successful tool (Orrell et al., 2013) which can be used in multiple care-home settings. It was developed by analysing literature reviews, policy guidelines, reviews of recent buildings, design guidance, building surveys, quality indicators, focus groups with extra care housing residents and their relatives, and expert consultations (Lewis et al., 2010a). EVOLVE is particularly useful in wellbeing and quality of life research, highlighting correlations between design principles and quality of life for people with dementia (Orrell et al., 2013). However, orientation and wayfinding is mentioned only twice in this toolkit, and the guidelines remain rather generic. Specifically, in the overview document of the tool, Lewis et al. (2010) highlight “memorable features that help people to navigate their way around the building” (p.8). The EVOLVE circulation section stipulates the need for “distinctive internal landmarks at less than 30m along the travel routes” (Lewis et al, 2010a, p.7).

EHE Environmental Assessment Tool

The EHE Environment assessment tool (The King's Fund, 2013a) emphasises the users’ and their carers’ perspectives and how they interact with the environment. This tool has been field tested by 70 care organisations and is currently used in hospitals and care-homes.

The tool includes a section on ways to “promote orientation”, highlighting the use of signage, avoiding mirrors, and briefly mentioning the use of landmarks. For example The King's Fund (2013b) state “Are pictures/objects and colour used to help people find their way around?” (p.8) suggesting that the implementation of colours and objects that serve as landmarks can help people when navigating.

Environmental Audit Tool (EAT)

The Environmental Audit Tool (EAT) (Fleming, 2011), includes 72 items that fit within 10 main design principles, including that environments should “Be simple with good visual access" and "Provide for planned wandering." (p.109). Although this tool has been empirically shown as robust in measuring the quality of environmental design for people with dementia, it offers little guidance on ways to reduce disorientation or support successful wayfinding for people with dementia.

Moreover, in one of his design papers, Fleming, one of the authors of the EAT tool, draws attention to the limited empirical evidence supporting the use of signage and memorabilia to guide orientation (Fleming & Purandare, 2010):

> Perhaps surprisingly, the evidence for the beneficial effects of signage is not strong (Hanley, 1981; Namazi and Johnson, 1991b) and weak empirical support was found for the use of the display of personal memorabilia as aids to orientation (Namazi et al., 1991) (Fleming and Purandare, 2010, p.111).

This may be a reason why orientation has not received much attention within the EAT tool.

NHS Scotland Wayfinding document

The NHS Scotland Wayfinding document (2007) is an in-depth guidance tool containing multiple ways to promote effective wayfinding and signage within healthcare facilities. The document focuses on the benefits landmarks have in aiding wayfinding: "prominent landmarks for people to notice, remember and recognise, internally and externally" (Health Facilities Scotland, 2007b, p.15) and highlights that environments without landmarks may lead to disorientation (Health Facilities Scotland, 2007b). As well as emphasising the importance of wayfinding, it also illustrates how multi-facetted aspects the problem of wayfinding is. For example, discussions on how environmental features influence decision making, how to give effective route descriptions and ways that could hinder orientation are also included. The latter is particularly interesting as it emphasises the way people use language, an issue that has not yet been addressed empirically.

Excellence in design; optimal living space for people with Alzheimer's disease and related dementias

Devised by architectural firm Perkins Eastman, this guideline includes a wide spectrum of design principles, surrounding safety and security, entry and egress, active engagement and wayfinding, aimed to help those with a dementia, particularly those with AD (Chmielewski & Eastman, 2014). Their wayfinding chapter holds that "Spaces should be distinct, both in appearance and overall layout. Repeating or mirroring floor plans can be confusing for some people, since they may perceive households as the same." (p.16). This guideline also discusses landmarks providing more detailed information than most other guidelines:

> At each decision-making point, such as hallway junctions, there should be orienting landmarks to help with wayfinding. Since distinctive cues are more memorable than subtle changes (e.g., a change in colour finish), landmarks should be unique and varied, such as recognizable objects, artwork, or a view to a specific outdoor feature. (Chmielewski & Eastman, 2014, p.16).

These more detailed descriptions provide more specific direction of how, and where, wayfinding aids should be present.

Additional architectural research suggestions for dementia friendly design

Architectural features of complex built environments generally affect navigation and orientation. For example, navigation performance, decreases with increasing floor plan complexity (O'Neill, 1991). On the other hand navigation performance is facilitated when (1) visual access is increased, (2) there is a degree of architectural differentiation, (3) with improved floorplan configuration and (4) when signs and room numbers are used consistently within the environment. (Arthur & Passini, 1992; Emo, Hoelscher, Wiener, & Dalton, 2012; Weisman, 1981; Werner & Long, 2003). Passini and colleagues therefore, argue that the ease of wayfinding within a build environments should be a vital factor of a building's design (Arthur & Passini, 1992; Passini, 1984).

While architectural form and structure have been discussed in dementia friendly design guidelines and research reports reviewed above, this section will focus on evidence from the field of architecture in more detail.

Floor plan and structure

An environment's layout and structure is generally accepted as having an impact on orientation abilities. Many of the dementia friendly design guidelines have emphasised this as an important factor to improve wayfinding and orientation for people with dementia (Dementia Services Development Centre, 2013c; L. Mitchell, Burton, & Raman, 2007; Passini et al., 2000). However, only a limited number of studies from the realms of architecture have systematically studied how the structural features of built environments impact on orientation and navigation in people with AD.

To decrease spatial disorientation in people with dementia, circulation systems should be simple (Marquardt et al., 2011b; Marquardt & Schmieg, 2009). Elmstahl, Annerstedt, & Ahlund, (1997), for example, identified that L-shaped floor plans led to less disorientation in comparison to corridor or H shaped environments (see Figure 5.1). The easiest floor plans though are straight circulation systems, with no changes in direction (Marquardt & Schmieg, 2009)

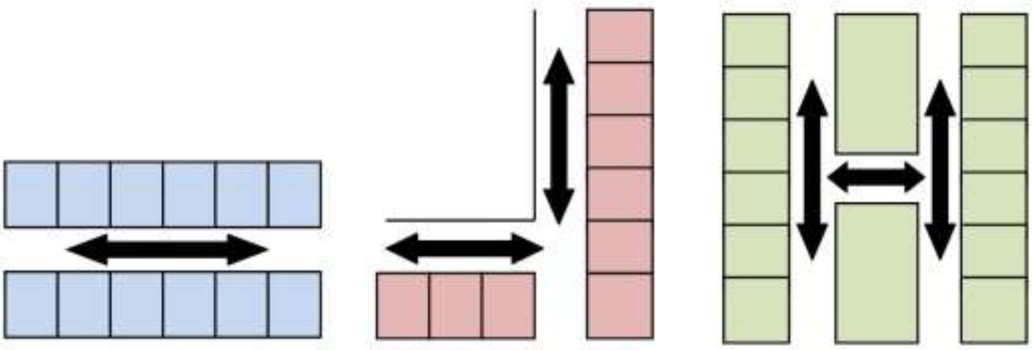

Figure 5.1: From left to right, a straight layout system, an L-shaped corridor (with a change in direction) and an H-shaped corridor.

Marquardt and colleagues found that spatial layouts that are more connected to the whole spatial system (intelligible) as opposed to environments that are broken up by rooms, stairs and circulation areas (convexity) affected people with dementias ability to complete activities of daily living (e.g. eating, sleeping). Specifically, environments with higher "convexity" and those that were more broken up, supported participants' daily activities better (Marquardt et al., 2011a). While care-home design often addresses components of the environment that relate to the accessibility both within and outside of the care-home (e.g. ramps, door width and stairs), modifications that assist cognitive function for those with memory problems are often not considered (HM Government, 2010). Marquardt and colleagues argue that inaction to modify existing environments results from scepticism about the benefits design can have on cognitive functioning (Marquardt et al., 2011b).

Table 5.1: Guidelines and papers that discuss ways to alleviate disorientation for people with dementia, and the specific environmental features that they cite.

Tools & papers	Layout/Structure	Landmarks	Colour	Other wayfinding aids stated
DAT Tool	✓	✓	✓	Memory boxes
EVOLVE Tool	✓	✓	✓	
EHE Tool	✓	✓	✓	Signage, memory boxes, avoiding mirrors
EAT Tool	✓			
NHS Scotland wayfinding document	✓	✓	✓	How routes are described
Excellence in design	✓	✓	✓	
Utton, (2009)		✓	✓	

Mitchel, Burton and Raman(2004)	✓		✓	How routes are described
Marquardt (2009)	✓			Signage
Passini et al., (2000)	✓	✓		

Interior design features: landmarks and colour

In addition to the structural form of the building, architects also discuss the use of colour and landmarks. Utton (2009), for example, describes two dementia friendly care-home projects where “a combination of feature wall colour contrasts, large and distinct paintings, and wall-mounted light fittings aid orientation and help with wayfinding” (p.383). As such design features are easy to implement in already existing built environments, it is vital to provide empirical evidence to demonstrate that they can guide orientation and navigation in people with dementia. Moreover, it is important to develop a detailed understanding of how these design features exactly impact on orientation and navigation skills.

Other reports have highlighted the importance of giving appropriate route directions. Mitchell et al. (2004) for example, state that “Older people with dementia continue to plan and visualise proposed routes and tend to use landmarks and other visual cues rather than maps and written directions as wayfinding techniques” (p.2). This again emphases the importance landmarks have in promoting successful wayfinding and navigation in people with dementia. However, simply adding additional landmark or objects in the environment could result in “information clutter” which could have detrimental effects on orientation (Passini et al., 2000). More empirical research is needed to understand how much orientation and navigation cues are optimal in compensating for declining orientation and navigation skills in people with dementia.

5.3 Interim conclusion

Design guidelines and architectural studies highlight the importance of similar environmental features when it comes to decreasing spatial disorientation in people with dementia, specifically the structural layout and the availability of landmarks. Only few sources give specific direction regarding the type of landmarks that should be used, as well as where they should be positioned (e.g. decision points). Another aspect frequently mentioned is to design areas such that they are memorable, salient and easily distinguishable from other areas. However, empirical evidence demonstrating the effectiveness of these manipulations are and how exactly they are used for navigation in people with dementia is limited. To develop an in-depth understanding of how good environmental design can compensate for dementia-related orientation deficits and to improve dementia friendly design guidelines, it is therefore crucial to systematically manipulate environmental factors using experimental design approaches. This is where psychological and neuroscientific research can come in.

5.4 The psychology of navigation

Psychology and neuroscience have studied navigation and orientation for decades (Maguire et al., 2003; Moser et al., 2008; O'Keefe et al., 1998; Taube, Muller, & Ranck, 1990; Tolman, 1948). Psychology has investigated the mental representations as well as the cognitive processes involved in successful navigation and different navigation tasks. Cognitive neuroscience, in turn, has described different types of neurons coding spatial information (place cells, grid cells, and head direction cells) and the contribution of different brain areas to navigation. Together, these disciplines have developed a comprehensive theory and an in-depth understanding of the principles of navigation.

It is beyond the scope of this paper to provide an in-depth overview of theories of navigation in psychology and neuroscience, thus we will focus on landmarks and their role in navigation. We will then report some of the findings into the effects of AD on navigation behaviour, before discussing ways in which (neuro-) psychological research can inform dementia friendly design guidelines in the future.

Landmarks: definition, properties and functions

A substantial part of the navigation research focuses on the role of landmarks in supporting and guiding navigation and while different definitions exist, a landmark is typically defined as an object or (sensory) feature in the environment that is used to identify a specific location to guide navigation.

The majority of the design guidelines discussed above highlight that landmark objects needs to be easily seen, recognised and need to enable someone to establish their location. These properties are also reflected in landmark models in psychology. Stankiewicz and Kalia (2007) state that landmarks need to be (1.) persistent, i.e. they need to be present when the navigator returns, (2.) they need to be salient, i.e. navigators must be able to recognise the landmark when returning to the same place, and (3.) they need to be informative, i.e. they need to carry information about the position of the navigator and the action to be taken to move towards a destination (Stankiewicz & Kalia, 2007).

It is important to note that landmarks serve different functions in navigation depending on the exact nature of the landmarks, the actual navigation task, and the context (Chan et al., 2012). An in-depth understanding of these landmark functions is paramount in developing, improved and more specific dementia friendly design guidelines.

Landmarks as beacons

The most basic way in which landmarks can guide navigation is if they function as beacons. Landmark-beacons are situated close to the actual target location. If this spatial relationship is memorised, recognition of the beacon can lead navigators close to the goal. Beacons have been shown to be particularly efficient navigation cues when learning complex and long routes (Waller & Lippa, 2007). Moreover, older participants show a preference for navigation strategies that utilize beacons over other route learning strategies (Wiener et al., 2013) which may suggest that beacon-based strategies are more resilient to age-related changes in navigation abilities than other navigation strategies.

Landmarks as orientation cues

When asked to name landmarks, most people think of the Eiffel Tower, Big Ben, the Sydney Opera or the Golden Gate Bridge. These landmarks are visible from a large distance and are therefore, often referred to as global landmarks. Global and distant landmarks provide “compass like” orientation information, as local movements do not change the spatial relationship between the navigator and distant global landmarks much (Steck & Mallot, 2000). In other words, even if navigators get lost in the local environment, global landmarks provide them with compass-like directional information for the whole environment, which can be used to facilitate reorientation and navigation.

Landmarks as associative cues

One of the most prominent everyday navigation tasks is that of navigating familiar routes, for example when commuting from home to work and back. When navigating such – often overlearned – routes, landmarks are thought to serve as associative cues: the recognition of a landmark triggers the movement response required to continue along the route, for example “Turn right at the church” (Trullier, Wiener, Berthoz, & Meyer, 1997; Waller & Lippa, 2007).

However, when learning a novel route, not all objects in the environment are equally likely to be remembered. Specifically, in order to be remembered, landmark objects need to be positioned at navigationally relevant locations, i.e. decision points (Aginsky, Harris, Rensink, & Beusmans, 1997; Janzen & van Turennout, 2004; Schinazi & Epstein, 2010). Moreover, the positioning of the landmark can affect whether or not it is used as a beacon, or an associative cue (Waller & Lippa, 2007). Not all objects make equally good landmarks: uniqueness, saliency and how easily nameable a landmark is, affect how likely it is to be selected as a landmark (Klippel & Winter, 2005).

Place recognition

One of the most fundamental functions of landmarks is to help us recognise places we have visited before. Place recognition is a crucial component of successful navigation as it allow us to orientate and localise ourselves in the environment. The actual landmark information used to recognise is often referred to as local position information and can range from views that are specific to a particular location (Gillner, Weis, & Mallot, 2008) single unique objects or even configurations of landmarks (Mallot & Gillner, 2000; Steck & Mallot, 2000; Waller, Friedman, Hodgson, & Greenauer, 2009).

Landmarks & cognitive mapping

Integrated representations of space, often referred to as cognitive maps, provide information about the spatial relationships between various places in the environment. Cognitive map-like knowledge of environments allows us to relate our current location (place recognition) to other locations in the environment which are beyond the current sensory horizon. While route knowledge guides navigation only between the start and the destination of the route, cognitive maps allow for flexible and goal directed navigation, the planning of novel routes and shortcutting behaviour (Wiener, Ehbauer, & Mallot, 2009). Landmarks are often described as an organising principle of cognitive maps (Presson & Montello, 1988), as they serve as the fundamental building blocks and reference points.

How AD affects navigation

The effects of AD on navigation have been described in a now growing body of literature: typically, AD, as well as amnesic mild cognitive impairment (MCI), is associated with severe declines in navigation skills, particularly with the ability to learn novel environments or new routes through unfamiliar environments (deIpolyi et al., 2007; Pengas et al., 2010). These navigation impairments are explained by the substantial overlap of the network of brain areas involved in successful navigation and the network of brain areas that are affected already during the earliest stages of AD (for a recent overview, see Lithfous et al., 2013). Tasks that assess spatial memory ability (e.g. route learning tasks, landmark location tasks) are particularly sensitive to the effects of early AD and prodromal amnesic MCI. In fact, it has been argued that these tasks can be used to discriminate AD from other forms of dementia such as semantic dementia, suggesting that spatial memory tests could be used as clinical tools for the early and differential diagnosis of dementias (Bird et al., 2010; Pengas et al., 2010).

The most prominent navigation paradigm used in studies investigating the effects of typical and atypical ageing is that of learning a novel route through an unfamiliar environment. While a substantial body of research has studied the effects of typical ageing on route learning abilities (Head & Isom, 2010; Wiener et al., 2013; Wiener, Kmecova, & de Condappa, 2012) fewer studies have tested people with AD. The results of those that have, demonstrate marked impairments in route learning (Bellassen, Iglo, Cruz de Souza, Dubois, & Rondi-Reig, 2012; Cushman et al., 2008; Pengas et al., 2010). However, in the context of this paper it is important to note that not all aspects of route learning are affected equally by AD. For example, Cushman and colleagues guided participants (young group, older typical ageing group, older with MCI group and older with AD group) along a relatively complex route in a hospital setting and asked them afterwards to solve a series of different tasks (Cushman et al., 2008). These tasks included, among others, retracing the route (route learning), recognising whether or not particular photos were taken on the encountered route (photo recognition) and locating photos or short videos taken from along the route (photo or video location). By comparing performance between the four participant groups, Cushman and colleagues isolated the effects of typical and atypical ageing. While the deleterious effects of ageing and AD were reflected in performance declines from the young to the older group to the MCI group and the AD group, this decline was not the same for all subtasks. The most severe AD-related declines were found in tasks that required integrated representations of space or cognitive maps (video and photo location) while other tasks such as the photo recognition task were less affected. While such findings suggest AD related difficulties in learning spatial properties of novel routes, other aspects of route knowledge seem fairly resilient to AD related declines. Understanding how these aspects of route knowledge can be used to help guide orientation, is of paramount importance for the development of improved dementia-design guidelines.

5.5 Ways forward

While (neuro-) psychological research has led to the development of comprehensive theories of landmarks and navigation, our understanding of how AD affects navigation is still limited. Most investigations into AD-related orientation and navigation impairments do not systematically address different navigation tasks or the different functions landmarks play in successful navigation. Many of the more recent studies rely on computer graphics or virtual environments technology (Cushman et al., 2008; Kessels et al., 2011; Pengas et al., 2010). While such technologies allow for full control of the stimuli or environmental cues in the scene, and allow researchers to isolate the impact of single cues, the environments often lack the detail and richness of real environments. Finally, most experiments in cognitive (neuro-) psychology are single session experiments, and results frequently suggest that people with AD cannot successfully learn novel environments in such a short time-span. While such approaches are appropriate to study the orientation and navigation processes and components that are affected by AD, they may underestimate the orientation and navigation abilities in real world settings. Moreover, these approaches may not be the most suitable approaches to investigate how we can improve dementia friendly design guidelines in order to minimise spatial disorientation in residential sheltered living or care-home settings.

We believe that combining methods from psychology and social sciences provides an advantageous way forward to improve dementia friendly design guidelines. For example, rather than testing participants' abilities to learn unfamiliar environments – a task people with dementia do not face on a daily basis – it may be fruitful to assess what environmental cues or features they use for navigation once they have learned an environment. This may require multi-session experiments, in which participants learn unfamiliar environments over several experimental sessions. An alternative approach would be to assess people's knowledge of their own environment, for example, several months after moving into a retirement, sheltered living or care-home environment. In addition, qualitative interviews with the residents may reveal (1) orientation strategies that people with AD use to compensate for decreasing navigation abilities, and (2) which cues they select for navigation. Finally, knowledge from such investigations needs to be translated into design suggestion, ideally in close collaboration with professionals such as carers, designers and architects, to improve dementia friendly design guidelines.

5.6 Conclusion

In this paper we have highlighted the need for greater specificity in dementia friendly design guidelines that address orientation and navigation. Although many guidelines discuss the importance of landmarks, few give specific examples of how they should be implemented in actual environments. We argued that theories of orientation and navigation, as well as research approaches used in cognitive psychology, can be used to inform the improvement of dementia friendly design guidelines in order to minimise spatial disorientation.

More research should focus on the impact different landmark features have on orientation for people with AD and mild memory difficulties; this will allow more precise and effective environmental manipulations supporting orientation to be implemented. In addition, designers should explore how they can inject the users' voice (such as older adults with and without cognitive impairments) into the design process of care environments to ensure they capture their preferences and cater to their needs.

CHAPTER 6: “All the corridors are the same”: A qualitative study of the orientation experiences and design preferences of UK older adults living in a communal retirement development.

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CHAPTER 6: “All the corridors are the same”: A qualitative study of the orientation experiences and design preferences of UK older adults living in a communal retirement development.

6.1 Overview

Environments need to be designed such that they support successful orientation for older adults and those with dementia who often experience marked difficulties in their orientation abilities. To better understand how environments can compensate for decreasing orientation skills, voice should be given directly to those experiencing dementia to describe how they find their way and to understand their design preferences. The review of existing dementia friendly design guidelines that address disorientation in the built environment (see Chapter 5) demonstrated that there has been limited involvement from the person with dementia (or memory difficulties), during the generation of design guidelines and the design process. There are still gaps in these design guidelines related to (1) the specificity of the design suggestions made in relation to landmark properties and more so (2) the consultation with residents and users of such environments to provide experiential accounts and preferences of the environment they use.

This next study (Chapter 6) explored the navigational experiences and design preferences of older adults with memory difficulties living in a retirement development. In-depth semi-structured interviews with thirteen older adults experiencing memory difficulties were conducted. All participants were residents of one retirement development in the UK. Questions began broadly, for example, to describe their experiences of navigating in their living environment, before discussing any specific navigation difficulties in detail. Thematic Analysis identified three main themes: highlighting environmental design that causes disorientation, strategies to overcome disorientation, and residents’ suggestions to improve the design. The design suggestions were particularly informative, heavily focusing on the importance of having memorable and meaningful spaces which were favoured more than signage as an orientation aid. The findings demonstrate the need to consider environmental design to support orientation for those with memory difficulties. Of particular importance is the use of meaningful and relevant landmarks as orientation aids which can additionally stimulate conversation and increase wellbeing. Given the range of suggestions in dementia friendly design guidelines aimed to support orientation, it is crucial to speak directly to those living in different environments to learn how they find their way around and what design works in their environment.

6.2 Introduction

Older adults who are experiencing early symptoms of cognitive impairment and dementia often encounter difficulties executing day-to-day tasks. Among the first tasks affected are those involving spatial learning and spatial memories. Typical examples are remembering the route to where a car is parked, or learning and navigating through a new living environment one has just moved into (Caspi, 2014; Marquez et al., 2015). Cognitive psychology has characterised how typical ageing affects navigation abilities; older adults typically take longer to learn unfamiliar environments (Head & Isom, 2010) and perform better when using landmark-based navigation strategies compared to more map-based strategies (Sjolinder et al., 2005; Wilkniss et al., 1997). These effects are even more pronounced if individuals develop mild cognitive impairment (MCI) or Alzheimer's disease (AD) (Bellassen et al., 2012; Bird et al., 2010; Monacelli et al., 2003; Pengas et al., 2010), and are often explained via the structural and functional changes that occur in the hippocampus, a brain region that is crucial for spatial learning and spatial memory (O'Keefe & Nadel, 1978; Raz et al., 2010).

To compensate for age-related decreases in spatial abilities, navigational aids such as landmarks and signage, as well as architectural properties of the built environment and appropriate floor-plans, could support successful orientation and therefore increase independence (Marquardt & Schmieg, 2009; Marquez et al., 2015; Utton, 2009). In the case of landmarks, small manipulations to landmark properties such as their saliency (i.e., how much it stands out; Klippel and Winter 2005) or their positioning in the environment (Waller & Lippa, 2007; Wiener et al., 2013), can affect the ease routes are learned, as well as the specific navigation strategy used. Despite our knowledge of how navigational aids can generally support navigation, little research has explored how this knowledge can be applied in real world settings to support people with dementia and to compensate for declining orientation abilities. Applying this knowledge could improve independence, wellbeing and quality of life for older people, people with mild cognitive impairments and people with dementia (Day, Carreon, & Stump, 2000; Liu et al., 1991; Lynch, 1960; Orrell et al., 2013).

Very few existing age friendly design guidelines (World Health Organisation, 2007) address ways to support orientation for our ageing population, and those that do focus predominantly on signage visibility. Some dementia friendly design guidelines suggest additional ways to improve orientation, such as including landmarks in the environment or using/avoiding particular floor plans (see Chapter 5; O’Malley, Innes and Wiener 2015 for a recent review). However, these dementia friendly design guidelines, if adhered to, are often only targeted towards, and implemented in, living environments exclusively used by people with dementia such as care-homes and hospital wards (Lewis et al., 2010; The King's Fund, 2013b) and are therefore not benefitting older people with memory difficulties and dementia living in other settings. In the UK, two-thirds of people with dementia live in the community (Alzheimer’s Society 2016), either in their family homes or in alternative housing options (that are typically chosen prior to developing dementia). It is therefore surprising that little work has considered how these other housing options could be designed to be more supportive for those with memory difficulties. This said, the importance of the environment in promoting wellbeing for those living with dementia has now been acknowledged via UK policy directives (Department of Health, 2015), creating a new context for the development of enabling environments for those living with dementia in different settings.

Retirement housing is a popular housing option amongst older adults, due to the increased home security, people’s wish to “down-size” and because of the opportunities to meet and socialise with others of a similar age. Importantly, a substantial proportion of those living in such developments are likely to develop cognitive impairments and dementia whilst living there. Therefore, these and other environments used by people with memory difficulties and dementia, need to be designed in a supportive way which would allow residents to live independently for longer and experience a good quality of life (Kitwood, 1995; Marquardt & Schmieg, 2009).

CHAPTER 6: "All the corridors are the same": A qualitative study of the orientation experiences and design preferences of UK older adults living in a communal retirement development.

Many of the dementia friendly design guidelines that aim to reduce spatial disorientation have not been validated systematically (Chapter 5; O'Malley et al., 2017a) and it is therefore unknown which orientation aids are most supportive. Additionally, design suggestions are often based on expert opinion and professional practice, rather than the users' experiences and preferences. To gain insight into the perspective and experience of the person with dementia, family members and/or paid carers have been questioned (Passini et al., 2000). Although carers' opinions are informative, people with dementia belong to the most excluded groups in society (Dewing 2002) and to fully appreciate their needs, it is necessary to give them a voice (Jonas-Simpson, 2003).

This need to give people with dementia a voice is well demonstrated by a recent study comparing the colour preferences of care-workers and residents within a care-home (Godwin 2014). Not only were people with dementia able to express their opinions on potential design, their preferences also differed systematically from those of the care-workers. Specifically, the most popular colour among residents was blue, which was the least favourite colour among care-staff. Care-staff, on the other hand, preferred mauve which was the least favourite colour among the residents. Differences in preferences have also been observed in other studies, for example addressing meaningful activities for people with dementia; whilst the person with dementia focused on activities that addressed their social and psychological needs, care-staff and family carers focused on those that maintained physical abilities (Harmer & Orrell, 2008). Overall, these findings demonstrate that people with dementia can express their views, and that their preferences are not necessarily consistent with those of others using the same environment.

Aims

In this study we conducted interviews with residents of a retirement development who reported memory difficulties to (1) explore the wayfinding experiences of older adults living in a communal retirement development; and (2) to explore their design preferences. For reasons outlined above, it was important to speak directly to users of the environment. This gives them a voice to convey how they use the shared living environment to orientate and provides them with an opportunity to share their design preferences. Results from this study can be used to support, or contrast, existing dementia-friendly design guidelines.

6.3 Method

Setting

The research was conducted in a retirement development (independent living) in the south of England, UK. This particular development was chosen due to its similarity in interior design to other retirement developments, as well as its multiple floor levels (i.e. 3 floors) which allow for a degree of route learning/wayfinding to take place (see Figure 5.1). The development consisted of forty-two privately owned self-contained apartments, with a shared communal lounge, kitchen, garden, rubbish and laundry rooms. Forty-two residents lived in the development at the time of the study, seven of whom were males. Residents were made aware that their responses would not be traced back to them, and that the researchers were external and not associated with the property developer.

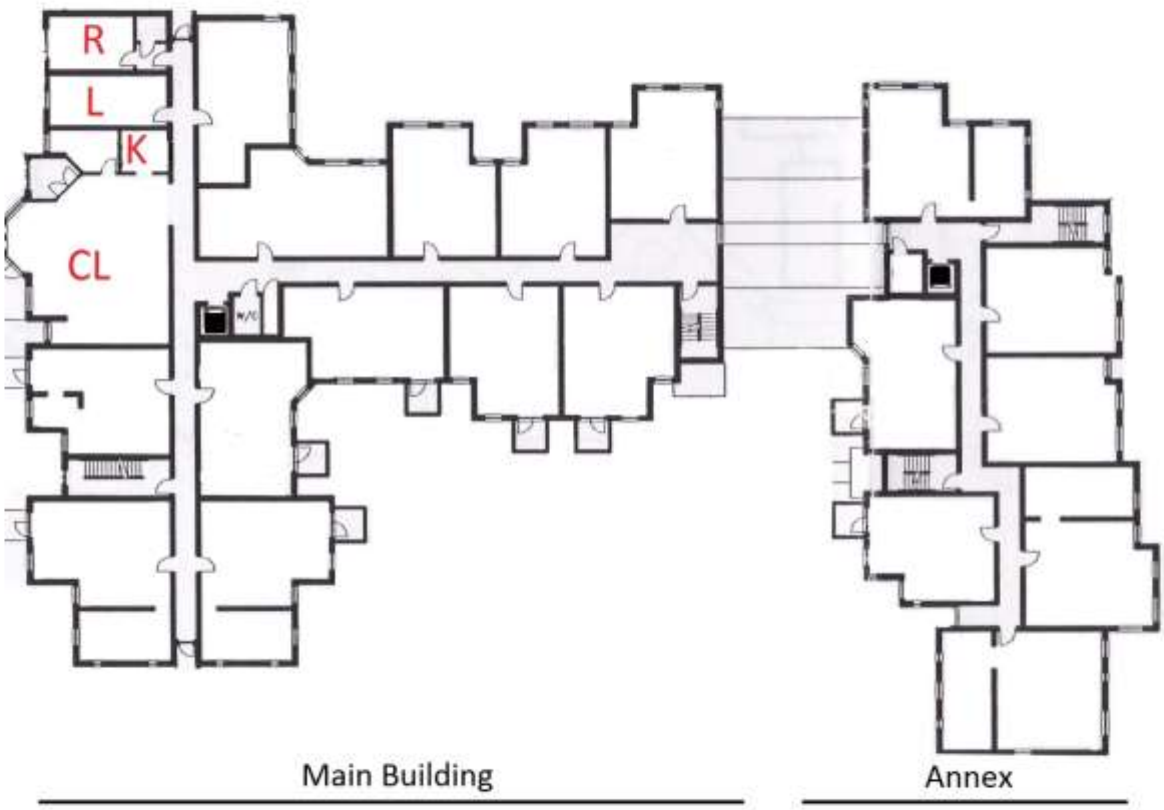

Figure 6.1: Floorplan of the ground level of the development. The communal lounge (CL), communal kitchen (K), laundry services (L) and refuse room (R) were all situated by the entrance to the building on the ground level. The main entrance was from the communal lounge. The two black squares indicate where the lifts were situated. The Main building and Annex were connected by a circulation area (hall space).

Figure 6.2: Image of communal corridors.

Ethics

Ethical approval for the interviews was obtained from the Bournemouth University ethics panel (2014). Following the Mental Capacity Act (2005) section 2 and 3, capacity to consent was assumed unless participants were unable: (1) To understand the information relevant to the decision to participate, (2) To retain the information, (3) To use or weigh that information as part of the process of making that decision and (4) To communicate that decision. All participants were able to give informed consent. In addition, we used on-going process consent procedures (Dewing, 2008), where residents non-verbal behaviour and body language were observed; if residents showed changes in their eye contact, vocal intonation, body language or fatigue, residents would have been asked whether or not they would like to continue (Moore & Hollett, 2003). There were no occasions during the study when participants expressed behaviours that indicated they were uncomfortable. All data was anonymised and pseudonyms were given to all participants.

Study sample

Thirteen participants (eleven females and two males) from the retirement development participated in the study. The ratio of female to male participants in this study is representative of the general demographic of those living alone in retirement and residential housing (Office of National Statistics, 2014). As the participants all referred to themselves as “residents” of the development, the researchers continued using this term throughout the interview. All residents were aged 65 years or older, with a mean age of 81.84 years. Two of the thirteen residents had received a diagnosis of Alzheimer’s disease and all participants reported memory difficulties, a strong predictor of cognitive impairment (Waldorff, Siersma, Vogel, & Waldemar, 2012). This was confirmed using the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005), a brief neuropsychological tool; the average MoCA score, 22.8/30, is below the threshold of what is suggested as indicative of “healthy ageing” (26/30; Nasreddine et al., 2005). The average duration of residents’ stay at the development was 2.88 years, but four residents had lived in the development for over 7 years. Table 6.1 summarises the participants’ demographic data.

Table 6.1: Participant demographic data.

Participants (pseudonyms)	Age	MoCA score	Gender	Formal Diagnosis of Dementia	Duration of Residence (years)
Anne	76	22	Female	No	4 months
Doris	83	20	Female	No	2 years
Joyce	84	26	Female	No	7 years
Brenda	88	28	Female	No	7.5 years
Lillian	92	23	Female	No	7 years
Betty	83	17	Female	No	1.5 years
Myra	75	16	Female	Yes	3 months
Gloria	86	23	Female	Yes	7 years

Helen	82	26	Female	No	1.5 years
Ethel	82	27	Female	No	1.5 years
Harry	65	28	Male	No	1 year
Jean	82	24	Female	No	4 months
Colin	86	22	Male	No	4 months

Research design

Following ethical approval, one of the researchers (Author 1) attended the weekly coffee morning in the retirement development and explained the purpose of the study (see Appendix 1 for the participant information sheet). Thirteen residents volunteered to participate and spoke with the researcher prior to the interview on at least two occasions. The interviews then took place in the participant’s own apartment. The researcher (Author 1) and resident spent roughly 15 minutes talking about the local surroundings to establish rapport before the interview commenced. A semi-structured interview guide (see Appendix 2) was followed, with new questions asked to follow the direction of the conversation. At the start, all participants were encouraged to walk freely during the interview if they wanted to discuss a particular area. Two of the participants (Myra and Brenda) showed the researcher certain aspects of the corridors (see Figure 6.2) and the communal lounge whilst discussing them. The interviews lasted between 28 and 80 minutes and data was collected until the themes reached data saturation – in our case after thirteen interviews. This is consistent with research by Guest, Bunce and Johnson (2006) who observed that data saturation was reached within twelve interviews, with the basic elements (meta/sub-themes) present after six interviews.

Key questions for interviews

The aim of the interviews was to engage directly with residents’ wayfinding experience as well as their design preferences for the communal shared living areas of the retirement development (as opposed to individual apartments). Eight questions (e.g.

“How would you describe your abilities in finding your way around your home and the communal areas in the retirement development?” and “Are there any areas of the environment that you find particularly helpful or more memorable to help you get your way around”) surrounding their wayfinding experiences and design preferences were prepared (see interview guide in Appendix 1). These questions were informed by existing literature surrounding design and wayfinding though the specific questions depended upon what residents reported.

Data analysis

Following Braun and Clarke (2006), an inductive Thematic Analysis was used as the specific method, as opposed to a process for an analytical tradition such as grounded theory. First discrete ‘units’ (Lincoln & Guba, 1985) or ‘incidents’(Glaser & Stauss, 1967) were identified and then coded into categories. The definitions and content of the categories changed as the units were categorised. It is also important to emphasise that the researcher played an active role during the analysis as themes do not simply emerge from the data (Braun & Clarke, 2006). The themes are primarily at a semantic (explicit) level, though, where appropriate, latent coding was used (particularly when interpreting and understanding the reasons for disorientation). The transcripts were initially coded by author 1; together with author 2, these codes were checked, modified and verified. See Appendix 2 for a breakdown for the stages of Thematic Analysis used.

6.4 Findings

Three main themes were identified. For an overview, please see the Theme Table in Appendix 3. The first theme expresses disorientation as a result of interior design features and the architectural structure of the development. The second theme highlights how residents overcame and avoided disorientation using specific orientation strategies and environmental cues. The third theme focuses on residents’ design suggestions: including making spaces meaningful and memorable. The themes have been developed with illustrative data (verbatim quotes) examples. Whilst qualitative frameworks and inductive Thematic Analysis practice does not require one to quantify the number of respondents that articulated each theme (Braun & Clarke, 2006), each theme was expressed by at least two-thirds of the residents. To gain more detail and precision, we provided the number of participants who discussed a particular issue for some sub-themes.

Theme one: Disorientation as a result of interior design features and the architectural structure of the development

All residents had experienced disorientation within the development on at least one occasion, particularly during the initial period (i.e. first weeks and months) after moving in.

Initial feelings of awkwardness, due to the design of the development were expressed:

Betty: "When I first came I found it very awkward ... Because they (the corridors) all look the same."

Lillian: "At the beginning of course it's a bit of a maze but eventually you get learn when where to go and who's living where and all that."

Although most residents reported that they became more comfortable with the surroundings with increased familiarity, they were able to identify specific reasons as to why they experienced disorientation and the areas they found problematic. These reasons were sub-themed as either design dependent or location dependent. Design dependent reasons relate to the design of the building or design factors within the development, location dependent reasons relate to the location of where rooms, items or places are situated.

Design dependent reasons for disorientation: Repetitive layout causing confusion

The most frequently reported reason for disorientation was the repetitive design throughout the development, particularly along the corridors (see Figure 6.2):

Colin: "You can get completely disorientated and the reason is because all the corridors are the same. You don't know which one you're on, or what level you're on really until you look at the little messages on the side … It's important to have some sort of navigation aid I think in a big place like this."

Due to the repetitiveness in design, residents had to rely on the signage - if areas were more distinctive, residents would potentially not need to rely so heavily on signage as a cue when re-orientating.

Design dependent reasons for disorientation: Making separate floors and areas identifiable

Spread over three floors, connected by five staircases and two lifts, residents highlighted difficulties moving and differentiating between the floors. The two lifts were identical in design and easily caused residents to become confused with which lift to use.

Helen: "Well when I first came, I did get lost. I took the wrong lift and went up to the wrong floor and well in the end I walked down the stairs. I gave up with the lift."

Colin: "…what I found was that no sort of indication as to which lift one should use to get up to the first floor, so I decided it would be better to go up the stairs, and that was a big mistake as that was an easier way to get lost, starting to go upstairs."

Many participants reported that they moved to the development to avoid the use of stairs - ensuring lifts are user-friendly, well signposted and distinctive is vital. Even when having to use the stairs though, the poor signage and repetitive design in the stairwells was reported as problematic and disorientating:

Harry: "…in the stairwells, on the backs of the doors of each floor, there's no sign saying which floor it is."

> Ethel: “it says that ‘fire exit’. It doesn’t say stairs ground floor.”

To limit confusion, appropriate use of signage could be introduced. Additionally, incorporating the residents’ views for where signage is best placed would capture the users’ needs and requests.

Location dependent reasons for disorientation

Where exactly a resident lived in the building, and the specific routes they took, had a strong influence on their experiences of disorientation. The location dependent reasons were either due to residents’ apartment locations or were influenced by the dissociation between the two areas of the development, the main building and the annex:

Ethel: “I’ll be quite honest, there is a jumble down there when you go to that section (the annex) … that’s difficult down there. And I have got lost once, I think because I wasn’t concentrating.”

This ambiguous circulation area, connecting the main building to the annex, caused particular confusion for most of the residents. Here, residents talked about the use of environmental cues (for example, the table with the flowers) and signage to support them on their route.

The accessibility of the communal spaces was influenced by the positioning of the separate apartments within the development. This played a role in how frequently the communal spaces were used and affected residents’ initial choice of apartment:

Helen: “I’m right at the end of the building … it’s a long walk to go to the laundry (laughs). I usually do Sunday mornings when it’s quiet. But, by the time you’ve put your laundry in and then waited for that to do, and go back again, and put it in the tumble drier, it’s three journeys to and fro…”

Colin: "I was completely unaware of how long the corridors were to get to some of the properties, and that was one of the reasons, because of the long corridors, that we decided that we didn't want to go for that flat - Too far from the services, too far from the entrance exit of the building."

The distance between apartments and communal areas should be minimized as it can be seen that this poses problems for residents located further away from communal areas. Additional support should be provided for residents living further away to ensure activities of daily life are met with ease.

Theme two: Overcoming and avoiding disorientation using orientation strategies and environmental cues

Participants reported multiple strategies to learn the environment and to overcome feelings of disorientation. While some actively tried to familiarise themselves with the environment, others had specific orientation strategies, relying on environmental cues and aspects of design.

Spaces to trigger memories

Spaces filled with distinct features (e.g. photographs, louvre windows and flowers on a table) were frequently mentioned as being particularly memorable.

Doris: "… when you get, halfway up, there is a rug that's about as big as my entry there and somebody puts flowers there and that's quite nice... I think it's quite nice, it cheers it up. And you think "oh that looks lovely" and there's "oh what are they today" and they're mostly fresh flowers ... It's quite nice."

Additionally, residents whose apartments were further away from communal areas had specific route planning strategies to get to the communal facilities (e.g. laundry, refuse):

Helen: “Oh yes, well I go out my door here, down the corridor, and then, I do it in three sections really. First to the bend, then the next bit, past the table with the flowers, and then the third bit takes me to the lift. Up in the lift and then it’s easy from there because you’re right outside the lounge and um, you can see the notices.”

These examples highlight that environmental cues along the route (for example the table with the flowers, the lift and signage) were seen as useful in creating a strategy whereby separate distinctive sections of the route could be remembered.

Signage and door numbers - following numbers consecutively

Signage and the apartment door numbers guided some residents to their goal location:

Colin: “The signage is quite good actually as long as you, you stick to it.”

Individual apartment door numbers, on the occasion where they were inconsistent (not consecutive) could contribute to disorientation:

Jean: “…It might just be …a bit confusing that you have the numbers mixed up a little bit, it’s only some of the numbers, you expect to see all the 40s together and you don’t!”

Remembering the door numbers proved problematic for some residents;

Brenda: “I’m not very good on names of things. I know where things are and I could say to you “oh yes I know where so and so lives” but I probably wouldn’t know the number of the flat, I would just know when I got there as it were.”

These quotes highlight individual differences in strategy preferences – while some residents relied on signage, others found signage difficult to use. This suggests that one design solution does not fit all.

Avoiding the corridors - shortcutting

Residents living in the annex part of the development reported avoiding the corridors, when possible:

Helen: “here is a shorter way out … I use, what they call, the shoppers entrance. I come through the garden and that cuts off a lot of the corridor.”

Harry: “the gate which is a boon for this development … I use that probably more, just as much if not more than I use the main entrance … You don’t have to walk along, you don’t have to go up in the lift, you don’t have to use your fob (key tag), no you’re out! So that’s a boon that gate for people like me on the lower ground”.

If buildings are complex and corridor systems become confusing as a result for those living there, it may be sensible to provide clear alternative routes. This “shoppers entrance” example not only avoids corridors, the entrance itself functions as a distinguishable landmark point (i.e. a well-signed door to outside).

Theme three: Residents’ design suggestions: making spaces meaningful and memorable.

Three residents were extremely happy with the design of the development and had no suggestions on how it could be altered or improved, for example:

Lillian: “Leave it as it is. Yeah. Oh I’m more than happy with it – it’s the nicest one I’ve seen”

The majority of residents were able to raise design issues and give their opinions on aspects they thought should be improved. These included the design of the corridors such as the colours and pictures along the walls, and reducing the distances between locations.

The overall design and the distances between locations were critiqued:

Gloria: “I really think that was badly designed because they do have a long way to come, you know two lifts to have to use. Or two flights of stairs or whatever but not for me because as I say I’m well placed.”

The importance of short distances between places was further highlighted:

Colin*:* “the short distance between here and the lounge is very important and the front door, very important to me. Not having to trek a great deal of distance to get there.”

Ensuring that distances between the individual apartments and the communal areas are short and minimising the need to move between levels is crucial.

Moving away from the “hotel-look” for long term living environments

Three residents explicitly mentioned how the development resembled a “hotel” in its design, one thought this was ‘pleasant’ but the other two did not:

Betty: “All the apartments look the same. And the corridors all look the same … Looked a bit like a hotel.”

For those who were newer to the development, such as Anne who had lived in the development for 4 months, the pleasant set up may have appeared luxurious, reminiscent of a holiday environment. Residents who had lived in the development for a longer period (Betty, 1.5 years, and Harry, 1 year) spoke less fondly of the hotel look (e.g. repetitive layout, signage). Additionally, although not explicitly described as “hotel” design, many others referenced the repetitiveness and blandness as negative aspects of the design. Based on the reports of residents in this study it would be prudent for designers to consider that retirement developments are people’s long term homes, not short-term living spaces. Orientation cues which may be suitable in a hotel, such as signage, may not be the most appropriate in a long-term living development.

Using colour to make areas distinctive

The "relaxing" pale coloured corridors were liked by many of the residents

Betty: "It's got to be restful I suppose. You can't have bright colours."

The use of colour to differentiate areas along the corridors and separate floors was the most frequently reported design suggestion. For example:

Harry: "I think each floor, if it was up to me, would have a different coloured carpet. … red, green and blue, you know? Three easy colours. You would know straight away."

One resident suggested a colour change each time there is a right angle bend:

Helen: "Well perhaps every time you come to a right angle bend, the carpet colour could change."

Putting up interesting pictures

Another area of interior design that generated conversation was the choice and use of pictures along the walls. While some residents used words like "pleasant" and "something to look at" to describe them, others critiqued them as "boring", "impersonal" and "cheap and nasty".

One resident was outspoken in her views of the pictures:

Helen: "Awful (laughs). Very boring and very repetitive (laughs). Yeah, well I expect they buy them, you know, a job lot. And that's it!"

"Repetitive" and "non-descript" were also frequently used to describe the pictures situated along the corridors. This could be a possible reason why the pictures were never reported by the residents as memorable or useful in guiding them through the development. One resident even noted that:

Ethel: "if somebody was lost and there was sort of one bright picture, it might help."

The importance of picture choice and selection was further emphasised:

Brenda: “you know William Morris said ‘have nothing that isn’t either useful or beautiful, preferably both’ (laughs) I don’t think those (the pictures) qualify for us!”

Some pictures which captured usefulness and beauty were those of the local surroundings situated in the communal lounge.

Myra: “There is one of the pictures. At the beginning. Because my nan lived in … umm … she lived …”

One of the featured pictures in the lounge was, coincidentally, a picture of Myra’s grandmother’s house. Having local pictures which are relevant and personal to the residents can elicit conversation as well as emotion, making them more memorable and purposeful.

Using a variety of colours and more specific pictures would support residents’ memory of the environment and therefore help them in finding their way. Taken together, design features that make areas distinctive and personal will make the space more memorable, and therefore easier to learn and navigate.

6.5 Discussion

This study explored wayfinding experiences and design preferences of older adults with memory difficulties living in a communal retirement setting. The participants in this study had lived in the development for up to seven or more years and we did not capture whether their (self-reported) memory difficulties began before or after moving into the development. Despite this, all participants had experienced disorientation in the communal parts of the development on at least one occasion. While this was mostly upon first moving in, experiences of disorientation regularly occurred when having to navigate along less familiar routes and when travelling to certain parts of the development (e.g. the annex). Participants reported that the main reasons for disorientation were the repetitiveness of the design, the long distances between locations and the dissociation between the main building and the annex part of the development. Additionally, reports of disorientation were influenced by the participants' apartment locations, with those living further away from communal areas reporting to experience disorientation more frequently.

These findings reflect work by Marquardt and colleagues (2011), who reported that more intelligible spatial layouts (i.e. more connected to the whole spatial system) that had fewer circulation areas (e.g. stairs and lifts), caused fewer problems for those with dementia when completing daily tasks. In the current study, long corridors appeared to influence residents' ability to complete some of their daily tasks (e.g. navigating to the laundry room). Although the residents' physical limitations need to be considered, our findings support the notion that environments designed to avoid unnecessary circulation areas would best support people both cognitively (for route memory) and physically (for mobility; (Elmstahl, Annerstedt, & Ahlund, 1997; Marquardt & Schmieg, 2009).

To overcome or avoid disorientation, residents mainly reported using design features of the environment, such as signage, door numbers and memorable objects (e.g. louvre windows, or a table with a vase of flowers). Particularly when longer routes had to be taken, these environmental cues were incorporated during route planning and when recalling the routes. Residents who reported using door numbers often relied on these being in consecutive order. Accordingly, non-consecutive numbering led to confusion, highlighting the importance of a consistent numbering system (Hölscher, Büchner, Meilinger, & Strube, 2009). Unsurprisingly, most residents reported signage as the most readily available cue to support orientation. However, it remains unclear whether or not signage was actually used in day to day life; although most residents said it was there to support them, many were unsure of the last time they had stopped to look at it. Rather than using signage, the majority of residents reported that they preferred more personal environmental cues or features such as relevant pictures and memorable spaces.

Preferences in orientation strategies differed greatly between participants. While most reported to use environmental features (i.e. landmarks) to help with orientation, some reported to actively avoid confusing areas (e.g. the annex, moving between levels), as well as sticking with the same, habitual routes to avoid confusion. This demonstrates that residents, while relying on landmark information, adopted individual techniques based on their abilities and familiarity with the environment. To further investigate how residents use and learn the environments, it would be particularly interesting to investigate whether spatial strategies change over time, for example by comparing reported strategies upon first arrival at the development with those reported after having lived in the development for several months. The "hotel-look", initially favoured by some of the residents upon moving in, was less liked after they had lived there for some time. This clearly suggests that design preferences and the way residents view the environment (e.g. they had accepted it as their home) changes over time. This mirrors previous research into residents' perceptions of assisted living environments where the communal areas were neither perceived as homely nor personal by the residents (Zavotka & Teaford, 1997). These finding are also in line with work highlighting the importance of having "homely", familiar and personal items within care environments for people with dementia (Innes et al., 2011).

Repetitive layouts were cited as a major reason for disorientation. Without environmental cues that allow locations to be uniquely identified, repetitive layouts limit the strategies available to learn and navigate along routes through the environment (Waller & Lippa, 2007). Moreover, as we age, we tend to rely more heavily on landmark-based navigation strategies as opposed to strategies that require survey knowledge or cognitive maps (Cherrier et al., 2001; Wiener et al., 2013; Wilkniss et al., 1997). To support the use of such landmark-based strategies, it is important to provide appropriate environmental cues and landmarks, particularly in larger retirement developments, which often feature repetitive layouts. One way landmarks can be made more memorable and useful for navigation is by increasing their salience. Klippel and Winter (2005) suggested three ways in which landmark saliency (how much the landmark object stands out) could be manipulated: structurally (the build and shape of the landmark), visually (the colour and appearance) and semantically (the semantic meaning behind the landmark). In residential environments the saliency of navigation cues could be addressed when deciding upon the pictures used along the walls. Residents in this study explicitly mentioned that they wanted to move away from the "non-descript" pictures currently present in the development. These could be replaced by more salient pictures both semantically (e.g. pictures that are relevant to the residents) and visually (e.g., by using pictures with strong colours). In fact, residents reported a strong preference towards pictures which were taken in the local town as these were most meaningful to them. These pictures not only stimulated conversation between residents but were also more memorable and seen as more unique.

These findings link well with previous research in psychology demonstrating that navigators rely on verbal codes to memorise landmarks they encounter along routes (Garden et al., 2002; Meilinger, Knauff, & Bülthoff, 2008). It is therefore crucial that landmarks are unique and easily nameable. If residents, as suggested in this study, use pictures on walls as landmarks, these should be different and meaningful. The use of multiple pictures depicting objects of the same category, in contrast, renders these cues/landmarks unreliable: "Turn right at the picture with the waterlily" will only effectively support orientation and navigation if there is only one picture of a waterlily in the environment (Strickrodt, O'Malley, & Wiener, 2015). Expanding on this, for people with semantic dementia who typically experience difficulties finding the right words, in particular, pictures would have to be distinct enough (i.e. belonging to a different category such as flowers, cars, animals) to make them more memorable as the disease progresses (Bozeat et al., 2003). Using interesting and relevant pictures, rather than repetitive neutral images as often used in residential and care home settings, could greatly enhance residents' sense of wellbeing and act as an aid for successful orientation.

Additional orientation cues can be introduced by the use of colour to differentiate areas within the development, as suggested by the residents. While colour has been used and tested as a reliable cue to support orientation (Helvacıoğlu & Olguntürk, 2011), it has not yet been systematically tested in the older population or those with memory difficulties or dementia. Despite this, many dementia-friendly design guidelines have emphasised the use colour has, predominantly along the walls, in supporting orientation (L. Mitchell, Burton, & Raman, 2004; The King's Fund, 2013b). Changes in carpet style or colour between parts of the environment, as participants suggested in this study, is known to cause freezing in those with more advanced symptoms of dementia as breaks in colour can be misinterpreted as steps or holes in the ground (Utton, 2009; Van Hoof, Kort, Van Waarde, & Blom, 2010). It is therefore important to ensure that colour is used appropriately and does not cause unintended barriers for the residents. The unique design features (e.g. the flowers which were regularly changed by one of the residents and the pictures of local areas) in the development showed beneficial for describing areas, particularly for the residents who had a diagnosis of Alzheimer's disease. These two residents did not report more disorientation, though they found remembering the names of areas and items (e.g. carpet) particularly difficult, and often described their key features (e.g. "the green bits") in place of their name. Interior design with salient features, which are easy to describe, would support orientation in those who experience word-finding and language difficulties (e.g. those with frontotemporal dementia). Understanding how these design suggestions and orientation strategies are cognitively represented would be the next step in allowing us to investigate how successful certain manipulations are in supporting orientation.

It is important though to ensure that environments are not overloaded with too much salient landmark information (Passini et al., 2000). Davis et al. (2009) found that older women performed best in a wayfinding task when exposed to an environment with few salient orientation cues as opposed to environments without salient orientation cues (bare condition) or with too many salient orientation cues (complex salient condition). This suggests that it would be more beneficial to ensure that selected areas of retirement developments are salient, as opposed to making them all salient, something which needs to be emphasised more clearly in existing design guidance documents.

Designing more environments in a supportive way

Many of the design preferences mentioned by residents in this study closely resemble some of the existing dementia-friendly design guidelines, such as: 'Spaces should be distinct, both in appearance and overall layout. Repeating or mirroring floorplans can be confusing for some people' (Chmielewski and Eastman 2014, p.16). This strongly suggests that dementia-friendly design suggestions should not be viewed as relevant solely for dementia care environments and should rather be viewed as "user-friendly" for anyone. Their implementation in other environments will result in a better design for all (Marshall, 2001), benefitting a wider spectrum of older adults experiencing memory difficulties. Given the wide range of preferences and abilities, the findings reported in this paper highlight that one design solution does not fit all. Whilst dementia friendly guidelines (Fleming, 2011; The King's Fund, 2013b) and the recent UK policy directive on the environment and those with dementia (Department of Health, 2015) provide an initial outline of concepts to consider, talking directly to the users would ensure that the design and wayfinding solutions is best suited to their needs and requirements.

It should be noted at this point that the current study focused on one group of residents living in one shared retirement development. However, for a number of reasons we believe that the results will, at least in principle, generalise to other groups of residents living in other environments. Firstly, both our group of residents and our test environment are not uncommon examples of the type of residents and living arrangements in UK retirement housing. With this form of housing continuing to rise in popularity (Evans, 2009) and with the prevalence of subjective memory complaints amongst older adults at around 30% (Fritsch, McClendon, Wallendal, Hyde, & Larsen, 2014; Montejo, Montenegro, Fernandez, & Maestu, 2011), we believe our study captures a reliable insight into the navigation and orientation experiences of residents living in UK retirement housing. Secondly, the interviews highlighted a number of navigation and orientation strategies and reasons for spatial disorientation issues that are well known in the psychology literature. Finally, some design principles, which are established and accepted to be best practice, are mirrored in the residents’ reports.

6.6 Conclusion

By actively engaging with and talking to retirement home residents with memory difficulties, this exploratory study has highlighted a number of reasons for disorientation, the strategies used to learn and navigate the environments (and overcome potential disorientation) and residents’ design preferences. By utilising the Thematic Analysis of residents’ self-reports we can conclude that avoiding unnecessary circulation areas, repetitive layouts, and ensuring individual apartments are close enough to communal spaces, is vital to consider when considering the structural build and floorplan of the environment. In relation to interior design, it is important to create areas with distinctive environmental cues that have semantic meaning and relevance to the residents. The use of appropriate and relevant landmarks and design features (e.g.

well-known pictures of landscapes) stimulated conversation amongst residents. As a result, these landmarks became more memorable and useful for navigation. Importantly, all environments used by older adults should support and enable successful orientation. Future studies should build on these findings and develop more fine-grained propositions of how living environments can alleviate the orientation difficulties associated with typical and atypical ageing and which environmental features are best captured in memory and are least susceptible to forgetting. Additionally, future studies should consider how people’s attitudes and perceptions of living spaces change over time - this would inform designers on how to design suitable short-term and long-term living spaces for people with dementia. Together with results from this, and similar studies (Caspi, 2014; Godwin, 2014; Marquardt et al., 2011a; Passini et al., 2000), this knowledge will allow us to develop improved design principles that minimize spatial disorientation and therefore improve people’s independence, quality of life, and wellbeing.

CHAPTER 7: How older adults find their way when visiting a care environment for the first time: a qualitative study

CHAPTER 7: How older adults find their way when visiting a care environment for the first time: a qualitative study

7.1 Overview

In Chapter 6, voice was given to residents living in a retirement development who were experiencing memory difficulties, to express their experiences of navigating within the development. The reports shed light on key considerations, namely causes of disorientation, the orientation strategies they reported using when navigating in the development as well as their design preferences and opinions of the developments current design. This next Chapter (Chapter 7) will now explore older adults' experiential accounts of navigating in a new environment.

When it comes to learning new, unfamiliar environments previous navigation research addressing the effects of ageing has mainly focused on experimentally testing older adults on their route learning abilities using quantitative measures (Head & Isom, 2010; Zhong & Moffat, 2016). Until recently, there has been little research that has focused on the users' experiences and accounts of navigating within an environment. This is vital for ensuring that environments are designed such that they are supportive for older adults and those displaying symptoms of early cognitive impairments. More so, it is vital to also understand how new visitors to an environment report navigating within it, and how residents who have lived in an environment for some time report navigating within it to understand if there are any similarities or differences in these reports.

Four open-ended questions, focusing on participants' orientation strategies, reasons for disorientation, and their design preferences, were given to participants after they had completed a short route learning task through an unfamiliar retirement development. The questions were formed based on the themes found in an earlier study (Chapter 6; O'Malley et al., 2017b).

A Content Analysis (Elo & Kyngäs, 2008) was applied to participants' responses. While the findings are in line with the O'Malley et al. (2017b; Chapter 6), there was a stronger focus on participants' ability to memorise and retrace routes based on verbally encoding the route in this study rather than on their ability to remember landmarks. Creating less institutional developments, with unique spaces to assist memory, was the most reported design suggestion.

This study has demonstrated that older adults are able to articulate their wayfinding experiences after limited exposure to an environment, highlighting that they used both verbally encoded directions of the route as well as landmarks to learn the route. To improve existing age and dementia friendly design guidelines, older adults should express their wayfinding experiences in different settings. It was evident that participants in the present study had well-thought out and insightful design wishes which is should be heard to ensure the design of environments encompass the preferences and navigation strategies that they report.

7.2 Introduction

Until recently, the design of care environments (i.e. care-homes, retirement housing, assisted living) has mainly been informed by professionals, in particular, care-staff, architects and designers (see Chapter 5 for a review). Dementia friendly design guidelines have illustrated a number of considerations when designing a home for someone with cognitive impairments such people with dementia. Ensuring that environments are designed such that they cater for those with decreasing orientation, perceptual and mobility skills is an example of how environments are changing to become more age and dementia friendly (Department of Health, 2015). However, for these suggestions to be age and dementia friendly they should directly involve older adults who use the environment to ensure that their preferences and experiences are accounted for. Up until recently, this voice has been mostly ignored and has been spoken on behalf of, by carers and care professionals (Jonas-Simpson, 2003).

The importance of speaking directly to the user has been demonstrated by Godwin (2014), who found that residents of a care environment had opposite preferences in the colour/décor to care-staff of the same environment. The users' voice and opinions on design have also been expressed with retirement development residents who reported how the repetitive design layout and interior finishes contributed towards increased feelings of disorientation (Chapter 6; O'Malley, Innes, Muir & Wiener, 2017b). Additionally, the importance of 'homely' environments has also been communicated as a vital environmental consideration (Day et al., 2000; Innes et al., 2011; O'Malley, Innes, Muir, & Wiener, 2017b; Zavotka & Teaford, 1997). Collectively, these studies demonstrate that older adults with memory difficulties can express their experiences on how they navigate within an environment, and offer opinions regarding the design.

Feelings of disorientation amongst older adults are experienced more frequently in new, unfamiliar environments (Lipman, 1991; Monacelli et al., 2003; Phillips, Walford, Hockey, Foreman, & Lewis, 2013). This has been documented in a realm of navigation experiments, highlighting that older adults perform worse in a number of spatial navigation tasks than younger controls and require more exposures to unfamiliar environments than younger controls to confidently navigate through them (Cushman et al., 2008; Chapter 3; O'Malley, Innes and Wiener, 2018).This is due to the age-related degeneration that occurs with the hippocampus (Raz et al., 2010), the area that is heavily involved in encoding and retrieving spatial memories, which as a result, makes particular strategies and representations (e.g. map-based or birds-eye view navigation) harder to use by older adults (Cherrier et al., 2001). These age-related declines in navigation abilities lead to a shift in navigation strategies, away from more complex allocentric/cognitive map-like strategies to more egocentric strategies (Rodgers et al., 2012; Wiener et al., 2013). More so, these declines are even more pronounced if early signs of atypical ageing (i.e. cognitive impairment or dementia) are present, resulting in fewer available strategies and more support being required to successfully learn and retrace a route (Benke et al., 2014; Cherrier et al., 2001).

Experiments in which older adults have been systematically tested on aspects of their route memory have demonstrated that older adults display preferences for landmark-based navigation strategies (Monacelli et al., 2003; Cherrier et al., 2001). In particular, landmarks which serve as beacon landmarks and are in the direction of turn ("head towards the church"), rather than associative cue landmark strategies ("turn right at the church"), have been found to be easier for older adults to use (Wiener et al., 2013), potentially as a result of the extrahippocampal circuits they employ, in particular the striatal circuit (Featherstone & McDonald, 2004), which are shown to be less affected by the effects of typical and early atypical ageing than allocentric hippocampal reliant tasks (such as map-based perspective taking tasks).

For those displaying early signs of cognitive impairment, these effects are exaggerated (Monacelli et al., 2003). In these cases, unfamiliar environments become incredibly difficult to learn, and disorientation additionally affects familiar environments (Pai & Jacobs, 2004; Passini et al., 1995). Landmark-based strategies, including the temporal order of landmarks and places seen along a route, the directions at landmarks and the memories of where landmarks were, are significantly affected by cognitive impairment (deIpolyi et al., 2007), though other aspects of landmark memory such as landmark recognition memory are still relatively intact (Cherrier et al., 2001).

It is unfortunate that these declines in learning novel environments occur at a time when older people may be planning to move into, and familiarise themselves with care environments or residential developments. Additionally, decisions on moving to a particular aged housing facilities are often made having had limited experience or time to familiarise with the environment. By asking older adults about their experiences in a new, unfamiliar environment after having only navigated one particular route through it, will provide detail on older adults' first impressions on the design and the ease of finding their way through a retirement development. This will expand existing knowledge on how people initially experience a new care environment, which is presently not well understood. The current study, stems from the earlier work (Chapter 6; O'Malley et al, 2017b), though aimed to investigate the experiences and preferences of older adults who were new and unfamiliar to a care environment.

Aims

This study aimed to explore older adults' experiential accounts of navigating within a new unfamiliar environment. Specific focus was on their reports on how they found a particular route through a retirement development as well as their design preferences (i.e. of their ideal living environment as well as their preferences on the test setting). Based on previous findings and existing navigation literature with ageing adults (Head & Isom, 2010; Marquez et al., 2015), it was hypothesised that participants would report some feelings of disorientation, and exhibit a preference for landmark-based navigation strategies. The previous study (Chapter 6) also illustrated the need for homely and inviting living environments with minimised repetition throughout. Although traditionally, qualitative research is purely exploratory, this study aims to further explore previous findings within a new context (i.e. unfamiliar environment). The findings from this study can be used to support, or contrast, existing age and dementia friendly design guidelines and allow comparisons to be made between retirement development residents' views (Chapter 6; O'Malley et al., 2017b) and older adults who are unfamiliar with a retirement development.

7.3 Method

Setting

The study took place in a retirement development in the south-west of England. This environment had 92 self-contained apartments, spread over five floors, as well as communal facilities (i.e. communal lounge, kitchen, manager's office, garden, laundry and refuse). None of the participants had ever visited the development.

The Route

Participants were guided along a route within the retirement development starting from the front entrance and ending in the communal lounge. They were instructed to follow the researcher and to try to learn and memorise the route as best they could. The route consisted of seven decision points across three levels, making use of two staircases (see Figure 7.1). After being shown the route once, participants were guided back to the starting point (front entrance) via a door in the communal lounge that took them around the building to the front entrance (thus no additional route/corridor exposure from within the building was experienced). Participants were then asked to guide the researcher along the route they were shown. The researcher followed the participant and recorded the following measures using a floor plan of the development: (1) the route taken by the participant; (2) where participants hesitated for longer than three seconds; (3) where participants made errors when repeating the route (i.e. turning the wrong way at an intersection, or going up/down the stairs incorrectly). If participants were unable to accurately recall the route - i.e. if they made errors that they were unable to correct, they were taken back to the start place and were shown the route again. Participants repeated the route until they could accurately recall it without errors. After successful learning of the route, participants completed a series of tasks addressing different aspects of route memory and were subsequently asked to complete a questionnaire focusing on their navigational experiences and design preferences. The details and findings of the quantitative route memory tasks will be presented in the next Chapter (see Chapter 8). This Chapter will concentrate on the qualitative reports from participants.

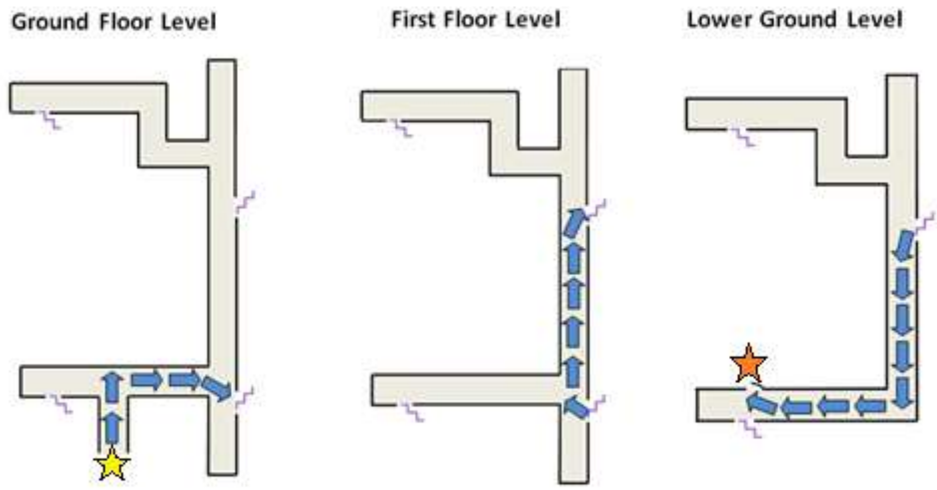

Figure 7.1: This image depicts the route participants took through the development. The yellow star indicates the start of the route, and the orange star shows where the route finished.

Figure 7.2: Left is a snapshot of one of the corridors walked along within the development. Upper right is the lobby at the start of the route that participants took. Bottom right is some of the artwork shown along the corridor walls.

Ethics

Ethical approval was obtained from the authors' University ethics panel (2015). Following the Mental Capacity Act (2005) sections two and three, capacity to consent was assumed unless participants were unable: (1) to understand the information relevant to the decision to participate, (2) to retain the information, (3) to use or weigh that information as part of the process of making that decision and (4) to communicate that decision. All participants were able to give informed consent. In addition, an on-going process consent procedure was adopted (Dewing, 2008), where participants non-verbal behaviour and body language was observed; if participants showed changes in their eye contact, vocal intonation, body language or fatigue, they would have been asked whether they wished to continue (Moore & Hollett, 2003). There were no occasions during the study where participants expressed behaviours that indicated they were uncomfortable. All data was anonymised and pseudonyms were given to all participants.

Study Sample

Thirty-two older adults (aged over 65) took part in the study. Opportunity sampling was adopted whereby all participants were from the local county and had seen advertisement through local charities regarding the study or through the Bournemouth University Recruitment System. The mean age was 70.18 years old (SD = 4.01), with 17 female and 15 male participants. Fourteen of these participants displayed possible early symptoms of atypical ageing, scoring between 22-25 out of 30 on the Montreal Cognitive Assessment (MoCA) (Lee et al., 2008; Chapter 3; O'Malley et al, 2018), while the remaining 18 scored between 26-30 out of 30, suggestive of typical ageing. This is to demonstrate that a mixture of participants showing no and early symptoms of atypical ageing were included. The participants' responses were analysed together (see Table 7.1 for demographic information, MoCA scores and route learning performance from the participants).

Table 7.1: Participant demographic and route performance data. For the MoCA Group column (column 4), 'High' signifies a high MoCA score (between 26-30 out of 30) and 'Low' signifies a low MoCA score (between 22-25). The number of learning trials (column 4) represents the number of learning trials required to correctly recall the route. At the end of the study, participants were asked whether they could still remember the route (sixth column); 'No' means they could not recall the route, whilst 'yes' means that they could.

Name (Pseudonyms)	Age	MoCA Score	MoCA Group	No. Learning Trials	Ability to Recall the Route
George	74	26	High	1	Yes
James	69	23	Low	2	No
William	75	23	Low	2	No
Anna	70	30	High	1	Yes
Joseph	73	25	Low	2	Yes

Robert	65	26	High	1	Yes
Florence	73	27	High	1	Yes
Elizabeth	69	30	High	1	Yes
Clarence	65	25	Low	2	No
Margaret	69	25	Low	1	Yes
Harry	70	24	Low	2	No
Walter	69	28	High	2	No
Arthur	67	27	High	1	No
Bertha	69	28	High	1	Yes
Alice	73	27	High	1	Yes
Albert	75	29	High	2	Yes
Fred	68	25	Low	1	Yes
David	81	26	High	2	Yes
Edward	75	27	High	2	Yes
Grace	68	28	High	1	Yes
Ethel	65	26	High	1	Yes
Sarah	66	25	Low	2	Yes
Ella	76	28	High	2	Yes
Martha	73	24	Low	2	Yes
Nellie	68	29	High	1	Yes
Bessie	66	28	High	1	Yes
Annie	66	27	High	1	Yes
Henry	74	23	Low	3	No
Minnie	69	24	Low	2	No
Betty	65	23	Low	2	Yes
Clara	66	22	Low	3	No
Charles	75	25	Low	2	No

Questionnaire

The questions were informed by the findings from earlier work (Chapter 6; O'Malley et al., 2017b), particularly focusing on the strategies used to learn the route, the causes of disorientation, and design preferences and suggestions. Participants were presented with open-ended questions on separate sheets of A4 and asked to write as much or as little as they wished. The researcher left the participant to write their responses on their own and in their own time.

The questions were:

1. What strategies do you feel you used more when learning this new environment?
2. Were there any disorientating features in this environment?
3. Please could you describe your ideal development? (i.e. what would you like it to look like, and to feature?)
4. Please discuss how you find the design of this development.

Question four acted as a case study/vignette example to gain a greater understanding of participants' design preferences based on their experiential accounts of the environment. Using the current setting as an example provided a richer level of detail regarding their preference in design.

Data Analysis

Questionnaire responses were analysed following Elo and Kyngäs (2008) inductive, directed Content Analysis process (Hsieh & Shannon, 2005). This analysis was chosen as it enabled the data to be qualitatively analysed, though and at the same time quantitatively discussed (Gbrich, 2007); its descriptive approach allows coding of the data and the interpretation of quantitative counts of the codes (Downe-Wamboldt, 1992; Morgan, 1993). Additionally, it is an appropriate method for questionnaire analysis (Kondracki, Wellman, & Amundson, 2002) and previous studies have used content analyses when analysing open-ended questionnaire responses (Hunter, 2006). All responses were analysed collectively, though given the directed frame-work of this study, responses were categorised depending on if they related to orientation strategies, reasons for disorientation or design preferences. Sub-themes in each category were driven by the responses made and the number of participants reporting each topic was noted. The definitions and content of the categories changed, as the units were categorised. Categories and ideas were constructed, inter-coded, and checked with the research team help to add rigour and validity to the analysis process (Cavanagh, 1997).

7.4 Findings

Content Analysis revealed participants' self-perceived orientation strategies, their reasons for disorientation and their design preferences. The reports are presented below using verbatim quotes from the questionnaires, as well as quantifying the number of participants responding or a particular sub-theme. These will now be discussed individually.

Table 7.2: Summary of the findings and number of reports per strategy, reason of disorientation and design suggestions.

Topic	Strategy	Number of participants reporting
1. *Orientation Strategies*	***1.1. Verbalising the route***	13
	1.2. Visual cues: landmarks, signage and door numbers	16
	1.3. Structural cues	3
2. *Reasons for Disorientation*	***2.1. No disorientation***	6
	2.2. Lack of and inappropriate use of, environmental cues causing disorientation	4
	2.3. Repetitive design	8

	2.4. Long corridors and number of turns	6
	2.5. Forgetting where the goal is	1
3. Participants' views on an ideal development	***3.1. Less institutional and more welcoming corridors***	21
	3.2. Having unique spaces in the building	9
	3.3. Importance of navigation aids	2
	3.4. Geographical position and access to activities and surrounding community	3
	3.5. Access to outdoor spaces	6

Orientation Strategies

The analysis highlighted participants self-perceived orientation strategies used, which were predominantly focused on learning the sequence of direction (verbalising the route) and memorising the visual cues along the route to support orientation. Two participants stated that they additionally relied on the structural cues to form a "mental map" and used external visual cues through the windows to self-localise per level. These will now be discussed in greater detail with quotation examples provided:

Verbalising the route

The most commonly reported strategies to remember the route was verbalising the directions (relying on the sequence of turns) which was reported by thirteen participants: "Route learning "out loud" in my head of the directions (R/L) and the gestures/physical" (Anna), with one participant discussing how she categorised the route "I divided the route into two sections based on the staircases (they were like two mini routes)." (Fred).

Visual Cues: landmarks, signage and door numbers

Remembering the visual cues, to support orientation along the route (particularly landmarks and signage), was reported by 16 participants. The reports surrounding visual cues mainly focused on how landmarks were used by participants. Three participants noted how they associated places/landmarks with directions “The landmarks help me decide when to turn/ change direction” (Elizabeth) suggesting associative cue strategies (Waller & Lippa, 2007) were adopted, while eight participants focused on their memory of the pictures along the wall “tried to look out for particular objects when learning the route. E.g. the notice boards, favourite paintings” (Henry). Henry’s quote is important as it shows that all kind of objects can serve as landmarks. In addition, participants also paid attention to the relevant signage (n=8 who reported signage and door numbers as an orientation strategy).

Structural Cues

The structure of the development was also reported as playing a role by three participants, in particular how the floor plan guided and informed participants if they were taking the correct route “I realised I went the wrong way when the corridor zig-zagged and I was not straight” (Bessie) and how they used outside as a global landmark to localise where they were in space “Noticing the outside environment to orientate myself” (Nellie). This demonstrates that the outside can be used almost as compass information, emphasising the importance of windows for orientation when considering design (Wang & Brockmole, 2003).

Disorientating Features

No Disorientation

Six participants reported no disorientating features along the route. These were an equal split of male (n = 3) to female (n = 3), though four of these participants were in the Low MoCA group, with three of them requiring additional exposures of the route following the initial exposure. The remaining 26 participants all reported experiencing some disorientation along the route, with 17 able to specify the aspects which they found disorientating.

Lack of, and inappropriate use of, environmental cues causing disorientation

The lack of signage was reported by two participants: “I would have liked to see more reminders of where things were” (Fred). Additionally, the lack of windows along the particular corridors to localise participants’ position in the development was noted as both causing disorientation: “Corridors were long so you could lose sense of position – no windows with views” (Alice). The windows informed participants of which floor they were on: “Yes, when there were no windows on the bottom floor. But this also alone reminded me of which floor I was on so was in a way helpful once I realised” (Edward). This is closely related to the orientation strategies discussed above where participants reported using the outside to stay orientated, providing them with compass information.

Interestingly, two participants stated how they felt the landmarks had a detrimental effect on how well they learned the route: “I was a bit distracted by some of the nice/eye catching pictures” (Bessie). This quote offers a contrasting the view to the other reports, but is consistent with the concept of ‘information clutter’ (Passini et al., 2000) whereby too many landmarks cause confusion.

Repetitive design causing disorientation

The repetitive design of the environment was the most cited cause of disorientation: “Décor is very similar on all floors. Carpet and lighting are all similar.” (Henry) as was the lack of unique spaces: “I found it hard trying to make places memorable - there were some things that stood out (the gold flowers) but other times it was really disorientating.” (Elizabeth). Ensuring environments have areas which are unique to break up any possible repetitiveness and allow for architectural differential could help participants better learn routes (Marquardt, 2011).

Long corridors and number of turns

Six participants reported the length of the corridors and number of turns as their reason for experienced disorientation. It is also important to note an interesting differentiation between the length of the corridors (n = 3), “Corridors were long so you could lose sense of position” (Alice), and the number of turns along the route was made (n = 3) “Always panic in these buildings with many twists and turns” (Florence). These causes of disorientation could be related to accumulating errors in path integration (Biegler, 2000).

Forgetting the where the goal is

One participant noted on how he forgot where he was going along the route: “I sometimes forgot where I was going” (Albert). While this could relate to forgetting the goal location, this report could also relate to forgetting the route, and trajectory he was travelling along.

Participants’ views on an ideal development design

All participants clearly illustrated how they would like their ideal development to look with the majority emphasising the importance of smaller environments with more unique spaces

Having unique spaces in the building

Having shorter corridors and fewer people was reported by participants: “I would love fewer people” (Elizabeth). Participants discussed how ideally they would prefer brighter corridors, with unique spaces and alcove seating areas: “Wider corridors and more spaces to sit along the way. Maybe a coffee machine by one of the windows (a little alcove space)” (Edward) Particularly for larger built environments which have long corridors, making sure there are breaks along the way, in both the design and the as places of rest, will encourage people to go out and use the corridors, as well as potentially visit new unfamiliar surroundings.

Participants also noted how empty spaces along the corridors of the environment should have been filled: “There were too many blank spots especially at junctions” (William). This report reiterates the importance of having landmarks positioned at decision points (Aginsky et al., 1997). If people tend to remember landmarks at decision points better than at non-decision points (Aginsky et al., 1997; Janzen & van Turennout, 2004), it suggests that these landmarks are relevant for navigation which, in turn, means that people look for (and expect to have) landmarks at these decision points.

Less institutional and more welcoming corridors

Ensuring developments are designed such that they are inviting and homely was also a key consideration, reported by 21 of the participants: “An ideal place would have thought out design and not patronising. Subtle and simplicity.” (Bessie). Additionally, ensuring the development has lots of character was also reported by the participants.

With regards to the test setting used, the effects of lighting and décor were frequently reported as having a negative impact on how participants navigated their way around the building. Some noted the institutional feel of the setting: “Inside it looks very much like a hospital.” (Bertha) and how the building felt: “rather impersonal.” (Annie). Ensuring the communal spaces are designed such that they are homely and inviting is important when considering the design of communal-living built environments (Innes et al., 2011; Zavotka & Teaford, 1997).

Importance of navigation aids in environmental design

Two participants additionally discussed the importance of having supportive navigation aids (maps, signage, colour coding areas and separated “wings”) to help identify where they are in the environment: “Having lots of signposts and maps. Exits indicated everywhere. Every floor indicating which floor you’re on. Numbers on doors indicating the floor you're on" (Joseph). This is an interesting suggestion as signage may provide additional navigational support in this context, however it does contrast participants' other reports of creating a less institutional environment (particularly when considering it as an ideal environment to live in). Evaluating what the key priorities are and (if) navigation can be supported through other means in a living environment should be explored.

Interestingly the use of colour to differentiate areas within an environment was also discussed by five participants (this was a sub-theme within unique spaces): "I should prefer each floor to have a different colour and also fire exits and lifts (if there are more than one)." (Clarence), which relates back to previous work surrounding design preferences and creating unique spaces to support orientation (see Chapter 6).

Geographical position and access to activities and surrounding community

Having a range of activities and a sense of community were also mentioned to be important "Hairdressing, swimming pool, activities and courses not specifically designed for elderly, access to shops, excursions to theatre and other cultural events/ semi-rural." (Annie).

In addition to the ideal services provided in-house, two participants also described the importance of local surrounding community that their ideal development would have: "Very good position next to the park and local shops" (Nellie). Ensuring environments are well-integrated with the community and that they have access to the surrounding facilities is an important consideration (Abbott & Sapsford, 2005).

Access to Outdoor Spaces

Access to natural light and outdoor space was frequently reported: "lots of natural light. I want to be able to easily go outside and not feel trapped." (Albert). Another discussed having a "Feature windows at the end of the corridors with a view." (Alice). This same participant expanded and discussed how bringing the outside in was equally important for her: "Large plant pots with attractive plants – even if artificial!" (Alice). These findings and reports made by the participants demonstrate how they had well thought-out and personal requests and preferences. Ensuring that there is scope in both existing and future builds to accommodate such wishes should be a priority.

Additionally, participants noted the importance of outdoor space, particularly how they liked the presence of the immediate surrounding gardens as well as the developments positioning within the community and how relation to local shops. Yet while some liked how the development was positioned within the community, the interior was not to their liking "The building is in a great location but I don't like the inside." (Albert).

7.5 Discussion

This study explored the experiential accounts of older adults' wayfinding experiences and design preferences in an unfamiliar retirement development. The participants in the study had no prior experience with the development before the study commenced, though they were members of the local community. Participants were initially required to learn a route, until they could accurately recall it, which took them from the front door of the development, across three floors, and finished in the communal lounge. All participants demonstrated that they had learned the route. Following this, they were then given four open ended questions, which asked them about the strategies they used to learn the route, any areas of disorientation, and their design preferences. The feedback data was analysed using a direct Content Analysis approach (Elo & Kyngäs, 2008).

Orientation Strategies

All participants were able to illustrate how they felt they had learned the route (after successfully demonstrating that they could repeat the route after an initial exposure), and identify the strategies and environmental cues they felt they had used. The presence of visual cues was vital for the majority of the participants (16 of the 32 participants reported this). In particular, the use of key landmarks (e.g. the pictures along the walls, the fire exit signage) along the route provided participants with potential strategies to adopt to orientate and learn the route through the environment. This is consistent with previous literature which highlights the importance of landmarks for navigation, particularly when first learning and familiarising oneself with a new route through an unfamiliar environment (Waller & Lippa, 2007) and how landmarks are especially important for older adults during route learning (Head & Isom, 2010; Monacelli et al., 2003; Wiener et al., 2013). Three participants noted that they associated directions to landmarks, highlighting that they had adopted an associative cue strategy at particular points in the environment (Waller & Lippa, 2007). Studies have shown that objects at decision points are remembered better, and as a result become landmarks (Aginsky et al., 1997; Janzen & Jansen, 2010; Janzen, Jansen, & van Turennout, 2008). Some landmarks, though, did prove problematic for one particular participant (Bessie), in that she was unable to dissociate key landmarks from distractor landmarks, resulting in some landmarks distracting her away from the route and consequently making the route harder to learn. Dissociating the relevant from the ambiguous landmarks relies heavily on where landmarks are situated along the route, with those at relevant positions (decision points) resulting in more activity in parahippocampal gyrus (Jansen and Janzen, 2010) a region that is vital in scene/place recognition. It has been suggested that dissociating between relevant and ambiguous landmarks becomes affected during the ageing and atypical ageing process (Kessels et al., 2011) which would explain why information clutter caused by too many landmarks present in a given environment (Passini et al., 2000), would cause detrimental effects to navigation.

Verbalising the sequence of route directions as an orientation strategy was reported by 13 of the participants. Verbalising routes and following route descriptions are amongst the most commonly used navigation strategies when directing people along new routes (Allen, 2000, Denis et al., 1999, Habel, 1988, Klippel et al., 2005 and Lovelace et al., 1999). Additionally, when repeating and retracing routes, thinking aloud protocols (i.e. repeating directions aloud) are also frequently used, and studies have highlighted that people do in fact use verbal codes during route learning, as interference is present when required to complete a verbal secondary task (Meilinger et al., 2008). One study even suggested that healthy adults are able to remember route sequences of turns up to 13 intersections (Denis et al., 1999), so it is conceivable that participants in this study were able to learn the sequence of directions at the 9 intersections, and verbalise the route efficiently.

Interestingly though, this study slightly contrasts the previous work from our lab (Chapter 6; O’Malley et al., 2017b), where retirement development residents expressing how they relied significantly more heavily of visual cues (i.e. prominent places and landmarks along the corridors) to support navigation rather verbalising routes (remembering routes by the directional information alone). There are two possible explanations for this. In O’Malley et al. (2017b; Chapter 6) all participants had self-reported memory difficulties, whilst the present study focused on typical ageing and earliest symptoms of atypical ageing. Our previous work has shown that the memory of sequences of directions gradually declines during typical ageing and early atypical ageing so it is possible that these verbalising strategies are more readily available for healthy older adults than those who are showing signs of cognitive impairment (Chapter 3; O’Malley, Innes & Wiener, 2018).

Secondly, the amount of experience and exposure with the environment may alter the strategies used; participants in the present study only had limited exposure to the route in the environment (depending on the number of learning trials needed), whilst O’Malley et al. (2017b; Chapter 6) had residents who had lived over seven years in their environment which may suggest that our strategies when first entering an environment for the first time (unfamiliar/ less familiar), differ from frequently travelled routes through environments (highly familiar). The findings could be environment specific depending on the other existing environmental cues that are present. For example, the positioning and salience of the landmarks present could alter whether they were considered as an informative navigation cue. Additionally, in the present study, participants were asked to comment on a specific route that they had demonstrated that they had learned, whilst in O’Malley et al. (2017b), residents spoke more generally about how they navigated and their overall experiential account of navigating during the course of their residency there.

Disorientation

Six participants reported no disorientation within the environment. Interestingly though, four of the six participants who reported no disorientation scored in the lower bracket of the MoCA, suggesting early symptoms of cognitive impairment. Additionally, when looking at their performance on accurately repeating the route after the first exposure, three of out of these four low MoCA participants required additional learning trials (i.e. they were unable to learn the route after the initial exposure). In this case, a semi-structured interview rather than a questionnaire could prove beneficial for understanding these participants' causes for disorientation during the route learning phase. This would allow the initial feelings of disorientation in the first trial to be directly questioned. Additionally, walking interview techniques (Evans & Jones, 2011) would allow further exploration of this is if carried out during the experienced disorientation during route learning.

The corridors caused a lot of problems for participants when learning the route - the most frequently reported cause of disorientation within the setting was the repetitive design, followed by the length of the corridors and the number of turns, emphasising the need to ensure corridors in such environments are designed correctly. Repetitiveness was a cause of disorientation with retirement development residents in O'Malley, Innes and Wiener (2017; Chapter 6), though, this issue can be easily overcome with careful design consideration. Even improving the environmental design (e.g. differentiating segments along corridors so that they appear shorter, and easier to identify), it would reduce the additional causes of disorientation reported particularly given the importance visual cues have in supporting orientation strategies.

Proximal/local landmarks have been shown to play a crucial role in supporting older adults during navigation (Moffat, 2009) so it is not surprising that participants reported the lack of landmarks within the environment as a key reason for why they felt disorientated. Whilst there were some landmarks within the environment (i.e. each floor had a 'theme' such as flowers or landscapes and displayed pictures according to that theme), it may have been that the landmarks present were not unique or salient enough, or they may not have been at relevant points for navigation (Aginsky et al., 1997). Landmarks help shape and support the orientation strategy we use to learn and recall a route through a space (Waller & Lippa, 2007), with older adults performing better at navigation tasks involving beacon landmarks (e.g. “head towards the church”) (Wiener et al., 2013) and view salient landmarks as critical route-maintaining events along learned route (Lipman, 1991). Further research should look at these factors, and explicitly assess these landmark characteristics when testing route memory and asking for experiential accounts of navigation.

An interesting differentiation between the length of corridors and number of turns as a cause of disorientation was reported by participants. One possible explanation for this relates to the role of path integration (i.e. keeping track of the position within the environment) as with increasing corridor length, uncertainty about one’s position increases. Moreover, path integration abilities have been shown to decline with age (Allen, Kirasic, Rashotte, & Haun, 2004), which could explain why one participant in particular noted disorientation along one long corridor (i.e. no decision points present). An alternative interpretation that is related to this point is how both of these factors (i.e. length of corridors and the number of turns) also feed into existing models of navigational theory, in particular cognitive graph theory and cognitive map theories. These suggest that number of turns (irrespective of corridor length; Mental Model; Meilinger, 2008), versus corridor length (irrespective of number of turns; Mental Walk; Byrne, Becker & Burgess, 2007) differentially affect navigation performance, with the more corridors or turns between a navigators current position and landmarks along a given route independently affecting performance in pointing latency. Whilst research suggests that we hold both forms of representation (Mental Model and Mental Walk), with the length of corridors and the number of turns both affecting navigation performance, it is clear that reducing both of these factors will reduce levels of disorientation. This is particularly important for older adults and those displaying early symptoms of atypical ageing (Marquardt & Schmieg, 2009) and is echoed in existing age and dementia friendly design guidelines which emphasise the importance of short corridors and interconnected areas.

Two participants, Alice and Albert, emphasised the differentiation of being disorientated between where you are, and where you are going, when they discussed the length of the corridors. Localisation and memory of the goal location or route to the goal are both important aspects of navigation, and both should be kept in mind during navigation. This additionally highlights how the length of corridors appeared to influence both spatial localisation and route retracing abilities independently. Whilst the route used in this study was chosen to explicitly test route memory, ensuring routes are short (as also found in Chapter 6) and (or) the shortest possible routes are highlighted on navigation aids, would assist with these difficulties of memorising longer routes. Older adults, particularly atypically ageing adults have difficulties learning longer routes (Pengas et al., 2010), so making sure routes between places are short, with few decision points, is vital. Additionally, older adults navigate better in environments consisting of open-planned spaces (Marquardt & Schmieg, 2009). This could prove more beneficial particularly for new visitors to an environment, when they are trying to familiarise themselves within the space.

Design suggestions

Design wishes expressed by participants were well thought-out and insightful. Participants made design suggestions and shared their preferences on how their ideal living environment would look, using the test environment as an example to compare their vision with. Twenty-one participants emphasised the importance of having a homely and welcoming environment, focusing on how the design should not be patronising and must be respectful. This is in line with previous research (Day et al., 2000; Innes et al., 2011; Zavotka & Teaford, 1997), though still appears to be an issue which has not fully been addressed. De-institutionalising shared living facilities through design (1) would create a more person-centred environment, (2) would potentially result in the whole development being used and viewed as their home (rather than only individual rooms/apartments), and (3) would welcome a wider audience of potential residents to consider such housing as an option. This said, navigation aids were also mentioned by participants for an ‘ideal development’. It is not usual to have signs in your typical home, therefore ensuring visible maps, useful landmarks and colours are injected into the design, yet still making sure that the environment is homely, is critical to supporting successful navigation. Further research is needed to investigate how to design supportive signage such that it is not reminiscent of airports or hospitals.

The importance of outdoor space and natural sunlight was consistently reported amongst participants. The apparent reduced levels of natural light within the setting had immediate effect on the participants who had spent, at most, one hour within the retirement development/grounds. These reports are in line with researchers who have found these to be important qualities when enhancing wellbeing in care settings (Innes et al., 2011). However, these studies (Innes et al., 2011) reported the effects of natural light on mood with individuals who had prolonged exposure to an environment. Chalfont (2008) discussed how the connection people living in care environments have with nature is less understood than other aspects of design due to staff wishing to manage risk as a priority and having control over residents' behaviour. This said the psychological and emotional need for nature is an important aspect in a person's life (Chalfont, 2008). Exposure to natural sunlight has also been found to reduce stress levels in older adults (Rodiek, 2002). Particularly for those with potential reduced mobility, ensuring direct access to outdoors be easily available and accessible is vital to support enhanced wellbeing, as is making sure natural light is plentiful. Care environment planners should consider older adults' wishes when designing and environment and what they would want in an ideal environment prior to build.

Importantly, participants also noted how they used the view from the windows as landmarks as they provided them with global external landmarks. Having windows within the environment allows one to see the outside world which may help with orientation. Research into 'nested environments' (i.e. immediate surroundings, such as a room, in relation to the outside surroundings such as a university campus) (Wang & Brockmole, 2003) demonstrates that we do not automatically update our orientation/location in the outside world, as we navigate inside. Having windows present along corridors could better support a navigator's orientation within a building by providing compass cues that would support path integration and allow them to correct for errors in estimated heading direction.

It is important to note that this study is a case study that only involved 34 participants. Whilst there have been similarities in reports between this study and the findings from Chapter 6, the findings from this study are not aimed to be generalised to the rest of the ageing population. Instead, they demonstrate that older adults can articulate the places where they experience issues of disorientation, identify strategies that they use to navigate in an environment, and outline clear design preferences for their ideal development. The potential impact of patient and public involvement with regards to supportive and well-designed environments, is also illustrated in this study and should be adopted in future practice.

7.6 Conclusion

By giving older adults the opportunity to openly describe their navigation abilities and their design preferences, this study has been able to demonstrate that particular navigation strategies and representations are more readily available for older adults new to an environment. The open-ended questions provided participants with a blank canvas to describe how they felt they navigated within the setting, and express how they would want an ideal environment for them to be designed. This information can help to better understand the design of environments used by older adults and to inform existing age and dementia friendly design principles. Repetitive layouts and a lack of landmarks proved problematic and resulted in disorientation for many of the participants. With regards to orientation strategies, there was a clear distinction between route verbalising strategies and landmark-based strategies. Importantly, this study has demonstrated that older adults are able to articulate their wayfinding experiences after limited exposure to an environment – future studies should focus on asking older adults in different settings to ensure the design of environments accompanies the strategies and preferences they report.

Secondary Interim Summary

The last three Chapters have focused on the lived experience of finding ones way in a building (in both familiar and unfamiliar) as well as design applications to better support successful orientation and wellbeing within the setting. Using qualitative interviews with a Thematic Analysis approach (Braun & Clarke, 2006), Chapter 6 highlighted (1) familiar residents' experiences surrounding navigation within their home environment (i.e. retirement setting) demonstrating the importance of unique memorable areas to support successful navigation and how repetitive layouts should be avoided (Chapter 6). In Chapter 7 visitors of a retirement setting were asked to express their experiential accounts of navigating along a new route and their design preferences of the environment. Using a questionnaire with open-ended questions, participants' responses were analysed using Content Analysis (Elo & Kyngäs, 2008). This study highlighted a differentiation between verbal and visual strategies to memorise the specific route, though still highlighting the need for homely and inviting environments that have good access to outdoors. Overall, these qualitative studies have provided an experiential and person-centred angle to the PhD, which captures their personal accounts adding to the overall picture of navigation amongst typically and early atypically ageing adults.

Understanding how navigation in the real-world (as highlighted in Chapters 6 and 7) relates to navigation in simplistic VR environments (as highlighted in Chapter 3), would provide insight into how generalizable findings using VR methods are. In particular, the Literature Review demonstrated a wide scope of both VR and real world experiments that have investigated route learning in typical and atypical ageing, however given that the majority of spatial cognition research in the last decade has made use of simplistic VR environments, understanding how well results from these simplistic VR set-ups translate to complex real-world settings is vital.

The next and final experimental Chapter (Chapter 8) synergised the methods used, by testing typically ageing adults and older adults displaying early signs of atypical ageing on their route memory in an unfamiliar real world setting. In addition, all participants were required to complete a short version of the route learning experiment introduced in Chapter 3, to investigate how well navigation abilities in complex real world settings can be assessed using simplistic VR set-ups. Similarities and differences between the two conditions for typically ageing adults and older adults displaying early signs of atypically ageing are discussed.

CHAPTER 8: Older Adults' Route Memory Abilities in Real and Virtual Environments

8.1 Overview

So far, this thesis has explored the effects of typical and early atypical ageing on navigation abilities by firstly using quantitative VR route learning protocols to assess route knowledge after successful route learning. The thesis has also adopted qualitative methods to provide experiential reports from older adults who were familiar or unfamiliar to a particular retirement environments. The findings from the VR studies (Chapter 3 and 4) have highlighted that older adults showing early signs of atypical ageing are significantly worse at identifying a previously learned route from a map perspective, as well as when using maps to plan routes to navigate to a goal location.

The literature has highlighted that aspects of route knowledge (particularly landmark recognition memory) have been shown to be less affected by the effect of early atypical ageing (deIpolyi et al., 2007). This corresponds to qualitative reports of both residents of a retirement setting (Chapter 6) and new navigators in a real world retirement setting (Chapter 7). In both Chapter 6 and Chapter 7 participants emphasised the importance of landmarks and memorable areas to support successful navigation. These reports are in line with previous research highlighting the importance of landmarks for orientation (Passini et al., 2000; Head & Isom, 2010) and their resilience to the effects of ageing (Lipman, 1991).

The novel route learning paradigm developed in Chapter 3 ensured participants were successfully trained to learn short routes through a simplistic virtual environment (route learning) before testing them on aspects of route knowledge. One aim of the current study therefore was to investigate whether this protocol could also be applied in a complex real world scenario, using longer and more realistic routes. Specifically, the objectives of Chapter 8 were, first, to investigate the effects of early atypical ageing on route knowledge in a real world scenarios, and second, whether route memory measured in simplistic lab-based virtual reality (VR) environments reflects Real World route learning.

A large proportion of navigation studies have used simplistic VR environments to measure navigation abilities (Zhong & Moffat, 2017) though little is known about how well these findings translate to complex real world navigation (see Cushman et al., 2008).

In Chapter 8, two groups of participants (between-subject, typically ageing and early atypically ageing) learned routes through a real world and a virtual environment (within-subject) and completed a series of route memory tasks (e.g. landmark sequence task, landmark direction task, map task, sequence of directions task) for each condition. Both conditions used the same protocol as described in Chapter 3 where participants were initially trained to learn the route before testing them on aspects of route memory.

We found that the older adults displaying early signs of atypical ageing performed significantly worse than the typically ageing group in all of the tasks in the VR condition, and some of the tasks in the Real World condition. For the Real World condition, the aspects of route knowledge that were affected by early atypical ageing were the number of trials required to learn the route (Route Learning), whether or not participants could later remember and recall the route during a post test phase (Route Recall) and the ability to identify the correct order that landmarks at decision points were seen along the route.

Tasks which were not affected by early atypical ageing in the Real World condition were (1) the memory of a landmark and its associated directional change along the route (Landmark Direction Task), (2) the ability to identify the correct order that landmarks at non decision points (i.e. corridors) were seen along the route (Non decision point Landmark Sequence Task), (3) the sequence of directional changes along the route (Direction Sequence Task) and (4) the ability to identify the learned route from a map perspective (Map Task). The VR condition was therefore more sensitive in detecting the early difficulties in navigation abilities for early atypically ageing adults.

Although there were similarities in performance between the two conditions, the VR condition detected more pronounced effects of atypical ageing. This may have implications for neuropsychological assessments of early atypical ageing, and the inclusion of VR spatial navigation tests during assessments. Possible explanations for why the Real World condition produced less pronounced effects of navigation difficulties associated with early atypical ageing could be because the real world contains more complex and rich environmental cues. These additional cues could have been allowed for additional strategies than the simplistic VR environment could offer. Importantly, the study also raises issues for simplistic VR studies that discuss the applications of their findings and conclusions to the real world settings.

8.2 Introduction

Learning routes, particularly routes through new, unfamiliar environments becomes much harder as we age (Head & Isom, 2010; Raz et al., 2010). These difficulties are more pronounced if a person experiences early symptoms of cognitive impairment or dementia (deIpolyi et al., 2007; Hort et al., 2007; Pengas et al., 2010). The effects of early atypical ageing, particularly Alzheimer's disease (AD), are consistently shown to negatively affect spatial memory, particularly memories for where landmarks were located, the temporal order in which landmarks were encountered during navigation, and the ability to identify a recently navigated route on a map (Benke et al., 2014; Cherrier et al., 2001; deIpolyi et al., 2007).

Real world navigation involves processing a wide range of landmark properties (e.g. their positioning, their saliency) (Chan et al., 2012), the use of multiple floor levels (Hölscher et al., 2009), and involves using vestibular input and optic flow input used for path integration (Loomis, Klatzky, Golledge, & Philbeck, 1999; Wiener, Berthoz, & Wolbers, 2011). So far, real world behavioural studies exploring how older adults and people with dementia navigate in real world settings (Benke et al., 2014; Cherrier et al., 2001; Marquez et al., 2015; Wilkniss et al., 1997), have generally involved showing participants a route through a building (e.g. a hospital), and subsequently testing them on aspects of route memory (i.e. the landmarks along the route, the sequence of direction changes). These studies have found that typically and atypically ageing adults generally display slower rates of learning (see Chapter 3 and Chapter 4), perform poorly on map-based tasks (Cherrier et al., 2001) and have poor landmark direction memory. Despite this, older adults do rely heavily on landmarks (Marquez et al 2015), with relatively still intact landmark recognition memory (Cushman et al., 2008; Cherrier et al., 2001).

In order to accurately measure factors that influence navigation performance, many researchers now utilise, and rely on, VR technologies to create environments to test navigation performance. These VR environments often control for all influencing factors and variables. Since the emergence of VR, an increasing number of ageing and dementia navigation studies has been carried out in the lab, often using these virtual environments to test route memory and navigation (Gyselinck et al., 2013; Pengas et al., 2010; Wiener et al., 2012). The major benefit of VR is that researchers have full control over what is displayed to participants, that they can systematically manipulate properties of the environments, but also that VR can be used in structural brain imaging studies to investigate brain correlates (deIpolyi et al., 2007). These experiments typically use very simplistic VR environments (i.e. minimalistic in terms of layout with less architectural differentiation and fewer environmental cues as well as restricted control of locomotion and often a smaller field of view) to measure navigation abilities in well controlled environments, and are therefore reliable in informing us on exactly what is visible in the VR environment and the cues people are using.

In recent years the quality of the environments used in VR studies has significantly improved, resulting in more realistic environments (for example, virtual models of towns and care environments) (Gyselinck et al., 2013; Pengas et al., 2010), however many VR set-ups still deprive participants from proprioceptive and even vestibular feedback which have been shown to play an important role in how we encode and map out the environment (Stackman, Clark, & Taube, 2002). They are also major contributors to path integration, an essential mechanism to judge distance and direction of travel (Harris & Wolbers, 2012).

Few studies have directly compared VR to real world navigation with ageing populations (Cushman et al., 2008; Richardson, Montello, & Hegarty, 1999). Cushman et al. (2008), for example, studied route learning in a real world setting (a route though a hospital) and using a VR environment (a route through a VR model of the hospital) with typically ageing adults, people with Mild Cognitive Impairment (MCI) and people with AD. All measures of route memory and performance rendered similar results in the two conditions (VR and Real World), suggesting that the mechanisms used to learn routes, as well as the memories formed, are similar between Real World and VR environments.

Although Cushman et al. (2008) were able to demonstrate similarities between conditions on the measure of route memory tested, the majority of spatial cognition research has used very simplistic VR environments, often with bare walls, displaying one landmark per intersection (Janzen & Jansen, 2010; Waller & Lippa, 2007; Wiener et al., 2012; Zhong & Moffat, 2016). While these studies have provided important insights into some of the mechanisms involved in navigation, there is very little research that has investigated how participants' navigation abilities in these simplistic VR environments relate to Real World navigation. Knowing whether or not the specific declines in navigation in early atypical ageing, are found both in simple VR as well as in complex real-world settings, will shed light on whether these ecological factors influence the overall mechanisms required to learn a route.

Whilst early atypical ageing has been studied in both real world and VR environments, few studies have addressed route knowledge after successful learning (Chapter 3). The present study aims to investigate whether the declines in route knowledge in older adults displaying early signs of atypical ageing are found in both simplistic VR environments and real world navigation when using a novel route learning protocol that ensures participants have successfully learned the route.

In an earlier study, we used a simplistic environment to measure route memory (see Chapter 3; O'Malley, Innes and Wiener, 2018). Using a novel route learning paradigm, young adults, typically ageing adults and older adults showing early signs of atypical ageing were required to watch videos of routes through a VR environment and demonstrate that they had learned the routes. They were then required to complete a series of tasks probing the route knowledge they have formed during route learning. We found that certain aspects of route knowledge were affected differently by the effects of typical ageing and early signs of atypical ageing. Specifically, tasks affected by typical ageing were those involving the memory for a sequence of turns and route recall memory (i.e. the ability to repeat the route a final time after completing the various route memory test tasks) whilst other tasks were affected specifically by early atypical ageing (i.e. recognising the route from a map perspective and associative cue memory). Yet, given the simplicity of the VR environment used, it remained an open question how reliable the set-up with its restricted ecological validity was in capturing a true reflection of navigation in the Real World. If findings from these simple VR environments do translate to real world navigation, it would suggest that simple VR environments are able to capture the specific atypical ageing related deficits in route learning and tap into the processes relevant for real world route learning.

The present study therefore aims to explore whether this new route learning protocol, that has been developed and tested in VR (see Chapter 3), can translate to the real world environment.

Participants were tested both on their ability to learn new short routes through simplistic virtual environments and their ability to learn a novel multi-level route through an unfamiliar complex real retirement development. We amended the procedure of our recent lab-based VR protocol (see Chapter 3; O'Malley, Innes and Wiener, 2018) to apply it to the real world before assessing different aspects of route knowledge. In addition, participants completed a shortened version of our lab-based VR study (see Chapter 3; O'Malley, Innes and Wiener, 2018) to investigate how results from lab-based navigation tasks in simplistic environments translate to real world settings. In both conditions, participants were first trained until they learned the novel route(s), before they were tested on different aspects of route memory. By using a within-subject design, the findings will shed light on the relationship between the navigation in simplistic VR environments and navigation in the real world. If there are similarities in navigation performance between Real World and VR conditions, it would demonstrate that simplistic VR experiments can capture the specific atypical ageing related deficits in real world route learning. Virtual reality set-ups that use simplistic VR environments allow full control of the environments, which is not possible in complex real world settings. In turn, this could have implications for diagnostic assessments for differential diagnosis of dementias, and potentially, the inclusion of VR navigation assessments during neuropsychological testing (Bird et al., 2010). To study the effects of early atypical aging, we tested two older participant groups, one of which scored high and the other scoring lower on a neuropsychological screening tool for MCI.

Based on the findings from previous literature (see Chapter 3, O'Malley, Innes and Wiener, 2018; Cushman et al., 2008; Benke et al., 2014), we hypothesised that there would be significant differences between typically ageing adults and older adults showing early signs of atypical ageing on particular tasks, specifically for associative cue and map-based tasks. Additionally, based on earlier findings (Cushman et al., 2008), we hypothesised that VR environments and real world testing would display similar patterns of performance between the participant groups. Real world, complex settings provide many more cues that people can use for orientation and therefore allows for additional (or alternative) strategies that could be used by atypically ageing adults to ameliorate potential declines in navigation abilities. In this scenario, performance differences should be exaggerated in the VR as compared to the real world setting.

8.3 Method

Participants

Thirty-two older adults (aged over 65) took part in the study. The mean age was 70.18 years (SD = 4.01), with 17 being females and 15 being male.

All participants completed the Montreal Cognitive Assessment (MoCA), a 30 point test designed to test for healthy ageing and to detect MCI and early stage AD (Nasreddine et al., 2005). The most commonly used and accepted MoCA cut-off for healthy ageing is 26/30. Lower scores indicate early atypical ageing (Nasreddine et al., 2005). Interestingly though, some studies suggested that cut-offs as low as 22/30 (Lee et al., 2008) and 23/30 (Luis, Keegan, & Mullan, 2009) would also be suitable to separate healthy ageing for atypical ageing. We here used the suggested higher and lower MoCA cut-offs to split our older participants into two groups. Specifically, participants in the High MoCA group scored between 26 and 30 points and participants in the Low MoCA group scored between 22 and 25 points. We used these cut offs in a previous study (Chapter 3; O'Malley, Innes and Wiener, 2018) and found that those in the Low MoCA group (22-25 out of 26) displayed significantly lower performance on some measures of route memory which was consistent with findings atypical ageing literature suggesting that MoCA scores between 22-25 are indeed indicative of early signs of cognitive impairments (Nasreddine et al., 2005).

In total we had 14 participants in the Low MoCA group (mean age= 69.78, SD = 3.64; 6 females and 8 males), and 18 participants in the High MoCA group (mean age = 70.5, SD = 4.46; 11 females and 7 males). There was no significant difference in the ages between the High MoCA and the Low MoCA group ($t(30) = 0.486$, $p = 0.631$). There was also no significant difference in years of education between the High MoCA and the Low MoCA ($t(30) = -1.352$, $p = 0.187$).

Participants took part in two separate conditions on different days; Condition 1 involved real world route learning through a retirement development, and Condition 2 involved route learning through watching short videos of routes, taken from a virtual environment on a laptop display. All participants first completed Condition 1, and on a separate date they completed Condition 2.

Ethics

Ethical approval for the experiment was obtained from the Bournemouth University ethics panel. The researcher was present throughout the whole experiment, adopting a person-centred approach (Cowdell, 2006) to reduce any possible feelings of discomfort or stress (Dewing, 2008). The same ethical principles discussed in Chapter 2 were followed during this study.

Condition 1

Study Location

Condition 1, the Real World navigation phase, took place in a retirement development in the south-west of England. This development had 92 self-contained apartments, spread over five floors, as well as communal facilities (i.e. communal lounge, kitchen, manager's office, garden, laundry and refuse).This condition used the same procedure and participants as in Chapter 7.

The environment and routes

The route consisted of seven decision points across three levels, making the use of two staircases (see Figure 7.1). None of the participants had prior experience/exposure to the development (see Figure 7.1 for a birds-eye view of the route taken and Figure 7.2 for images from within the environment).

Procedure

The Real World navigation condition consisted of three phases; the learning phase, the test phase, and the route recall phase.

Experiment

Training Phase

In the training phase (route learning**)**, participants were guided along a route within the retirement development starting from the front entrance and ending in the communal lounge. They were instructed to follow the researcher and to learn and memorise the route of the route as best they could (See Figure 7.1 for a birds-eye view of the route taken). After being guided along the route once, participants were brought back to the starting point (front entrance) via a door in the communal lounge that took them around the building to the front entrance (thus no additional route/corridor exposure from within the building was experienced). Participants were then asked the guide the researcher along the route they were shown. The researcher followed the participant and used a floor plan of the development and recorded the following measures: (1) the route taken by the participant; (2) where participants hesitated for longer than three seconds; (3) where participants made errors when repeating the route (i.e. turning the wrong way at an intersection, or going up/down the stairs incorrectly). If participants were unable to accurately recall the route (i.e. if they made errors that they were unable to correct themselves), they were taken back to the start place and were shown the route an additional time, and were afterwards asked to repeat the route. This procedure was repeated until participants could accurately navigate the route without any errors. After successful learning of the route, participants completed a series of tasks addressing different aspects or route memory.

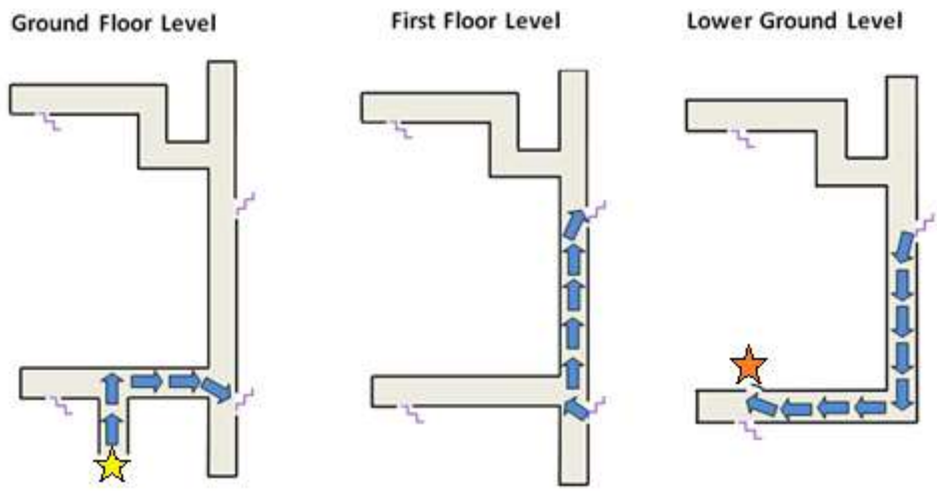

Figure 8.1: This image depicts the route participants took through the development. The yellow star indicates the start of the route, and the orange star shows where the route finished.

Figure 8.2: Left is a snapshot of one of the corridors walked along within the development. Upper right is the lobby at the start of the route that participants took. Bottom right is some of the art-work shown along the corridor walls.

Test Phase

The test phase consisted of seven separate tasks assessing different aspects of route knowledge, followed by a route recall phase (to measure whether participants could still remember the route after all tasks were completed).

Real World Route Memory Measures

Real World Landmark Sequence Task: This task was designed to assess participants' memory of the temporal sequence in which places were encountered along the route. Participants were presented with an A4 sheet of paper showing four rows of four photographs that were taken along the route and were asked to identify which row represented the correct order in which they encountered the depicted places along the route (see Figure 8.3). The photographs of places selected in this task were chosen at regular intervals along the route. Only one row showed the pictures in the correct order, the other three rows showed the same pictures, but in different orders. Participants repeated this task twice; once with pictures depicting objects/places at decision points (Landmark Sequence Decision Points) and once with pictures taken at non-decision points (Landmark Sequence Non-Decision points).There were four possible choices in this task, so chance level for this task was 25%.

Real World Decision Point Direction Task: This task was designed to assess participants' associative cue memory. Participants were shown photographs of all the decision points along the route, individually and in a random order, and were asked to state in which direction the route continued. Five of the nine decision points along the route were used in this task. Three were discarded because they were from within the staircases. Pictures were presented from the same viewpoint that they encountered from during navigation. Three of the decision points had two possible directions to choose between and two decision points had three directions to choose from. As such, chance level was 50% for three of the decision points, and 33.3% for two decision points. Overall chance level was therefore 43.20% (3 x 50 + 2 x 33) / 500).

Real World Direction Sequence Task: Participants were asked to talk through the route from beginning to end providing as much information and detail as they could. These route descriptions were recorded using a Dictaphone. Route directions were extracted and were marked as correct or incorrect. See Table 8.1 for example route descriptions.

Table 8.1: Examples of correctly and incorrectly recalled route directions during the Real World Direction Sequence Task.

Correct Recall	Incorrect Recall
Turn to the right. You pass a notice forward and at the end of that little corridor, there was a fire exit which led to the stairs. We went up one flight of stairs to the first floor. And then we turned right. Down that corridor. And then, at the last fire door, we turned into that and went up—no, we went down two flights to the lower ground floor and I hesitantly went the wrong way. We turned left following the pictures, I recognized, all over the wall. At the end of that, turned to the right and I noticed the fire hose department so I knew it was right there. I went to the end and there was a door which said, "The Residents' Lounge." (207)	*From the front door, turn right, through the fire exit, downstairs, turn left at the bottom, through the fire door, turn right—that's far as I can go. Turn right–turn left through the fire escape. Downstairs. Through the fire escape, turn right again. That's–I really am struggling ... I'm sorry. I got as far as I could." (219).*

Real World Map Task: This task was designed to assess participants' ability to identify a travelled route from a map perspective, which requires perspective taking and mental rotation abilities. Participants were presented with three schematic floor-plans of the development which depicted three different routes (see Figure 8.3 for an example of the stimulus). Their task was to select the map which they believed showed the correct route (i.e. the route that they had learned).There were three possible choices in this task, so chance level for this task was 33.3%. The scoring of the Map Task was either marked as correct or incorrect.

Real World Landmark Recognition Task: This task assessed participants' ability to recognise places they encountered along the route. Participants were presented with 24 pictures of places from within the development; 12 pictures were taken along the learned route, and 12 were distractors taken elsewhere in the environment. Participants were asked to indicate whether or not each place shown was or wasn't along the route by pressing the corresponding keys on the keyboard (1 for no, 0 for yes). Pictures from the route were either depicting a decision point (six from decision points) or a non-decision point (six from non-decision points). There were two possible choices for each of the 24 pictures, so chance level was 50%.

Real World Landmark Location Task: This task was designed to assess participants' ability to remember the locations of where places from along the route were within the environment. Participants were presented with a schematic floor-plan of the development in which 13 places were highlighted (star icons, see Figure 8.4). Participants were then presented with individual pictures taken at the highlighted places, all of which were along the route that participants had learned. Participants were required to indicate where each picture was taken on the map/floor-plan of the development by stating the star which they believed corresponded to each picture. Presentation of the pictures was randomised and participants were able to go back to previously allocated locations on the map if they felt the presented landmark was in that location (despite having already allocated it). Given 13 possible choices, chance level for this task was 7.69% (see Figure 8.4 for an example of the task stimuli).

Real World Pointing Task: This task was designed to assess participants' knowledge of the spatial relationship from one position (the location at the end point of the route) to other places within the environment. Participants were shown 13 individual pictures of landmarks/places that were along the route (the same that were used in the Landmark Location Task) and were required to point to where they believed the shown location to be from their current position (this task took place in the communal lounge, i.e. the end point of the route). They were then required to point to the target by adjusting an arrow on a self-made pointing device (A4 sheet with a compass). As for any pointing task, chance level was 90 degrees (absolute angular error).

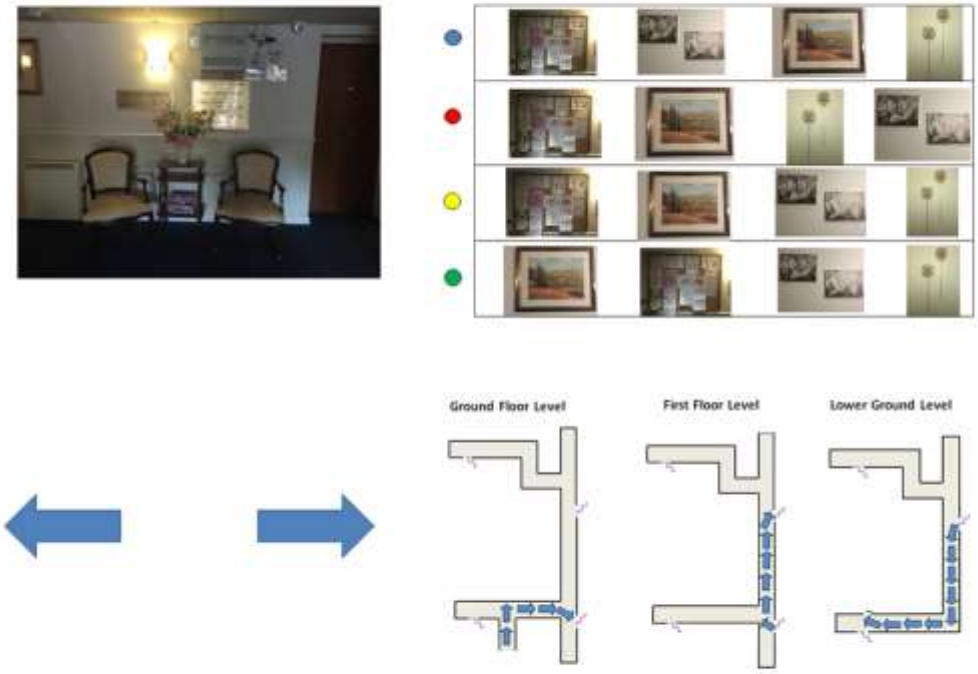

Figure 8.3: Three of the tasks used during the Real World condition. Left: Decision Point Direction Task – participants were shown individual pictures of places along the route and asked to indicate which direction they went at that point. Right Upper: The Landmark Sequence Task (decision points). Participants had to indicate which row was showing the correct order or landmarks. Right Lower: One of the three maps given to participants during the Map Task.

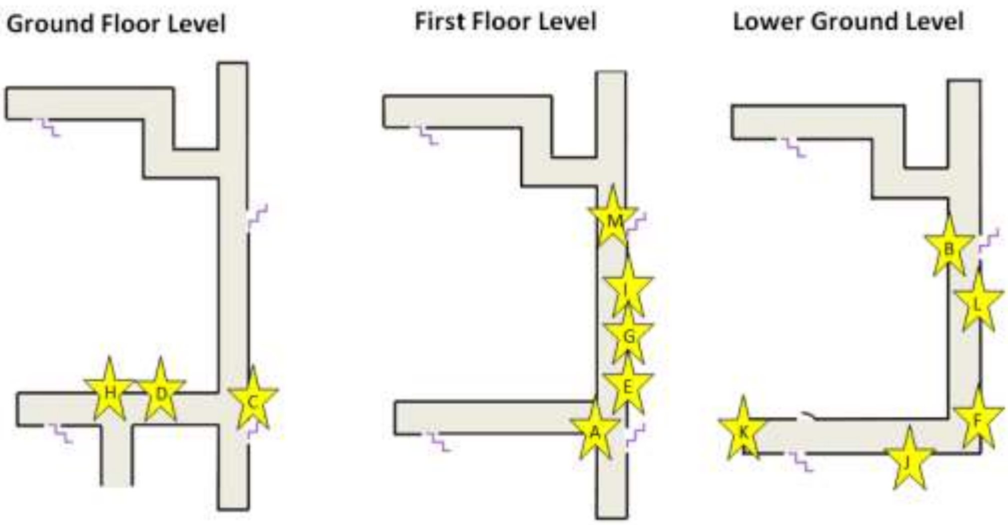

Figure 8.4: The stimuli used for the Landmark Location Task. Participants were presented with images of places along the route and were asked to state which star on the map that they corresponded to.

Real World Route Recall

Once participants had completed all seven test tasks, they were asked to repeat the route for a final time. This was done to investigate if participants could still remember the route and to assess memory decay.

Task Order

There were two different orders in which the tasks were administered (see Table 8.2), though we always began with the "landmark recognition" task to ensure performance in this task was not affected by the stimulus presentation in the other tasks. Half of the participants in both groups followed one order and the other half used the alternative order.

Table 8.2: The table below displays the two difference task orders that participants experienced the tasks as.

Order 1	**Order 2**
Landmark Recognition	Landmark Recognition
Landmark Sequence	Map Task
Verbal Directions	Decision Point Direction
Map Task	Landmark Location
Decision Point Direction	Verbal Directions
Landmark Location	Landmark Sequence
Pointing Task	Pointing Task

Condition 2

Participants were required to complete a virtual route learning task; this was a shorter version of the protocol presented in Chapter 3 (O'Malley, Innes & Wiener, 2018). This shortened version consisted of eight short routes which participants had to individually watch and learn. Once participants had demonstrated that they had learned the route, they were tested on their route knowledge with four different measures of route memory: Landmark Order Sequence Task, Perspective Shift (Map) Task, Landmark Direction Task and a Verbal Direction Task.

Study Location

Condition 2 took part in the Psychology Department at Bournemouth University's Talbot Campus.

The environment and routes

Using Vizard 3.0 (WorldViz) we created eight different short virtual routes. Each route consisted of four four-way intersections and each route featured one left turn, one right turn and one straight and one additional right turn, left turn or straight movement. Each intersection could be identified by a unique object (landmark) mapped onto a cube that was suspended from the ceiling in the centre of the intersection. We created a video of each route which showed a passive transportation along the entire route (each video lasted 28 seconds). During the experiment, the videos were presented on a Toshiba Satellite Pro Laptop (15" screen).

Procedure

Before starting the actual experiment, participants were shown a demo route and were talked through each of the tasks to ensure that they understood the procedure.

Experiment

The experiment consisted of eight separate blocks, each composed of a training phase, a test phase, and a route recall phase. Participants learned a different route in each block and the order in which routes were presented was random. Each block took approximately 6 minutes to complete, and participants were free to take breaks between trials if they wished.

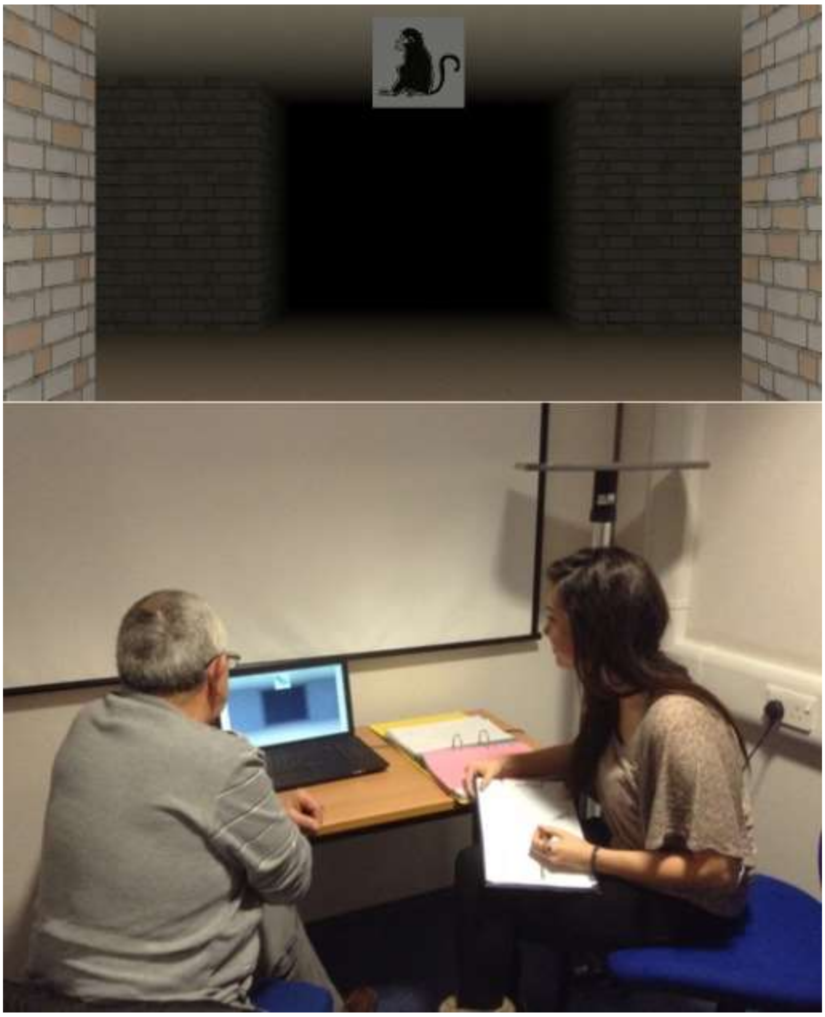

Figure 8.5: The top image shows the viewpoint of one of the routes used during the training phase. The lower image shows the testing room and room set-up during the experiment.

<u>Training Phase</u>

In the training phase, participants first watched a video of a route (see Figure 8.5). After the first presentation, participants were shown the route again, though this time the video was stopped at each intersection and participants were asked to indicate the direction of turn to continue along the route. If they made an error, they were shown the route again and asked to indicate the directions in which the route continued at each intersection. This procedure was repeated until participants were able to accurately indicate the direction of turn at each of the four intersections. The number of errors and the number of learning trials required to learn the route were recorded. Once participants successfully learned the route, they moved onto the test phase.

Test Phase

The test phase consisted of four different tasks that assessed different aspects of route knowledge:

VR Landmark Sequence Task: Participants were presented with four different arrangements of the four landmark objects of the route printed on an A4 sheet of paper. One of the arrangements displayed the correct temporal order in which the landmarks were encountered along a route, while the other three arrangements were variations of the correct order (e.g., the second and third object were swapped). The participants' task was to indicate which row of landmarks displayed the correct order of landmarks from start to finish on the route. The sequence task required participants to identify the correct sequence in which the four landmarks were encountered during route learning. Given four possible choices, chance level for this task was 25% (see Figure 8.6 for an example of the task stimuli). The scoring of the Landmark Sequence Task was either marked as correct or incorrect.

VR Landmark Direction Task: Participants were presented with pictures (printed on A4 paper) of landmarks from the route one at a time and in randomised order. Their task was to indicate in which direction the route continued at the corresponding intersection. The Landmark Direction Task (also referred to as the associative cue task) required participants to associate a movement direction to the landmarks during route learning. Chance level for reporting all four landmark direction associations correctly was 1.23%. For the Landmark Direction Task, a score was calculated depending on whether participants recalled all four landmark directions correctly (e.g. if participants got three out of four correct they were given 75% on that trial; see Figure 8.6 for an example of the task stimuli).

VR Direction Sequence Task: In the Direction Sequence Task, participants were asked to verbally report the sequence of direction changes or movements along the route (e.g. "left, right, straight, right"). Chance level for reporting all four direction changes correctly was 1.23%. For the Direction Sequence Task, a score was calculated depending on whether participants recalled all four directions correctly (e.g. if participants could give report the correct sequence of directions from the start to the end of the route they were given a score of 1, but if participants reported an incorrect direction along the route, they received a 0).

VR Map Task: Participants were presented with three different schematic map-like drawings of routes through a regular grid-like environment. One of these schematised routes depicted the route they had just learned while the other schematised routes were variations of the correct route (e.g. one turn was mirrored). The routes were printed on a sheet of A4 paper. The participants were required to indicate which route depicted the route they had just learned. The Map Task required participants to recognise the route from a top-down perspective. There were three possible choices during the Map Task, so chance level for this task was 33.3%. The scoring of the Map Task was either marked as correct or incorrect (See Figure 8.6 for an example of the task stimuli).

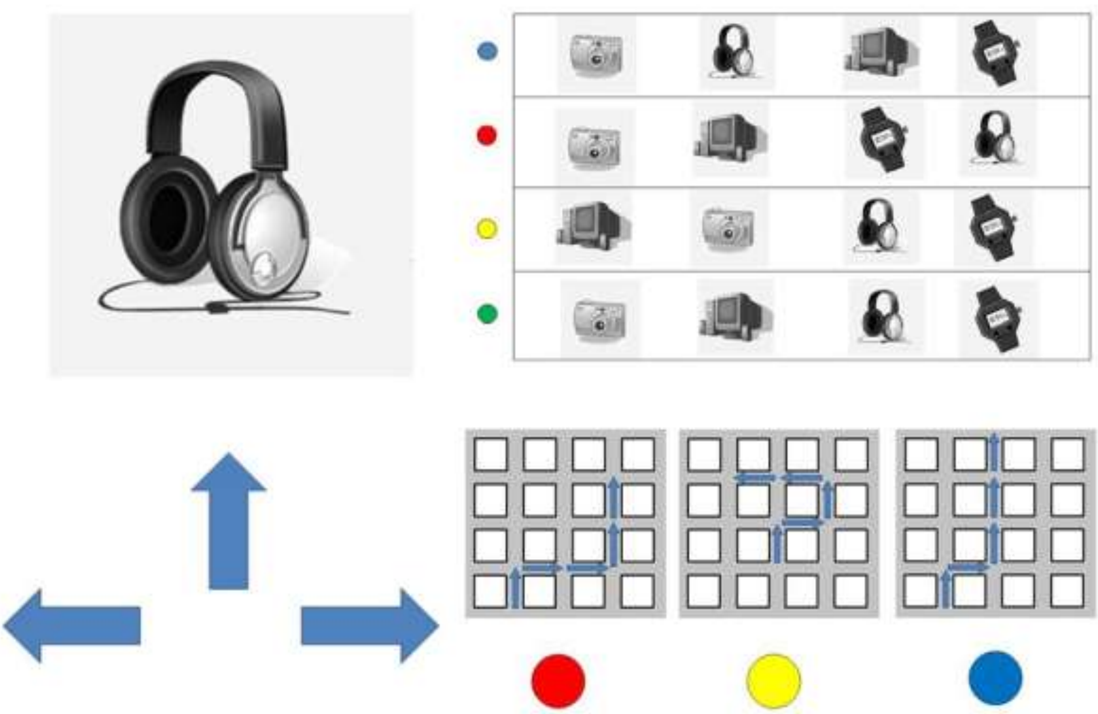

Figure 8.6: Stimuli used during the test phase. Left shows the Landmark Direction Task, upper right shows the Landmark Sequence Task, and the lower right shows the Perspective Taking Task.

VR Route Recall Phase

Once participants had completed the Test Phase, they were again presented with the video of the route to test whether they could still accurately recall the route. As in the learning phase, the video was stopped at each of the four intersections along the route, and participants were required to state the correct direction at each intersection.

Additional measures

Santa Barbara Sense of Direction Scale (SBSOD)

Two measures to assess participants' self-reported navigation abilities were issued. Firstly, all participants completed the SBSOD (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002), which has been used in numerous navigation experiments, though not in many ageing or dementia navigation studies (Taillade et al., 2016). The SBSOD scale consists of 15 statements that participants had to agree or disagree on using a Likert Scale. The SBSOD did not render significant differences between the two groups ($t(30) = -0.131$, $p = 0.897$).

Self-Ratings of Navigation Ability

Based on the findings from Chapter 4, it was important that we provided participants with a measure to assess navigational abilities that that related explicitly on their navigation abilities on the present day, as older adults can be less aware of the gradual changes to their navigational abilities that occur during ageing (Taillade et al., 2016). All participants were asked to rate (1) "How were your navigation abilities as a younger adult?" (Navigation Then) and (2) "How are your navigation abilities now?" (Navigation Now) using a 7 point Likert Scale ranging from 1 = Bad at finding my way to 7 = very good at finding my way.

Navigation Then: the High MoCA group participants rated their navigation abilities when they were younger adult as 5.72 (SD = 1.17) and the Low MoCA group participants rated them as 6.07 (SD = 1.14).

Navigation Now: the High MoCA group rated their current navigation abilities as 4.66 (SD = 1.28), whilst the Low MoCA group rated their current navigation ability as 4.57 (SD = 1.34).

An ANOVA with the between factor group (Low MoCA and High MoCA) and the within factor time (navigation now, navigation then) did neither reveal a main effect of groups ($F(1,32) = 1.009$, $p = 0.434$), nor a main effect of time ($F(1,32) = 1.425$, $p = 0.271$). There was also no significant interaction ($F(1,32) = 0.596$, $p = 0.750$).

8.4 Results

Overview

The analysis section will be divided into two sub-sections to address the specific research questions. We firstly looked at the performance of typical ageing and early atypical ageing on the specific tasks in each condition (Real World versus VR). Secondly, we compared performance between Real World and VR for those tasks which had protocols that allowed for this comparison.

Is there a difference between participant groups?

Real World Navigation

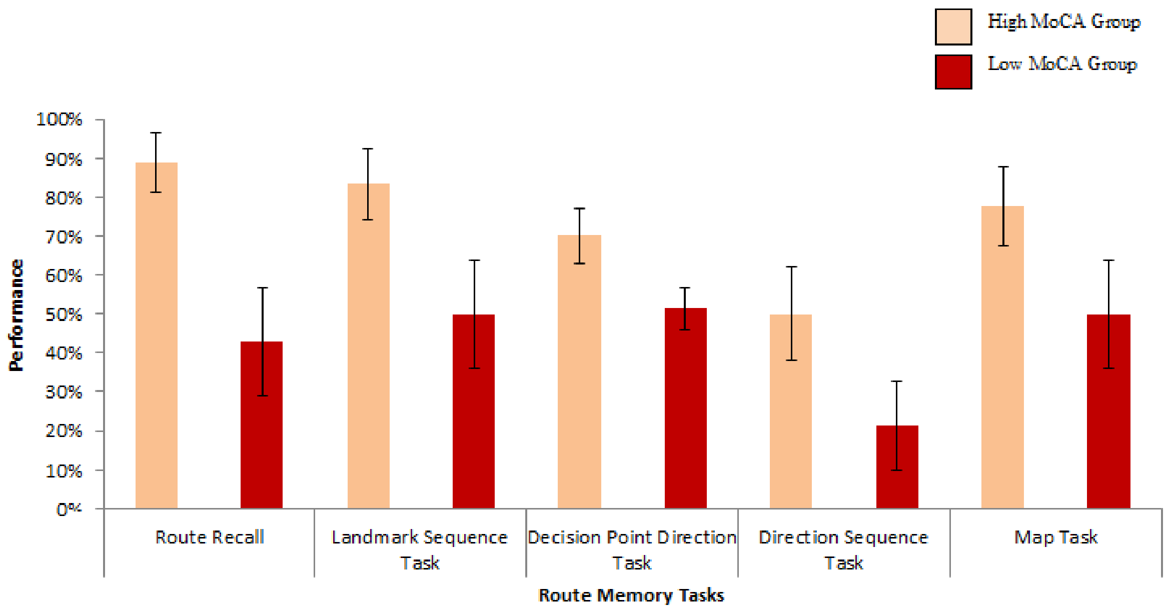

Figure 8.7: Performance by task in the Real World condition for both the typically ageing (High MoCA group) adults and the older adults displaying early signs of atypical ageing (Low MoCA group).

We first analysed whether there were any differences in performance between participants who scored in the higher MoCA cut-off bracket (26-30) to those who scored in the lower bracket (22-25). For this we ran t-tests, comparing the performance between the groups for each of the tasks, both in the Real World condition (see Table 8.3) and in the virtual environment (VR) condition (see Table 8.4).

Table 8.3: Summary of t-test comparisons between the High MoCA group (typically ageing) and the Low MoCA group (early signs of atypical ageing) on route memory measure tasks for the Real World condition.

Real World Condition and Tasks	**High MoCA Mean (±SD)**	**Low MoCA Mean (SD)**	**t**	**DF**	**P value**
Route Learning	1.28 (SD= 0.46)	2 (SD = 0.55)	4.02	30	< 0.001
Route Recall	89% (SD = 32.3)	43% (SD = 51.4)	3.10	30	< 0.005
Landmark Sequence Task	83.33% (SD = 38.38)	50% (SD= 51.88)	2.09	30	< 0.05
Landmark Sequence Task (non-decision points)	72.22% (SD = 46.08)	42.86% (SD = 51.35)	1.70	30	= 0.099
Decision-Point Direction Task	70% (SD = 29.30)	51.42% (SD =20.32)	2.02	30	= 0.052
Direction Sequence Task	50% (SD = 51.4)	21% (SD = 42.6)	1.68	30	= 0.104
Map Task	77.78% (SD = 42.77)	50% (SD = 51.83)	1.66	30	= 0.107
Landmark Recognition Task (C Criterion)	47.48% (SD = 41.05)	32.77% (SD = 43.93)	0.98	30	= 0.337
Landmark Location Task (Exact Position)	48.28% (SD = 19.88)	44.50% (SD =20.50)	0.53	30	= 0.602
Landmark Location Task (Correct Level)	82.73% (SD = 15.78)	73.40% (SD = 13.30)	0.64	30	= 0.086
Pointing Task	54.83 % (SD = 19.77)	49.57% (SD = 21.58)	0.72	30	= 0.479

For the Real World condition (see Figure 8.7 for performance on tasks), t-test analyses between the High MoCA and Low MoCA groups revealed significant differences in performance for the Route Learning, Route Recall and Landmark Sequence Task (decision points). All other measures of route memory did not render significant differences in performance between the groups (see Table 8.3 for results).

VR Navigation

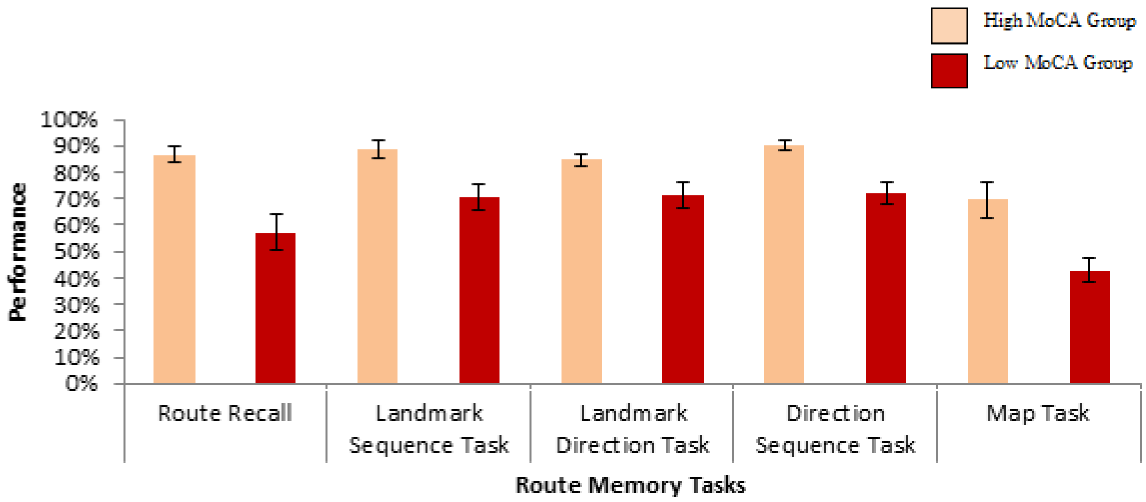

Figure 8.8: The performance (y axis) by task in the VR condition for both the typically ageing (High MoCA group) adults and the early atypically ageing adults (Low MoCA group).

Table 8.4: Summary of t-test comparisons between the High MoCA group (typically ageing) and the Low MoCA group (early signs of atypical ageing) on route memory measure tasks for the VR condition.

Condition and Task	**High MoCA Mean (SD)**	**Low MoCA Mean (SD)**	**t**	**Degrees of freedom (df)**	**P value**
VR Route Learning	1.701 (SD = 0.520)	2.160 (SD = 0.533)	2.45	30	< 0.05
VR Route Recall	86.16% (SD = 13.19)	57.14% (SD = 24.86)	5.06	30	< 0.001
VR Landmark Sequence Task	88.89% (SD =14.14)	70.54% (SD = 18.73)	3.16	30	< 0.005
VR Landmark Direction Task	84.72% (SD =10.38)	71.21% (SD = 17.47)	2.73	30	< 0.01
VR Direction Sequence Task	90.28% (SD = 8.29)	71.88% (SD = 15.55)	4.31	30	< 0.001
VR Map Task	69.44% (SD = 27.52)	42.86% (SD = 16.04)	3.21	30	< 0.005

For the VR navigation condition (please see Figure 8.8 for performance on tasks), T-test analyses between the High MoCA and Low MoCA found significant differences (see

Table 8.4 for results) in all measures of route memory (VR Route Learning, VR Route Recall, VR Landmark Sequence Task, VR Landmark Direction Task, VR Direction Sequence Task and VR Map Task). Table 8.5 provides an overview of the findings.

Table 8.5: summary of the findings on performance in the route memory tasks used for Real World and VR conditions. The effects of early atypical ageing were only found in the Route Learning, Route Recall and Landmark Sequence (decision points), whilst the effects of early atypical ageing were found in all measures in the VR condition.

Task	**Real World Condition:** Differences between High and Low MoCA	**VR Condition:** Difference between High and Low MoCA
Route Learning	✓	✓
Route Recall	✓	✓
Landmark Sequence Task (decision points)	✓	✓
Landmark Sequence Task (non-decision points)	✗	N/A
Decision Point Direction Task/ Landmark Direction Task	✗	✓
Direction Sequence Task	✗	✓
Map Task	✗	✓
Landmark Recognition (C Criterion)	✗	N/A
Landmark Location (Exact)	✗	N/A
Landmark Location (Correct Level)	✗	N/A
Pointing Task	✗	N/A

How does performance in VR navigation relate to Real World navigation?

Learning Trials

A Pearson's R correlation coefficient was calculated to assess the relationship between the number of learning trials required to learn the routes in the VR condition and the Real World condition. There was a positive relationship between the number of learning trials per condition ($r = 0.438$, $n = 32$, $p < 0.05$), suggesting that route learning performance assessed in simplistic virtual environments does reflect participants' route learning performance in more complex Real World environments.

Route Knowledge Tasks

In the VR condition, participants learned eight different routes, while in the Real World condition, only one single route was learned. Accordingly, for the majority of the Real World condition route memory tasks, only a single response (correct/incorrect) was recorded, while we had eight responses in the VR condition. To directly compare performance in the route memory tasks between conditions, we therefore split the data for each task according to whether or not participants did answer correctly in the Real World condition. If performance was related between conditions, we expected better performance in the virtual environment condition for those participants who responded correctly in the Real World and vice versa.

Figure 8.9 summarises the results of these analyses. In summary, participants who solved the real world tasks correctly also performed better in the VR condition in all but the Direction Sequence Task.

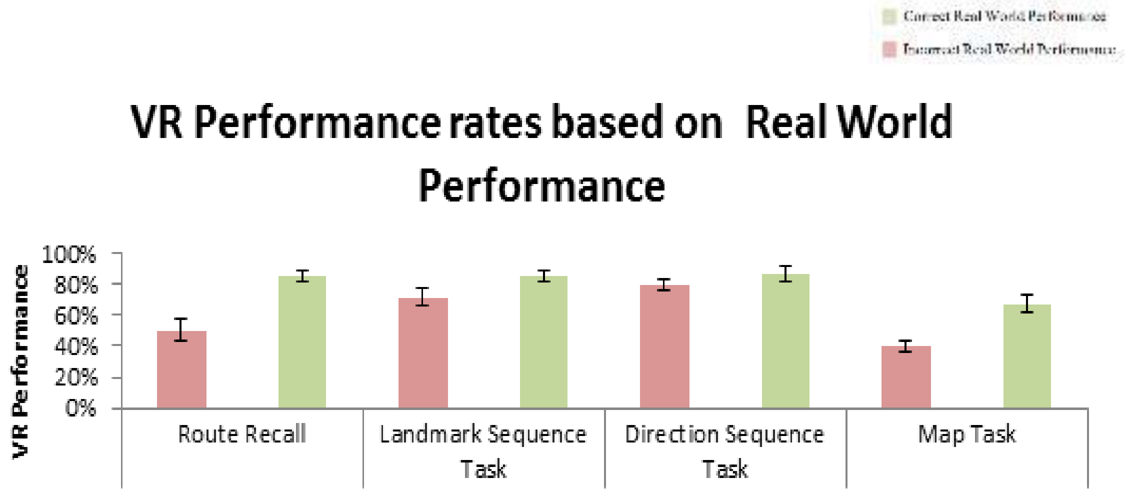

Figure 8.9: Performance on VR route memory tasks dependent on whether they were correctly (green) or incorrectly (pink) recalled during the Real World condition.

There were four tasks which were directly comparable between conditions. Paired sample t-tests were conducted on Route Recall, the Landmark Sequence Task, the Direction Sequence Task and the Map Task, irrespective of participant group. Table 8.6 provides a summary of the t-tests and findings, highlighting similar trends in performance for the Route Recall, Landmark Sequence Task, Direction Sequence Task and Map Task between the two conditions (Real World navigation and VR navigation). Please see Table 8.7 for a summary.

Table 8.6: Summary of t-test comparisons between the route memory measures for Real World and VR conditions for all participants.

Task	**Correctly Recalled Mean (SD)**	**Incorrectly Recalled Mean (SD)**	**t**	**Degrees of freedom (df)**	**P value**
Route Recall	84.66% (SD = 22.82) 16 High MoCA and six Low MoCA	50.00% (SD = 15.39) Two High MoCA and eight Low MoCA	5.063	30	< 0.001
Landmark Sequence	85.23% (SD = 17.52)	71.25% (SD = 17.72)	-2.084	30	< 0.05

Task	Fifteen High MoCA and seven Low MoCA	Three High MoCA and seven Low MoCA			
Direction Sequence Task	86.46% (SD = 15.21) Nine High MoCA and three Low MoCA	79.69% (SD = 14.67) Nine High MoCA and eleven Low MoCA	-1.247	30	= 0.222
Map Task	67.26% (SD = 26.94) Fourteen High MoCA and seven Low MoCA	39.77% (SD = 13.48) Four High MoCA and seven Low MoCA	-3.164	30	< 0.005

Table 8.7: A summary of the route memory measures which had similar results between the Real World and VR conditions.

Task	**Whether performance in the Real World condition predicts performance in the VR condition.**
Route Recall	✓
Landmark Sequence Task	✓
Direction Sequence Task	✗
Map Task	✓

The t-test comparisons showed that three of the four measures of route memory displayed similar performance for between Real World and VR conditions; participants who performed better in the Real World also performed better in the VR condition (see Table 8.7).

8.5 Discussion

This study focused on route learning in real world and VR environments amongst older adults to investigate which aspects of route memory are affected by early atypical ageing, and if navigation performance in simplistic VR environments relates to real world navigation. Specifically, this study has used a new route learning paradigm that assesses route knowledge after participants have been trained on a route (that was developed in Chapter 3) to apply it to the real world setting. Although previous studies have demonstrated comparable results between real world and realistic VR environments (Cushman et al., 2008), no study had yet compared simplistic VR set-ups in relation to real world navigation, despite the vast body of navigation studies that have used simplistic set-ups (Zhong & Moffat 2017; Janzen & Jansen 2010). This study therefore further explored whether performance in a complex real world setting was related to performance in a simplistic VR setting.

Performance on comparable tasks between VR and Real World conditions were similar for the Route Recall, Map Task and Landmark Sequence Task suggesting that both conditions were reporting and reflecting similar patterns in performance for these tasks.

Whilst there were differential effects of early atypical ageing on different route memory tasks, the overall effects of early atypical ageing were more pronounced in the VR condition. This suggests that simplistic VR settings are potentially more sensitive in detecting the earliest changes in navigation abilities in atypically ageing adults than in real world settings. One possible explanation for this is that real world environments are typically much richer, offer more cues, and therefore allow for more strategies to be adopted when learning them. These extra factors that real world environments offer could therefore be used to compensate for the declining performance when applying the specific in navigation strategies that simplistic VR settings are targeting.

Navigation in the Real World

The Real World condition required learning one route through a retirement development, and, after successful learning, completion of seven route memory tasks followed by a post-test route recall phase. We found the effects of early atypical ageing were only present for the route learning phase, for the route recall phase and the Landmark Sequence Task (decision points), but not for the other tasks (Landmark Sequence at non-decision points Task, Map Task, Landmark Recognition Task, Landmark Location Task and Pointing Tasks) during the Real World navigation condition. Existing research that has tested older adults who display early signs of atypical ageing on route memory abilities in real world environments (Benke et al., 2014; Monacelli et al., 2003; Cherrier et al., 2001) has been able to highlight differential effects of atypical ageing on a wider range of route memory measures. Importantly though, the present study differs from previous research (Pengas et al., 2010; Cherrier et al., 2001) in that route memory was tested only after participant had successfully learned the route. As earlier studies used the same training protocols for each participant group, it is not clear whether the differences in knowledge about the order of landmarks that were encountered or differences in identifying movement directions associated with landmarks (Head & Isom, 2010) highlight age-related navigation deficits or if they instead reflect differences resulting in slower route learning.

Map reading (or perspective taking) abilities (Cherrier et al., 2001), temporal sequencing (Bellassen et al., 2012) and landmark location memory (Cushman et al., 2008) have all been found in previous real world studies to be particularly sensitive to the effects of atypical ageing (atypical ageing defined as a diagnosis of MCI or AD in their experiments). However, these studies had not assessed whether or not participants had in fact learned the route.

Additionally, the ability to bind directional information to specific landmark object (i.e. associative learning as measured in the decision point direction task) has also been found to be impaired in early atypical ageing (Boespflug, Eliassen, Welge, & Krikorian, 2014). Whilst performance differences between groups in the decision point direction task did not reach statistical significance (with a p value of 0.052) it showed a strong trend which is consistent with Chapter 3 (O'Malley, Innes and Wiener, 2018), and suggests that binding directional information to landmarks does becomes weaker during early atypical ageing (Head & Isom, 2010; Old & Naveh-Benjamin, 2008; Salthouse, 1994).

No differences between the two groups were found for the Map Task which contrasts previous findings as map-reading and perspective taking have been shown to be affected during early atypical ageing (Cherrier et al., 2001). Given the multi-level nature of the route and the map presented, it may be that the route depicted on the three separate levels was easier to identify as each level depicted only two decision points. If participants could see that the distractor routes showed a different part of the route on level two, the correct map may have been easier to identify. Participants may have also been able to regionalise segments of the route dependent on floor level (Wiener, Schnee , & Mallot, 2004) which would make the Map Task simpler and may thus explain why this task did not yield a significant difference.

Most of the existing literature investigating landmark sequence memory has found differences between aged controls and those with MCI and AD (Bellassen et al., 2012). The present study did find differences between the two participant groups, particularly for the Landmark Sequence Task at decision points, although this was not the case for landmarks at non-decision points. Chapter 3 also did not find any differences between typically ageing adults and older adults displaying early signs of atypical ageing adults for the Landmark Sequence Task (though these were for decision points), so future studies should further investigate this effect explore the inconsistencies in results.

The Pointing Task did not yield significant differences between typically ageing adults and older adults displaying early signs of atypical ageing. Although these findings are consistent with the Pointing Task findings in Chapter 4, they do contrast some previous studies that have explored pointing ability in typically and atypically ageing adults (Tu et al., 2017). Path integration has been shown to be affected by ageing (Allen et al., 2004), however it may be that this ability is still reliable for short routes (as used in all the tasks), and less affected by early atypical ageing. Tu et al. (2017) found that participants with AD were significantly worse at completing a pointing task in a virtual supermarket environment than controls and people with behavioural FTD, while both the AD and behavioural FTD groups were equally poor at completing a map-based task. While the present study did not use clinical cohorts, Tu et al., (2017) did suggest that the declines in performance for their pointing task could be due to AD related effects on path integration. Path integration remained intact in the behavioural FTD group and control group in their study (Tu et al., 2017).

The findings from the present study firstly emphasise that participants categorised as early atypically ageing defined by the MoCA thresholds (Lee et al., 2008; Luis et al., 2009; Nasreddine et al., 2005), performed well on this task because, (1) they are still only experiencing the earliest symptoms of early atypical ageing which has not yet affected their path integration system or, (2) that they could be displaying forms of atypical ageing that are not Alzheimer's related (such as behavioural FTD) which would explain the declines in allocentric map-based tasks. Importantly though, unlike previous studies, the present study ensured that participants were trained on the route and could successfully repeat it. This could suggest either that participants' path integration system requires more exposures to reliably learn the route, which would subsequently affect performance on related route memory tasks, or that participants required more exposures of the route to accurately learn the route knowledge along the route.

Early atypical ageing did not affect landmark location memory either. This finding contrasts the literature (Cherrier et al., 2001; deIpolyi et al., 2007; Rusconi et al., 2015; Cushman et al., 2008), as previous studies have suggested that this aspects of route knowledge is significantly affected by early atypical ageing. Again, this may be explained by the protocol used in this study, which ensured participants had successfully learned the route. Previous studies have focused predominantly on the route learning process (i.e. only showing participants a route after a set number of exposures and then testing them on their memory) (Cherrier et al., 2001; Cushman et al., 2008), which would suggest that landmark location memory is an important factor that contributes towards successful route learning. Another consideration is that earlier studies have compared older controls with clinical groups (with a diagnosis of AD), which could also suggest that these changes in landmark location memory occur at a later stage during the atypical ageing process.

Additionally, landmark location memory in this study was tested on a multi-level route whereas previous studies had explored this on a single level basis (deIpolyi et al., 2007; Widmann, Beinhoff, & Riepe, 2012). Participants could have regionalised the route to create separate representations for each level (as compared to one complex representation), which would have facilitated their memory on this task (Wiener et al., 2004) and would explain why this task was easier to complete compared to previous studies that had used a single level. For example, in the Real World condition each floor displayed different categories of landmarks (e.g. floor two had pictures of landscapes along the corridors and floor three had pictures of flowers along the corridors).

The environmental cues (e.g. door numbers, floor level signage, themes of wall art) available in the Real World environment may have additionally facilitated learning aspects of the route, compared to the well-controlled VR route. This was also reported by Hölscher, Meilinger, Vrachliotis, Brösamle, and Knauff (2006) who found that navigators in a complex multi-level building used floor level signage and room numbers to orient. Future studies should further explore regionalisation of routes amongst typically and early atypically ageing adults as this could have implications for the environmental cues featured along a route if it better supports navigation. If navigators can learn routes and better memorise aspects of routes that have been regionalised through the use of environmental cues to create separate representations, it would explain why the complex retirement development better supported navigation than simplistic (or repetitive) environments, which may have important implications for the design of environments.

No significant differences between typically ageing adults and the older adults displaying early signs of atypical ageing were found in the Landmark Recognition Task, in which participants had to identify landmarks that were present along the route among distractors. Landmark recognition memory alone does not provide enough information to support navigation, as no directional information (which is vital and necessary for navigation) can be inferred purely from recognising landmarks. Rather, recognising landmarks that were present along a learned route serves as a prerequisite to egocentric navigation strategies as it needs to be recalled in conjunction with directional or location information to support successful navigation (Waller & Lippa, 2007; Wiener et al., 2013). The landmark recognition memory findings in this thesis are in line with Lipman (1991), who found that older adults tend to point out salient objects rather than turns or intersections as being navigationally relevant (Lipman, 1991). The fact that the typically ageing adults and older adults displaying early signs of atypical ageing showed similar performance rates demonstrates that memories of landmarks (when not associated with directional information) are less affected by the effects of early atypical ageing than other aspect of route knowledge. This is consistent with previous findings (Monacelli et al., 2003). The findings from the Landmark Recognition Task, together with the findings from the other route memory measures, demonstrates that differences between typically ageing adults and older adults displaying early signs of atypical ageing cannot simply be explained by non-specific differences in memory or memory decay. Instead, these effects of early atypical ageing are navigation specific.

Navigation in VR

The VR condition used a shortened replica of the Chapter 3 procedure, with participants watching videos of short routes through a VR environment, and after demonstrating that the route had been learned, completing four tasks assessing different aspects of route memory. We found that all measures of route memory, including route learning and route recall, were affected by early atypical ageing in the VR condition.

Route learning has been shown to be consistently affected by atypical ageing, with atypically ageing adults requiring more exposures to a route, as well as having difficulties learning routes that consist of more than five decision points (Pengas et al., 2010). We found effects of early atypical ageing present in the route learning (i.e. the number of learning trials required to successfully learn the routes). Interestingly, no differences were found between typical and early atypically ageing adults in Chapter 3 for route learning.

Consistent with Chapter 3, there were significant differences between the two participant groups for the Map Task (or the perspective taking task in Chapter 3). This effect in reduced map reading abilities has been repeatedly reported (Cherrier et al., 2001; Chapter 3; Chapter 4), reiterating that the ability to identify maps, is severely affected by early atypical ageing and should be considered as an inclusion when assessing for cognition.

Compared to the findings from Chapter 3, some of the findings on specific aspects of route knowledge in this Chapter were slightly contrasting. The participant groups showed significant differences for the Landmark Sequence and Sequence of Directions tasks, while effects of early atypical ageing on the Landmark Sequence Task and Sequence of Directions Task were less pronounced (or non-existent) in Chapter 3. Earlier studies investigating Landmark Sequence memory have used a variety of ways to test this, with some using free recall of directions or ordering pictures of places that were along a route (Bellassen et al., 2012; Head & Isom, 2010; Wilkniss et al., 1997).

The majority of previous studies testing temporal sequence memory have found the effects of early atypical ageing to be present when testing for sequence/temporal memory (Bellassen et al., 2012). One explanation for this discrepancy in findings for the Landmark Sequence Task between Chapters 3 and 8 could be because data from all routes, irrespective of whether or not they could still repeat the route during the post-test phase, were included during this analysis in Chapter 8. This route learning paradigm enables data to be separated based on whether participants could or could not correctly recall the route during the route recall phase. This was the case with the data reported in Chapter 3; only data from trials participants could correctly recall were included in the analysis. As this was not feasible in the Real World Condition (due there only being one route in this condition, and there not being enough data if doing so), this chapter used data from all trials (not just correctly recalled ones).

As a result, the findings for the separate measures of route knowledge were not controlled for by forgetting and memory decay, so declines in performance for the Landmark Sequence Task in this Chapter could be as a result of forgetting the route. Chapter 3 found that landmark sequence memory was unaffected by both typical ageing and early signs of atypical ageing. Supporting this argument, previous studies that have tested temporal sequence memory (Bellassen et al., 2012) have often not included a post-test route recall phase (to see if participants can still remember the route), and have reported differences in typical and early atypical ageing. This therefore could suggest that landmark sequence memory is important for repeating and remembering the route during a recall phase.

How does performance in the Real World condition relate to performance in the VR condition?

In both the VR and the Real World conditions, participants underwent the same route learning protocol; they first learned a route until they could successfully recall it, completed a series of tasks that assessed their route knowledge, and were then tested on their ability to recall the route during a port test phase. Participants who performed better in the Real World also performed better in the VR condition for the Route Recall, Landmark Sequence Task and the Map Task. This supports earlier findings from

Cushman et al., (2008) whereby performance in route memory tasks in VR environments reflect performance in Real World navigation. The present study furthers this by demonstrating similarities in performance even between simplistic VR environments and complex real world environments.

The only task which did not yield similar performance patterns between VR and Real World conditions was the Sequence of Directions task. This is not surprising to some extent, as the free recall of purely directional information along a longer multi-level route is a much more complex task than recalling the four turns experienced on the VR condition. The Real World condition required participants to indicate not only two-dimensional ("left, right, straight") directions, but also three-dimensional directions ("up and down") when at the staircases. Therefore, the nature of the task in the Real World condition was different from that measured in VR. There was little difference in the VR Direction Sequence Task performance (overall % performance) depending on whether or not participants got the directions correct or incorrect during the Real World condition (i.e. participants who performed better for the Direction Sequence Task in the Real World condition did not necessarily perform better in the VR condition; see Figure 8.9).

The length of the route was much longer in the Real World condition than the routes used in the VR condition, which would have affected temporal sequence memory. Specifically, recalling directions, if not presented with any other environmental information (landmarks, cues, signage) is harder if the if the route is longer (Waller & Lippa, 2007) which could explain why this task was harder in the Real World condition than the VR condition.

With regards to the differences between the Real World and VR conditions, the VR condition required participants to passively navigate along the route. Passive navigation does impact on the motion cues available during learning as it deprives a navigator of vestibular and proprioceptive input, which would subsequently affect path integration (Chrastil & Warren, 2012; Loomis et al., 1999). Although participants were trained to learn the routes and demonstrated that they had learned them, the passive navigation during the VR condition may have influenced how well participants memorised aspects of route knowledge and could explain why the effects of early atypical ageing were more pronounced in the VR condition than the Real World condition. For example, the effects of early atypical ageing were more pronounced in the simplistic VR condition compared with the Real World condition, and could result from the lack of motion cues in VR. The patterns in performance though, between conditions, were similar to earlier research that had older adults and people with MCI and AD passively learn a route through a hospital (via wheelchair) (Cushman et al., 2008).

Limitations

While the current study has demonstrated that there are some similarities and differences in navigation abilities in the real world compared with VR, there are some considerations that should be addressed. Firstly, it is important to note that all the participants were physically active older adults. It is therefore possible, that our results may not necessarily reflect navigation performance of all typically ageing (from a cognitive perspective) adults aged over 65, as it is frequently seen that mobility decreases with age (Alsnih & Hensher, 2003). The findings do demonstrate, though, that despite both groups having similar levels of mobility, there were strong differences in route memory ability in the VR condition, suggesting the effects are independent of level of mobility, and are as a consequence of early atypical ageing.

Likewise, the study demonstrated similar trends in the two conditions, which suggests that the role of passive (the VR condition) and active (the Real World condition) navigation had little (if any) effect on participants' performance on the three out of the four comparable route memory tasks (i.e. the Map Task, Landmark Sequence Task and Route Recall). This could potentially be explained by the measures of route memory used in the study. Active navigation has been highlighted as key to the development of our survey representations of an environment (Appleyard, 1970; Chrastil & Warren, 2012), and provides navigators with additional physical (e.g. idiothetic information) and cognitive factors (e.g. decision making and attention) when learning a route in an active versus a passive condition (Wilson, Foreman, Gillett, & Stanton, 1997). As this study focused especially on route memory rather than survey memory, the contribution of active navigation could not be properly explored. Future studies could also include survey tasks (pointing) in the passive condition to investigate the effects of passive and active navigation on a survey knowledge. Future adaptations of this study could also include a third condition where participants are shown a video of a Real World, which would include the additional environmental cues in the controlled, passive navigation set-up.

The Real World data was obtained from participants learning one route, and therefore relies on one trial (or data point) per participant, while the VR studies relied on data from multiple trials per participant. It is evident from the standard deviations that there was more variance in Real World condition which could explain why numerical differences did not reach statistical significance for some of the measures of route memory. Future studies should involve testing participants on a variety of routes within the Real World (ideally, the same number of routes as used in the VR condition if also run) to capture and investigate how navigation is affected by early atypical ageing more reliably.

8.6 Conclusion

This study used a new route learning paradigm in which participants were first trained to learn a route, and were then tested on different aspects of route knowledge. First developed and reported in Chapter 3 of this thesis, the study presented in this Chapter has demonstrated that the different effects of early atypical ageing are also present in a complex real world setting and for different measures of route memory. This is the first study to investigate whether typically and early atypically ageing participants who performed better in the Real World also performed better in a simplistic VR condition. Results demonstrate similarities in route learning and memory measures between conditions. The VR condition highlighted the effects of early atypical ageing in all measures of route memory, whilst the Real World condition only captured effects of early atypical ageing in the route learning, landmark sequence (at decision points) suggesting that simplistic VR set-ups are more sensitive in detecting early changes in navigation ability during early atypical ageing. This could have implications for the cognitive screening and neuropsychological measures (in detecting symptoms of early atypical ageing), which should be further explored.

CHAPTER 9: Discussion

The purpose of this thesis was to investigate the navigation performance amongst typically ageing adults and older adults displaying symptoms of early atypical ageing in the built environment. This was done by explicitly testing route memory in an experimental, controlled fashion, as well as by using qualitative methods to explore the lived experience and accounts of older adults when navigating in a real world environment. As such, the thesis adopted a mixed-methods approach, investigating route learning and route memory using VR environments (see Chapters 3 and 4). Qualitative techniques were used to capture older adults' experiences of navigating in the real world environment and their preferences towards aspects of built design they felt needed improving to better support their navigation. Route memory during VR and real world navigation was compared to investigate how generalizable results from simplistic VR environments relate to real world navigation. This was achieved using a new route knowledge paradigm that was developed for this thesis, initially developed in VR and then applied in the real world setting. This chapter will provide a summary of the key findings of the research presented, discuss the theoretical and practical contributions to the field of research, as well as suggest recommendations for future research.

Summary of Key Achievements/Findings

The key achievements and key experimental findings related to the route memories of typically ageing adults and older adults displaying early signs of atypical ageing were:

- The development of a new route learning paradigm that was first developed in VR and then applied to the real world that reliably tests route knowledge after participants have been trained (and have successfully learned) short routes (see Chapters 3 and 8).
- That memory for landmark direction associations (i.e. associating a landmark with a direction) was particularly sensitive to the effects of early atypical ageing. This highlights that associative cue memory deteriorates during early atypical ageing.

- The effects of early atypical ageing on navigation ability were clear-cut for map-based tasks that require changes between egocentric and allocentric perspectives, particularly when having to identify a recently learned route from a map perspective, and when having to first study a YAH map and then navigating to the goal location (see Chapters 3 and 4).
- YAH maps with predefined routes from the YAH point to the goal location were not more beneficial than maps that only had the YAH point and the goal location (termed free navigation routes in Chapter 4) in successfully navigating to the goal zone (see Chapter 4), in which case participants planned the route to the goal rather than following a predefined path.
- Clear differences between the Old Low MoCA (early atypical ageing) and Old High MoCA (typical ageing) groups were found in a number of route memory tasks, which confirms that the MoCA is sensitive to cognitive impairments.

The key findings relating to qualitative reports and the design of environments were that:

- The review of existing dementia friendly design guidelines that address orientation highlighted that these design guidelines still remain largely unspecific (1) in their suggestions of ways to reduce disorientation, that (2) there was little research to support the specifics of some suggestions, and (3) little guidance on how to successfully implement the design suggestions. These three points above particularly relate to how landmarks are used to support orientation, and where landmarks should be placed in the environment to support orientation, which was not currently specified in the guidelines (see Chapter 5).
- Design can impact on residents' confidence to freely navigate within the environment (see Chapters 6 and 7).
- Repetitive layouts were a major cause of disorientation for older adults in both familiar and unfamiliar environments (see Chapters 6 and 7), which is consistent with earlier reports (Passini et al., 2000).
- The importance of "homely" environments was echoed by both residents (familiar) as well as unfamiliar older adults within retirement settings (see

Chapters 6 and 7) which is consistent with reports from other settings (e.g. care homes) (Innes et al., 2011).

- Similarities in reports between participants that were familiar or unfamiliar with environments were found. Participants in both studies voiced the need for more memorable and unique spaces along the corridors to support their orientation (see Chapters 6 and 7).

Key findings related to VR navigation versus Real World navigation were that:

- The effects of early atypical ageing on route memory performance were enhanced and more visible in the VR condition than the Real World condition (see Chapter 8).

Theoretical contributions

Ageing, Atypical Ageing and Navigation

The effects of typical ageing and early atypical ageing on navigation performance were found in a variety of route memory measures. In Chapters 3 and 8, a novel route learning paradigm that tested route memory after demonstrating successful route learning was used, which allowed investigation of performance on routes that participants could correctly recall (and remember) during a post-test phase, versus those they could not remember. The findings from Chapters 3 and 4 highlighted the effects of typical ageing (by comparing typically ageing adults with young controls), whilst the effects of early atypical ageing (by comparing typically ageing adults with older adults displaying early signs of atypical ageing) were reported in Chapters 3, 4 and 8. Findings from specific route memory measures will now be discussed in relation to their employed strategy.

Egocentric Navigation

This thesis focused predominantly on egocentric route learning and knowledge which has been suggested to be less affected by ageing than allocentric survey knowledge representations. This would shed light on the mechanisms typically and early atypically ageing adults would use when learning a route (Harris & Wolbers, 2013; Moffat, 2009). Previous studies that investigated route knowledge in typical and atypical ageing have focused predominantly on route learning and not knowledge once participants have demonstrated that they have learned routes (Head & Isom, 2010; Wilkniss et al., 1997). There had therefore been little research that investigated route knowledge for successfully learned routes, which is pivotal to understand the navigation strategies used during successful navigation. This is because these earlier studies have not necessarily tapped into the memory processes of routes that participants can repeat. Earlier findings that report declines in performance for typically ageing adults, and older adults showing signs of early atypical ageing, could therefore be reporting findings that are attributed to forgetting and memory decay. Furthering our understanding of which aspects of route knowledge remain relatively intact in early atypical ageing, will highlight the navigational strategies adopted by such adults. This in turn could influence design guidelines as well as influence the suggestions navigational support for older adults. With this in mind, this thesis sought to understand the effects of early atypical ageing on measures of route memory to unveil which are more or less affected by these processes.

Associative Cue Memories

Associative cue memory involves landmarks to be bound to directional information to support orientation and route memory (Boespflug et al., 2014), relying on striatal network processes (Featherstone & McDonald, 2004). Associative cue memory (the memory of landmark direction association, or decision point direction associations in Chapter 8) was found to be affected by early atypical ageing in both Chapters 3 and 8, while Chapter 3 demonstrated that typical ageing (compared with atypical ageing) did not affect landmark direction associations to the same extent. This is consistent with earlier research demonstrating age-related declines in associative learning, which have also been documented in associative memory involved with episodic memories (Old & Naveh-Benjamin, 2008), as well as studies on atypical ageing (Collie, Myers, Schnirman, Wood, & Maruff, 2002) and navigation (Head & Isom, 2010). Importantly, the declines in performance in the associative cue tasks by those showing early signs of atypical ageing could also be attributed to AD-related neurodegeneration of the RSC

(Lithfous et al., 2013), which when damaged, leads to devastating effects on associative due and direction behaviour (Ino et al., 2007).

Memories of the recognition of landmarks

Having good and reliable landmark recognition memory is important to successfully support egocentric response strategies. Landmark recognition serves as a prerequisite of landmark directional associations as it needs to be recalled in conjunction with directional or location information in order to support successful navigation (Waller & Lippa, 2007; Wiener et al., 2013). No differences in landmark recognition performance between the typically ageing and early atypically ageing groups were found in Chapter 8, though previous studies have demonstrated deleterious effects and declines in performance between young controls and older adults (Cushman et al., 2008), suggesting that declines in performance for landmark recognition occurs as a result of impaired visual memory of scenes and figural memory during the ageing process (Cushman et al., 2008).

Memories of the location of landmarks

The memories of landmarks that were present along a route (landmark recognition memory) as well as the memories of where landmarks were situated in the environment (landmark location memory) were both found not to be affected by early atypical ageing in the paradigm used in this thesis. While landmark recognition memory (i.e. the ability to identify landmarks present along a learned route against distractor landmarks) has been hitherto shown to be less affected that other aspects of route knowledge by the effects on atypical ageing (Monacelli et al., 2003), landmark location memory has previously been reported as sensitive to the effects of atypical ageing (deIpolyi et al., 2007). As discussed in Chapter 8, the fact that landmark location memory was not affected by early atypical ageing could be because it was measured on a multi-level route whereas previous studies have explored this on a single level (i.e. on one floor of an environment) basis. One possible explanation for why the early atypically ageing adults could have benefitted from the multi-level route for the landmark location task is that participants could have regionalised landmarks situated on particular floors, which would have facilitated their memory on this task (Strickrodt et al., 2015).

Alternatively, these discrepancies between the present study's findings, and earlier work investigating landmark location memory, could be as a result of our criteria of early atypical ageing (i.e. using the MoCA alone to suggest possible early atypical ageing). It could be affected in well-diagnosed forms of atypical ageing, such as AD, as highlighted in the earlier literature (deIpolyi et al., 2007; Monacelli et al., 2003).

Memory of the temporal order of landmarks

The memory of the sequence/order that landmarks are seen along a route (landmark sequence memory) in isolation does not provide enough information to support navigation, as no directional information is associated to the landmarks. However, landmark sequence memory is a form of route knowledge that contributes towards strategies to later recall the route and allows one to tap into that aspect of route knowledge. For example, if one performs well on the landmark sequence task, it may aid performance on associative cue strategies that would support successful navigation. Route representations are best described as a series of Stimulus-Response-Stimulus (S-R-S) associations (O'Keefe & Nadel, 1978; Strickrodt et al., 2015), which emphasises the role landmarks have in our spatial representations during route learning. Additionally, not only do these S-R-S associations allow one to predict the next landmark or place along a route (Trullier et al., 1997; Wiener et al., 2012), they also make ideal building blocks for embedding single decision points into more integrated route representations (Schinazi & Epstein, 2010; Schweizer, Herrmann, Janzen, & Katz, 1998). Overall, landmark memory, particularly where landmarks are situated along a route, contribute towards more complex representations (such as S-R-S) which allow routes landmarks to be better integrated within route representations (Schinazi & Epstein, 2010; Strickrodt et al., 2015).

The memory of the order that landmarks are seen along a route (landmark sequence memory) was only minimally affected by early atypical ageing in Chapter 3. Specifically, in Chapter 3 we did not find differences in landmark sequence memory (for decision points) between young adults, typically ageing adults, and early atypically ageing adults, and no differences between groups were found in real world navigation when probing for sequence memory for landmarks positioned at non-decision points (e.g. along corridors; See Chapter 8). Having said this, the early atypically ageing adults performed worse than the typically ageing adults in the Landmark Sequence Task in the Real World condition (Chapter 8) when the landmarks in the task were positioned at decision points, so this should be explored further.

Previous studies that have explored the memory of the temporal sequence of landmarks along routes have used different measures to assess this form of memory. For example, variants of landmark sequence tasks include providing participants with a pile of landmarks to correctly order according to how they were experienced along the route, and free recall of landmarks in the order they were seen (deIpolyi et al., 2007; Head & Isom, 2010; Wilkniss et al., 1997). Importantly though, previous studies did find differences on temporal sequence memory between typically ageing adults and those with AD (Bellassen et al., 2012). This could suggest the task used in the present study (Chapter 3 and Chapter 8) to measure landmark sequence memory measured a different process (e.g. cued landmark sequence memory) than what earlier studies have measured (deIpolyi et al., 2007; Head & Isom, 2010; Wilkniss et al., 1997). These earlier studies (Wilkniss et al., 1997; Head & Isom, 2010) did not show participants different potential orders of landmarks. Instead, participants had to specify the landmarks orders themselves, rather than identify the correct order. Future studies should measure a range of landmark sequence measures to establish which measure is most reflective of participants' actual abilities to remember the correct order of landmarks present along a route.

Memory of the sequence of directional changes along a route

The ability to remember the sequence of directional changes along learned routes was affected by both typical ageing (see Chapter 3), as well as by early atypical ageing (see Chapters 3 and 8). This suggests that directional sequence memory is already affected through typical ageing, and is a part of the ageing process. Studies have shown that the sequential egocentric directions relies on the hippocampal circuit (Maguire et al., 1998; Rondi-Reig et al., 2006), an area which is particularly sensitive to the effects of (a)typical ageing (Raz et al., 2010), which could explain why this task was affected by both typical and early atypical ageing.

Egocentric response strategies, particularly the sequential memory of turns, are one of the key cognitive strategies used to learn routes through a complex environment (Igloi et al., 2009). It has been found that both spatial and verbal secondary tasks interfere with route learning performance. This suggests that spatial and verbal codes are used during route learning (Meilinger et al., 2008) and would explain both sequential memory of turns and the associative cue memory ("turn right at the church").

Verbal strategies have been found to benefit landmark memory, whilst visual strategies have been previously reported as having an influence on judgements of relative direction (Kraemer et al., 2017). The findings from the qualitative reports (in Chapter 6 and 7) as well as participants' ability to recognise landmarks from along the route against distractors (landmark recognition; see Chapter 8) suggest that older adults, including those displaying early signs of cognitive impairment better remembered the landmarks than the directions along the routes. Despite participants saying that they relied on verbal cues and the sequence of direction in remembering routes, disorientation was experienced when the environment was repetitive and when there were no memorable or unique spaces suggesting that visual cues are vital in orientation, which is consistent with earlier findings from Passini and colleagues (2000). If participants were using a sequence of direction change strategy exclusively, repetitive environments would not have been a problem. This highlights that the sequential memory of turns and verbal descriptions may rely on additional visual information to be present in order to successfully report the directions and repeat the route which is consistent with findings from Waller and Lippa (2007).

Allocentric Navigation

<u>Map Tasks</u>

In Chapter 3, the older adults who displayed early signs of atypical ageing (Old Low MoCA group) performed significantly worse than the young adults and typically ageing adults (Old High MoCA) at completing the task that required participants to identify their learned route (within a simplistic VR environment) from a map perspective.

Perspective taking from an egocentric perspective to a map perspective was most affected by early atypical ageing compared to other aspects of route knowledge (Harris et al., 2012; Harris & Wolbers, 2014; Iaria et al., 2009) which could be explained by the degeneration of the prefrontal cortex during early atypical ageing (particularly AD) (Pfefferbaum et al., 2005), which plays a role in successfully switching between representations (in this case, making perspective shifts between egocentric and allocentric perspectives) (Lester, Moffat, Wiener, Barnes, & Wolbers, 2017). It has also been highlighted that switching between perspectives is facilitated by the retrosplenial cortex (Byrne, Becker, & Burgess, 2007), which leads to disorientation when damaged.

These findings, that the Perspective Taking Task was particularly sensitive to the effects of early atypical ageing, motivated the paradigm reported in Chapter 4, as it was important to see whether the same effects were found when testing participants using an ecologically more valid scenario; to first study a YAH map of a VR care environment setting and then execute the route to the goal. The findings from Chapter 4 shows that this effect was still present when tested using a YAH map protocol, and provides strong evidence that perspective taking that occurs during map usage is particularly sensitive to the effects of early atypical ageing when measured in a VR environment. This is consistent with earlier work (Cherrier et al., 2001) and can be explained through the mental rotation and perspective taking abilities involved with changing from an egocentric perspective, to an allocentric perspective (and vice versa), which have already been shown to be affected during typical ageing (Aubrey et al., 1994; De Beni et al., 2006).

However, in a Real World condition in Chapter 8, there was no effect of early atypical ageing on the Map Task. There were two potential explanations for the lack of an effect. Firstly, real world navigation provides more environmental information to support self-localisation (e.g. windows) as well as allocentric representations (e.g. cognitive mapping). This could have provided participants with additional structural cues (i.e. the layout of the building) (Arthur & Passini, 1992; Werner & Long, 2003), which would make identifying where they were on a map (and which locations landmarks occupy) easier to complete. Secondly, as shown in Chapter 8 the effects of early atypical ageing are more pronounced in the VR condition.

Pointing Tasks

Pointing performance appeared unaffected by early atypical ageing in both VR and Real World environments (see Chapters 4 and 8). This contrasts with previous studies that have explored pointing performance in older adults (Muffato, 2015). The ability to point to places which are not visible from your current position can be done using egocentric path integration strategies (Smyth & Kennedy, 1982), but also requires the use of survey (map-like) knowledge.

Chapters 3 and 4 both found that older adults displaying early signs of atypical ageing were particularly worse at identifying a learned route from a map perspective, as well as using a map to learn a route from a YAH point to a goal location. These map findings suggest that the ability to accurately point to a location is explained by another process than the one used to interpret and plan routes on maps.

Although path integration has been shown to be affected by ageing (Allen et al., 2004), it may be that pointing performance is still reliable during early atypical ageing. A recent study by Tu et al., (2017), highlighted that following a route learning protocol through a virtual supermarket, both participants with AD and FTD were impaired on a task measuring allocentric memory (i.e. a map task). However, performance between the two groups during a pointing task (pointing from the end location to the starting point in the environment), differed significantly, with the AD group performing worse than the FTD group. These findings highlight differences between sub-types of dementia, suggesting that different neuroanatomical regions are responsible for the tasks. Firstly, this supports the findings in this thesis, as performance on the Map Task was significantly worse between the typically and early atypically ageing adults (which was also found in Tu et al., 2017). The pointing task findings by Tu et al. (2017) demonstrate the differences between sub-types of dementia, which in relation to our non-differences between typically ageing group and the group showing early symptoms of atypical ageing, could suggest that they were displaying non-AD forms of atypical ageing. The pointing performance findings from this thesis also highlight that the early atypically ageing adults were still able to remember where they had come from. Therefore, future studies should include a “route retrace” (i.e. have participants navigate to the starting point from the end goal) variable to measure path integration (and to compare it to pointing performance).

The benefits of adopting both qualitative reports of navigation as well as quantifying route memory performance in environments

To gain a richer understanding of how typically ageing adults, and older adults displaying signs of early atypical ageing, learn routes through environments, this thesis adopted a mixed method approach. It was important to investigate route learning from an experimental perspective but to also capture the lived experiences of older adults when navigating. No studies at present have used an interdisciplinary approach (using qualitative methods in conjunction with experimental VR and real world navigation tasks) to investigate navigation abilities in typical and early atypical ageing adults, despite the fact that both perspectives (the users' voice measured through qualitative measures and quantitatively measured using experimental route memory paradigms) have been demonstrated to be highly informative to inform the design of environments for people displaying signs of atypical ageing (see Chapter 5).

Chapters 7 and 8 used the same cohort of participants, with the findings from Chapter 7 reflecting experiential accounts after completing real world route learning and Chapter 8 testing route memory using a series of route memory tasks. The majority of participants in Chapter 7 reported that landmarks were vital in supporting their ability to accurately recall the route. This is supported by some of the landmark memory tasks from Chapter 8, and the fact that both groups (typically ageing and early atypically ageing adults) performed well on the landmark recognition task and landmark location task (see discussion above). Other aspects of landmark memory (such as the memory of directions associated with landmarks) were affected by early atypical ageing. This shows that the spatial components of route memory are more sensitive to the effects of early atypical ageing than visual memories that are not associated with directional information (Cushman et al., 2008).

Despite most participants reporting that they verbalised the route, performance for the memory of the sequence of directions was particularly low. It may be that this strategy works best when navigating shorter routes (as seen in the VR condition), as participants often failed to include a complete account of the directions (forgot aspects of the route when stating the directions), or an accurate account (stated incorrect directions regarding navigation along corridors, or up and down the stairs). This also makes one question whether some of the participants were actually aware of the errors made when asked to report the direction changes along the route, or whether they use directional information in conjunction with other environmental cues (e.g. landmarks) to support orientation. Alternatively, the decrease in performance for memories of directions could also be explained by decreasing episodic memory abilities (Greene, Baddeley, & Hodges, 1996; Tromp, Dufour, Lithfous, Pebayle, & Despres, 2015). This would explain why participants had problems remembering a sequence of directions (which also relies on episodic declarative memories of the route), but were able to procedurally remember the route.

Using the MoCA as a screening tool

When assessing early atypical ageing, there are two approaches one could adopt. One could either assess people on a cognitive measure (such as the MoCA), and based on their performance, categorise them accordingly, or, one can rely on self-reports from their experiences, either with a formal diagnosis or just from their encounters and difficulties. This thesis has emphasised that (see Chapter 7) although we did not have any diagnosed cognitive impairments (apart from two participants in Chapter 6), the MoCA was able to capture the differences in navigation performance consistent with navigation literature of early atypical ageing (Monacelli et al., 2003; Benke et al., 2014; Cherrier et al., 2001), while self-reports alone are not sufficient to indicate early atypical ageing (see Chapter 7, Table 7.1).

Overall, the findings from this thesis provide strong support for using this specific threshold of 26/30 on the MoCA (Nasreddine et al., 2005), with higher scores indicating typical ageing and lower scores suggestive of early atypical ageing. Despite some earlier literature suggesting more liberal thresholds (Lee et al., 2008; Luis et al., 2009) of 22/30 or 23/30, the findings from this thesis highlight task-dependent declines in ability for specific measures of route memory for those with lower MoCA scores. Some of the present findings (particularly the map task and landmark recognition task findings) are consistent with studies that have explored typical ageing compared to those with MCI and AD (Cherrier et al., 2001; Cushman et al., 2008; Pengas et al., 2010) emphasising that older adults who score below 26/30 on the MoCA should be further investigated (as this could be suggestive of early MCI). It is well documented that cognitive abilities decline with increasing age (Lindenberger & Baltes, 1997). However, this thesis has demonstrated that the declines in performance in route memory tasks for the Low MoCA groups (suggestive of early atypical ageing) are not the result of increasing age, but rather are accounted for by what participants' MoCA scores reflect regarding their cognitive abilities (see Chapter 3). In Chapter 3, an analysis was presented that matched pairs of older participants on MoCA score but that differed in age, with the older participant of the pair assigned to the older participant group and the younger of the pair to the younger participant group. The analysis revealed that none of the differences in the tasks resulted from increased age alone. Although other cognitive screening tools and their associated thresholds were not investigated in this thesis, this work has demonstrated that a simple 10 minute screening tool can be used to identify early atypically ageing adults from typically ageing adults.

Importantly, the findings from this thesis have demonstrated clear-cut differences between particular measures of route memory (especially map-based tasks). The findings also have implications for earlier (Wiener et al., 2012) and future navigation studies that have used a MoCA score which is too low (Lee et al., 2008; Luis et al., 2009) as this may lead to overestimations of the effects of typical ageing. This is because such studies would not be separating participants that score high or low on the MoCA and would lead to results that potentially reflect more pronounced effects of typical ageing (when it is in fact early atypical ageing).

Self-reporting measures of direction

The results of Chapter 4 suggest that self-reported navigation abilities are unreliable when comparing typically and early atypically ageing adults scores on self-reported measures (such as the SBSOD) as they did not reflect participants' ability to reach goal locations.

Whilst scales such as the SBSOD have been shown to reliably reflect navigation performance in younger adults (Hegarty et al., 2002), there has been recent research that suggests that self-report measures of individual differences of spatial strategic preferences are unable to predict specific quantifiable navigational behaviour (Shelton, Marchette, & Furman, 2013). Additionally, it has been emphasised by Weisberg, Schinazi, Newcombe, Shipley, and Epstein (2014) that such measures should be considered as a starting point to understand someone's navigation ability, but should not be used to understand the subtle differences in navigation behaviour. Navigation behaviour should instead be explicitly tested in an ecologically valid scenario.

Older adults tend to overestimate their spatial abilities on the SBSOD (Taillade et al., 2016). This is consistent with the findings reported in Chapter 4, where older adults displayed a skewed and optimistic perception of their navigation abilities. We addressed this by asking participants to rate their navigation abilities as a younger adult and their current navigation abilities on a Likert scale (see Chapter 8). Results demonstrated that there were no significant differences between navigation then (as a younger adult) and navigation now.

We know from previous literature and Chapters 3 and 4 that navigation ability does decrease with age, emphasising that these participants were not aware of their decreasing abilities, or that they are in denial. Additionally, there were no significant differences in mean scores for navigation then and navigation now between the High MoCA (typical ageing) and Low MoCA (early signs of atypical ageing) groups. The results from the route learning and memory tasks do demonstrate significant differences between the groups emphasising that this self-reported tool of navigational ability is not a reliable measure of navigation ability.

These findings highlights two issues; first, the importance of explicitly testing route learning in an experimental fashion is invaluable given the instability, denial and lack of accuracy of some older adults' self-perceptions. Second, whilst not utilised in this thesis, the use of informants and advocates (i.e. family members and close family friends) in research involving older adults showing early signs of atypical ageing can provide reliable and practical complimentary details on specific deficits and examples from daily tasks (Rabins, Lyketsos, & Steele, 2006). Informants' reports can often compliment self-reports of cognitive abilities made by older adults with cognitive impairments (Rabins et al., 2006) particularly in cases where those experiencing early symptoms of atypical ageing and dementia are in denial, or are experiencing Anosognosia (i.e. they have a deficit of self-awareness) (Kashiwa et al., 2005).

Whilst it is invaluable to hear the person's experience, information from those close to the person can further our knowledge in the types of difficulties experienced (Gifford, Liu, Lu, Tripodis, & Cantwell, 2014). Self-reports of memory difficulties are not enough to establish a diagnosis of a memory disorder. Mitchell et al. (2009) emphasised the difference in reports, epidemiology and prognosis between those who have self-reported memory complaints and those with MCI, highlighting that despite being closely associated, subjective complaints may be neither necessary nor sufficient for a diagnosis of either MCI or dementia.

Overall, the literature surrounding self-reports of navigation abilities (Hegarty et al., 2002; Shelton et al., 2013), memory complaints and cognitive decline (Mitchell et al., 2009), demonstrate that in both domains, self-reports do not provide a true reflection of actual abilities and should be used in conjunction with other measures that assess behaviour.

Practical implications of the findings

The findings from this thesis have practical implications, in that they could help shape the suggestions made in dementia friendly design guidelines. They could also have implications for future diagnostic measures for detecting early atypical ageing. Finally, the thesis has highlighted practical implications for research design when testing route memory and navigation abilities. These will now be discussed.

Dementia friendly design guidelines

This thesis has highlighted the beneficial applications dementia friendly design principles have in non-dementia specialist settings. The findings reported in Chapters 6 and 7 suggest that people who are familiar and unfamiliar to the setting would benefit from landmarks and colours present along the corridors to reduce the repetitive design of the environment which is in line with some current dementia friendly design guidelines (Chmielewski & Eastman, 2014; Health Facilities Scotland, 2007a; The King's Fund, 2013b). The recent UK policy directive on environments for those with dementia (Department of Health, 2015) provides an initial outline of concepts to consider, though this thesis has demonstrated that talking directly to the users would ensure that the design and wayfinding solutions is best suited to their needs and requirements. Collectively, these findings emphasise the need for more organisations (e.g. companies that provide public spaces such as shopping malls), urban planners and architects to consider how dementia friendly their environments are, and for age friendly design principles to include more specific suggestions to support orientation.

Older adults displaying early signs of atypical ageing were particularly poor at reaching the goal location when using YAH maps (Chapter 4). Even with restricted routes depicted, the ability to successfully reach the goal location was still low. Future studies should assess YAH map usage using the protocol devised in Chapter 4 where participants first indicate that they have learned the route on the map and then execute the route however in conjunction with other measures/tools for navigation (e.g. verbal directions of routes, signage, landmarks) to investigate whether other navigation aids provide better support.

This thesis has also highlighted how interviews can be used to inform the design of retirement and care settings for older adults. The potential power qualitative interviews, questionnaires, and patient and public involvement (PPI) forums have in gaining insight into the lived experiences is invaluable (Beresford, 2007). Additionally, upon completion of Chapter 6, a design report of the main findings was presented to the retirement setting used. The report highlighted the areas where residents reported most disorientation, residents' wishes of having more memorable spaces within the communal spaces, their wishes to include pictures along the walls that have meaning to them, and further design recommendations. The managers of the retirement setting have since used this report to trigger further discussions with the residents and they have consequently fully refurbished the retirement development where Chapter 6 was based. Research should have an impact (Haines, Kuruvilla, & Borchert, 2004; Weiss, 1979), and the fact that those who participated directly have benefitted as a result of the findings, demonstrates the importance of the findings.

Diagnostic measures

The results presented in this thesis also suggest that VR navigation measures are particularly sensitive in detecting the effects of early atypical ageing on navigation abilities. This can have major benefits for improving diagnostic procedures such as by including additional VR route learning measures to detect the effects of early atypical ageing. This is particularly due to the fact that disorientation is one of the earliest symptoms of atypical ageing and route learning measures can be competed in a short time frame. Bird et al. (2010) had previously emphasised the potential contribution spatial diagnostic assessments could have for those with AD-related atypical ageing, and this thesis further supports this, with VR measures shown to be more beneficial in detecting the earliest declines in navigation performance. Additional potential benefits of using VR measures in a diagnostic setting are that they are easily transportable, which is ideal for testing patients, and are easy (as well as cost effective) to administrate.

Research Design

From a research design perspective, not giving participants direct feedback on whether they had successfully reached the goal (as was the case in Chapter 4), was very successful in that less frustration was exhibited for trials were participants were unable to reach the goal location from the YAH map. This was beneficial, particularly for those who were performing poorly and were displaying signs of early atypical ageing. Ensuring participants maintain dignity throughout the experiment and value the purpose of the research is vital, especially when testing participants using a measure that might challenge cognitive abilities that they struggle with. Studies that explicitly inform participants that they have not reached the goal location, and therefore provide direct feedback on performance, are less suitable when testing older adults. There were a couple of occasions during the testing in Chapter 3, where participants felt uneasy and frustrated, when they realised that the directions that they had given did not correspond with the video of the route (hence realising that they were incorrect). Future studies should consider this when designing route learning protocols to ensure that (1), they do not affect the participants' perceived ability of completing the task, which would consequently affect their dignity, and (2), that they promote participants to engage in future studies that involve testing navigation abilities (if they have left feeling positive about their contribution).

Additionally, the novel research paradigm developed and reported in Chapter 3, was found to be very efficient in teasing apart routes that participants could and could not successfully remember at a post-test phase. In contrast to previous route learning studies with typically and early atypically ageing adults that had only focused on route learning, this thesis was able to differentiate between learned and forgotten routes during the post-test phase, and reliably assess the aspects of route knowledge used in each or both of those conditions. Future research could delve further into the differences between forgotten and remembered routes to establish which factors are crucial in successful navigation.

Recommendations for Practice

Care environment designers and planners should carefully consider the design of their environment to ensure that the navigators' orientations are supported and that design is suited to match the users' preferences (see Chapter 5).

Navigation can be supported through appropriate implementation of landmarks. That is:

- Making sure landmarks and places are unique and memorable.
- Avoiding repetitive layouts through using landmarks (e.g. such as a table with flowers) to break up the route.
- Making sure landmarks are placed at navigationally relevant position to support navigation in typically ageing adults.

Specific navigation aids should be chosen with care. In particular:

- YAH maps are not necessarily the best navigation aids for adults showing early signs of cognitive impairments, as older adults showing early signs of atypical ageing performed significantly worse than the typically ageing and the young participant groups (see Chapter 4).

Care environment designers and planners should ensure that they speak directly to potential, and current, residents of their care environments to gain insight into their preferences and experiential accounts of orientation. In this thesis, qualitative research has highlighted the importance of:

- Colours to make areas easily distinguishable (especially to identify different floors/levels in a building).
- Homely environments through the use of pictures displayed on corridor walls (i.e. using familiar pictures that have meaning to the participants), and by not using excessive amounts of signage.
- Capturing the users' experiences of navigation within the built environment through qualitative measures to understand the self-reported reasons for disorientation as well as strategies used to successfully navigate.

What are the limitations to the thesis and what could be investigated in future?

Break-down of MoCA scores

To further understand the extent and reasons for the differences in navigation performance captured by the MoCA, future studies could explore scores on the specific sub-sections (e.g. attention sub-section, memory subsection, visuospatial memory subsection) of the MoCA (or similar, but longer cognitive assessments such as the ACE-III) in relation to navigation performance. It may be that declines in performance on specific sub-sections of the MoCA are suggestive of specific forms of early atypical ageing. Previous studies that have concentrated on the performance for sub-sections (the visuo-executive sub-sections) of cognitive assessments (the MoCA and the MMSE) have been able to highlight which cognitive assessments' sub-sections that measure visuo-executive skills, are superior in detecting cognitive impairment in stroke patients (Mai et al., 2016). For detecting cognitive decline following a stroke/TIA, Mai et al. (2016) were able to demonstrate that the MoCA was more sensitive than the MMSE in detecting cognitive changes. From a diagnostic perspective, this could provide insight into the types of early atypical ageing that participants are presenting and in which cognitive domain their difficulties predominantly lie.

The findings from this thesis, though, are consistent with existing literature that has demonstrated the navigation deficits associated with early atypical ageing (Cushman et al., 2008, Pai & Jacobs, 2004). If there were other causes for the low MoCA scores, one would not expect the patterned effects between measures of route memory that were found e.g. such clear-cut deficits on particular measures of route memory (e.g. map-based tasks, associative cue memory tasks), and intact memory for others (e.g. landmark recognition). The patterns in decline in route memory were largely consistent with existing literature on route memory and (a)typical ageing (Monacelli et al., 2003; Benke et al., 2014; Wilkniss et al., 1997).

It would be beneficial for future research to further explore and confirm the causes of the low MoCA scores, as well as investigate where the problems are when completing the assessment (e.g. the cognitive discipline, such as attention or memory, measured).

Influence of Landmark Characteristics on Navigation

There are still unanswered questions as to how older adults who show early signs of atypical ageing learn routes through environments, and how environments could be better designed to support successful navigation. For example, while we have been able to highlight which route memory tasks showed the biggest declines, it is still unclear which landmark features (i.e. saliency, positioning and uniqueness) are most beneficial and helpful for both typically ageing adults and also older adults displaying early signs of atypical ageing.

Summary and Future Directions

This thesis set out to examine (1), the navigation strategies typically ageing adults and older adults showing signs of atypical ageing use when learning environments, (2) how these findings could be used to improve the design of environments used primarily by this population, and (3), how well navigation performance in VR environments relates to real world navigation. In terms of theory, this thesis has provided evidence:

- For differences in route memory abilities during early atypical ageing (e.g. map reading abilities are affected during early atypical ageing whilst landmark recognition remains intact).
- That adults who show signs of early atypical ageing can successfully learn routes, if given appropriate route learn trials based on their requirements.

- For the use of the 26/30 threshold for the MoCA, with lower scores indicative of early atypical ageing.
- That VR (compared with real world) navigation is more sensitive in detecting difficulties in people displaying signs of early atypical ageing.

Future research should explore the use of other egocentric response strategies, such as beacon based strategies (which were not investigated in this thesis), as these may be less susceptible to the effects of early atypical ageing. Findings from the landmark sequence memory tasks from this thesis (see Chapters 3 and 8) have highlighted that early atypically ageing adults remember the order of landmarks along a route relatively well, which could be further explored. Landmarks acting as beacons do not necessarily have to be located at a decision point. Rather, landmarks along the connecting corridors (or streets) from the decision point which are clearly visible, can act as beacon landmarks and support this navigation strategy. Potentially positioning landmarks to support beacon strategy selection (e.g. along corridors) could be beneficial in supporting successful orientation for early atypically ageing.

In terms of practice, this thesis has provided evidence that:

- Self-reporting measures have their benefits, particularly in addressing design preferences; however, for measuring and navigation ability, this alone is not sufficient.
- Expanding principles of dementia friendly design guidelines to ageing communities, as they would benefit from these design implementations.
- The power of speaking to people directly to understand how they navigate can be used to aid the design of the environment and potentially reduce disorientation.
- Qualitative and quantitative measures can be used in conjunction to explore and measure one specific research question.
- The potential inclusion of VR to measure navigation ability in cognitive screening and neuropsychological testing of atypical ageing.

CHAPTER 10: Conclusion

To successfully support older adults' navigation in the built environment, measures of route memory must be tested efficiently to investigate what aspects of route memory the person has learned. A new route learning paradigm that tested route knowledge for successfully learned routes was developed and reported in this thesis – first developed in VR, it was then applied to the real world. This thesis has found that the most effective way of testing route knowledge is through using simplistic VR environments, as these set-ups can detect the earliest effects of atypical ageing that would not normally be noticeable after testing participants on one exposure of a real world route. Further research should adopt simplistic VR environments to reliably explore navigation amongst early atypically adults, which could be used in conjunction with diagnostic screening assessments for early atypical ageing. As specific landmark memories are still intact during early atypical ageing, future research should look more specifically at landmark properties (i.e. salience, uniqueness and positioning), to investigate their significance in supporting navigation during early atypical ageing.

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Appendix

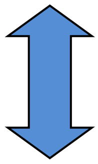
Appendix 1: Interview Schedule For Chapter 6

The key questions asked during the semi-structured interviews were:

1. *How do you find living here in the retirement development?*
2. *How would you describe your abilities in finding your way around your home and the communal areas in the retirement development?*
3. *Are there any areas that are easier or more difficult to get to in the retirement development?*
4. *Are there any areas of the environment that you find particularly helpful or more memorable to help you get your way around*
5. *Have you noticed any changes in how you find your way around?*
6. *How has this impacted on your sense of wellbeing or independence?*
7. *Is there anything that you think could be done to help people find their way around the retirement development?*
8. *How would you design your ideal home?*

Appendix 2: Analytic Process Table for Thematic Analysis For Chapter 6

Analytical process (Braun and Clarke, 2006)	Braun and Clarke's practical implication in NVivo	Strategic Objective	Iterative process through analysis
1.Familiarizing yourself with the data	Interviews are transcribed in Word using Olympus transcription software. This is followed by reading and re-reading the data and noting down initial ideas. The transcribed data are then imported into the NVivo data management tool.	**Data Management** *(Open and hierarchal coding through NVIVO)*	Assigning data to refined concepts to give meaning
2. Generating initial codes	Phase 2 – **Open Coding-** Interesting features of the data are coded in a systematic fashion across the entire data set, creating initial codes. This is continued; relevant data for each code is collected.		Refining more abstract concepts
3. Searching for themes	Phase 3 **- Categorisation of Codes** – Collating codes into potential themes. Going through all codes and gathering all data relevant to each potential theme		
4. Reviewing themes	Phase 4 – **Coding on -** Checking if the themes work in relation to the coded extracts and the entire data set. Also generating a thematic 'map' of the analysis	**Descriptive Accounts** *(Reordering, 'coding on' and annotating through NVIVO)*	Assigning data to themes/concepts to portray meaning
5. Defining and naming themes	Phase 5 **- Data Reduction -** On-going analysis to refine the specifics of each theme, and the overall story and more specific storylines] the analysis tells, generating clear definitions and names for each theme.		

<u>6. Producing the report</u>	Phase 6 – **Generating Analytical Memos -** Phase 7 – **Testing and Validating** and Phase 8 **Synthesising Analytical Memos**. This is final opportunity for analysis and allows us to make comparisons and differences between extracts and themes. Relating the analysis back to the research question and literature, and finally producing a report of the analysis and findings.	**Explanatory Accounts** *(Extrapolating a deeper meaning of the themes, drafting summary of themes and analytical memos through NVIVO)*	Assigning meaning  Generating themes and concepts

Appendix 3: Theme Table for Chapter 6

Theme	Sub-theme	Quotes
1. Disorientation as a result of interior design features and the architectural structure of the development	1.1. Design dependent reasons for disorientation: Repetitive layout causing confusion	• New residents, since I moved in the last two years, often wander around the floor, not knowing, wandering where they were because each floor does look alike. (Harry). • No I don't think so. I mean they're all (the corridors) pretty much the same. No nothing stands out as being extra special area if that's what you mean. (Jean). • You can get completely disorientated and the reason is because that all the corridors are the same. You don't know which one you're on, or what level you're on really until you look at the little messages on the side, but I think, they could certainly be improved. It's important to have some sort of navigation aid I think in a big place like this.

(Colin)

- Well it’s all the same at the moment and even the wallpapers the same, so I imagine it wouldn’t cost the earth to have a different wallpaper. A different theme in the wallpaper. When it was done originally , it would cost a bit now of course, but it’s all in fairly good condition, it’s too late to do anything about it but maybe at the beginning if you had a clean slate in front of you. You could do something like that. (Colin).
- It is difficult with all those corridors and I’m not the only that says that. And I laugh because I’m beginning to know it now but at first you know, you turn right and then “oh gosh” I don’t want to come here and then go back again (laughs). Because this is considered the upper lower ground floor, and the ground floor is up there, so it’s not quite what it says it is. You have to find your way around. (Doris).
- I’d like something that was a bit more definite, because they’re all a

	bit pastelly, wishy washy things, you know and um, even you know a few good photographs would be more interesting than those are, and if you're relying on them to find your way around as they're sort of rather repetitive, you, they wouldn't be a great deal of help! (Brenda) • All the apartments look the same. And the corridors all look the same, so you knew where you were. Looked a bit like a hotel. (Betty). • Um, well so many right angle bends. You can't see far ahead. And well it all looks much the same, these corridors (Helen).
1.2.Design dependent reasons for disorientation: Making separate floors and areas identifiable	• It doesn't say, it says that "fire exit". It doesn't say stairs ground floor … if you got lost, particularly if you got lost, and you saw the word stairs, you'd know where to go, wouldn't you? Brilliant. Because it just says fire exit, it doesn't say stairs. (Ethel). • I would put the exit signs on the fire exit doors … it's got a sign

across the top saying exit, but on the door itself, there isn't. And certainly on the outside (Harry)

- Yes, well it's difficult actually, because obviously, I don't know if the flats could … I don't know really. It's fairly difficult to know really because it's the way the buildings built and scattered about the flats. I haven't quite understood why we've got 40s, number 40s mixed up … well were not actually, there are 4 number 40s on this level, but I think the numbering is confusing, but I don't really know how it could be improved. (Jean).
- like I said before, a bit confusing that you have the numbers mixed up a little bit, it's only some of the number, you expect to see all the 40s together and you don't! (Jean).
- I think it's not bad, but as I say, one or two places where it could be improved at the end of the corridor which leads to the west and extreme eastern ends. Particularly in this one which indicates which

way you've got to go to the first floor. It does say lift 2, somewhere or other but you don't know where lift two is, I mean, you've gone past lift one, is this lift two? Nothing to say lift two. Not as far as I know anyway (Colin).

- Well I think the signs that are there are explicit enough. They're very simple to read. A little bit confusing when people see 40 and 44 which is up here on this level and then they've got to go right to the far end of the building to see 45 and 44 (Colin).
- …in the stairwells, on the backs of the doors of each floor, there's no sign saying which floor it is. (Harry)
- stairs themselves are not that easily identifiable, they're just emergency exit aren't they, that's the only thing you get to tell you there's a stair way there. So you'd have to have some knowledge to actually go through a particular door that says emergency exit, and find a stairway (Colin).

		• I mean I don't find it confusing but I think it's what people can find confusing. Because here is 14, no, 15 (walking) and 12 and 14 are around the other corner and we you go, see its exercise (Brenda). • Well when I first came, I did get lost. I took the wrong lift and went up to the wrong floor and well in the end I walked down the stairs. I gave up with the lift. (Helen) • …what I found was that no sort of indication as to which lift one should use to get up to the first floor, so I decided it would be better to go up the stairs, and that was a big mistake as that was an easier way to get lost, starting to go upstairs. (Colin).
	1.3.Location dependent reasons for disorientation	• Reasonably easy, but in the four months I have been here I have not gone all around XXXXXX Court. (Anne).I can't say I have had any problems but then I haven't really investigated all the other apartments. (Anne). • I'm right at the end of the building … it's a long walk to go to the laundry (laughs). I usually do Sunday mornings when it's quiet. But,

by the time you've put your laundry in and then waited for that to do, and go back again, and put it in the tumble drier, it's three journeys to and fro…(Helen)

- I was completely unaware of how long the corridors were to get to some of the properties, and that was one of the reasons, because of the long corridors, that we decided that we didn't want to go for that flat - Too far from the services, too far from the entrance exit of the building. (Colin)
- Well I have just been round there but that end there (points to the annex) that half there goes right the way around that way. And the houses there, or flats, look out over there grass like that. I.e. only been in there once to see what it was like. Other than that. I sit there or sit on the grass (Doris)
- But if you live in this part of the building you don't often have reason to go over to the other part so it's a bit isolated I suppose. (Joyce).

- Well we used to have communion… the vicar form the local church used to come across and do communion… I think it was once a month but now the curate's been ill so that seems to have fizzled out. (Joyce).
- The only time I might look on the board is when you're in the other wing, er, deciding which corridor they're on, on which floor. But it's so well signposted you'd be stupid if you got lost. (Joyce).
- Well when you come to the lift, you don't really know the stairs are around the corner. And there are two lifts, I've never been to the other one (Betty).
- It would be handy to know where things were. But then I just go along here to the lift and go up to the entrance really, that's all I use. I use the laundry and the rubbish place. (Betty).
- No I don't go up there. I'm not allowed to go up there. That's were

		all the other flats are up there. Well, I suppose I could but I've never been up there. Oh I did once. I took err, somebody, asked me to take a book up to somebody. (Myra).
2. Overcoming and avoiding disorientation using orientation strategies and environmental cues	2.1.Spaces to trigger memories	• I'm on the top one so we're very few of us up here. The second one down of course and the ground floor, which is very long "duh duh duh duh duh" someone's got a table there and they put on photographs and the odd flowers which is very pleasant. That's on the ground floor. But here, we have very short corridors, have you noticed (Ethel) • Mind you, to differentiate between the ground floor and the first floor is quite difficult, but the lower ground you can, more or less know I'm on the right floor. Um, because it's a bit dark, but of course walking up the corridor you're getting that light from the louvre windows, you've probably realised it, but you don't on this floor. (Harry).

- I know I'm on the first floor or the ground floor because of the louvre windows. The other stairwell I know I'm on the ground floor because of the pictures around the lounge. (Harry)
- If you leave my apartment and just go down on the way to the front of the building there's the shoppers door and there's a big space, and a table, and there's a little …. There's an arrangement of flowers on there, there's a photograph of a dog and that's fine and that's the shopper's door. So you know that's the shoppers door and so you know there's …so there are landmarks you can make on this floor and I think the other floors as well. (Harry)
- The louvre window, again there's a little table, an arrangement of photographs which if you live there you should see "oh this is not my floor that's the first floor, I'm on the ground floor" so you can make (Harry).

- I'm spatially aware. And I pick up things, you know, I even …. I sound a bit OCD really, even the sign for the lift … "this lift is repaired by whatever" if it's higher on one floor, than another, I'll notice it. That's just the type of person I am. (Harry).
- Some of the things you remember of course are the roof lights, because it's unusual to see roof lights in the bottom corridor, so you know that you're on a certain level when you see the roof lights here for example, and outside there. And you can look down the corridor and see the roof of the little flats down that way, so it's other things at the ends of the corridors that give you other navigationally. (Colin).
- There is, when you get, halfway up, there is a rug that's about as big as my entry there and somebody puts flowers there and that's quite nice … It think it's quite nice, it cheers it up. And you think "oh that looks lovely" and there's "oh what are they today" and they're mostly fresh flowers, not other ones. It's quite nice. (Doris).

- There's a pictures of their dog and there's always the flowers. And I wonder …. I think I know who puts them there regularly, but they're quite nice. They're usually carnations or something that lives quite well. (Doris)
- No not really, apart from the ones that go up on the lift (laughs). That's all I can say. No they're all the same aren't they. (Myra)
- Oh yes, well I go out my door here, down the corridor, and then, I do it in three sections really. First to the bend, then the next bit, past the table with the flowers, and then the third bit takes me to the lift. Up in the lift and then it's easy from there because you're right outside the lounge and um, you can see the notices. (Helen).
- Well pictures could be better. Um, you can't really put much furniture in the corridors because it's not wide enough but, that one table I think is a very good idea with the flowers and the photograph.

		I think some of the people in the flat next door to it look after that, yes I think that's their little hobby. Hmmm. (Helen).
	2.2.Signage and door numbers - following numbers consecutively	• Yes, well it's difficult actually, because obviously, I don't know if the flats could … I don't know really. It's fairly difficult to know really because it's the way the buildings built and scattered about the flats. I haven't quite understood why we've got 40s, number 40s mixed up … well were not actually, there are 4 number 40s on this level, but I think the numbering is confusing, but I don't really know how it could be improved. (Jean). • The signage is quite good actually as long as you, you stick to it. (Colin) • The signage is quite good actually as long as you, you stick to it. No I think the signage is pretty good, it's just if you … when you go out it looks so strange having, or look down in the hall in the by the lift, it

looks strange having these numbers mixed up. I think of things being consecutive. And people visiting actually, we've had a few tradesmen, they've been a bit confused. They find it easier going down to meet them (laughs). (Jean).

- I honestly don't think so. I mean it is well signed. It might just be a , like I said before, a bit confusing that you have the numbers mixed up a little bit, it's only some of the number, you expect to see all the 40s together and you don't! but um, but that's obviously the design of the …. I don't know quite other than renumbering them, they probably …. I don't really think so. It's not bad. (Jean).
- I think I follow the numbers. I don't follow pictures no. no the numbers are definitely the important bits. (Jean).
- …It might just be …a bit confusing that you have the numbers mixed up a little bit, it's only some of the numbers, you expect to see all the 40s together and you don't! (Jean)

- Well it's because of the way the flats are numbered. Um, you know so, it's, you see 1 starts … I'll show you! (Brenda).
  - See, right ahead of you that is flat one, and the it comes down this way till you get to 7 , that's on the, that's right, 1,2,3,4,5,6,7 and then when you go out of the, do you want to take your ….. (Brenda).
- So if you want number 8, this is number 7, this is the last one here, that's round that corner and you go right up round there till you get to number 11 and then you come back round there and you find um, I think that's number 12. Yes there's no number 13, because people don't like 13, might be difficult to sell (whispering) (laughs). And then you go along this side, you start at the numbers 14 until you get down to the end and then if you go, how well do you know the layout of the building, (Brenda).
- I mean I don't find it confusing but I think it's what people can find

confusing. Because here is 14, no, 15 (walking) and 12 and 14 are around the other corner and we you go, see its exercise (Brenda).

- I'm not very good on names of things. I know where things are and I could say to you "oh yes I know where so and so lives" but I probably wouldn't know the number of the flat, I would just know when I got there as it were. (Brenda)
- Well it might for some, but not for me. I don't look at the pictures, I look at the numbers on the doors. (Helen).Well because the numbers are consecutive, and I know if I follow them, when I get to number 3, I'll be almost at the lift. (Helen).
- But I do find that as you get to or the beginning of each corridor, its well signed, which numbers of the apartments are along that corridor etc. so I got no complaints about difficulty of getting round but I haven't done much myself. But it is well signed I think, speaking for myself. (Anne).

- On the signs at the end of each corridor, um thinking about it I am not sure if it is generally just the numbers along the corridor of what number is there (Anne).
- So how do you find where the lounge is positioned within the whole development? (MOM). Again it'll be signposted for instance, if I go out from my apartment, I know I only got to walk to the end and turn right and I am there. It's not so easy for some other people I am just in a very good position so I can, for me it's easy. (Anne).
- Well honestly, I don't look at the signage. I know where everything is so, you know I go down and no I don't look there's no need for me to look at it. When I came here I found where everything was and I don't need to look at it so I don't. I don't think I've ever looked at it, no I don't. I suppose when you come out of the lift, you automatically see it but it doesn't register because I'm not looking for anything. (Ethel).

- On each floor you know if you didn’t have your bearings it would be difficult to know what was on. And that’s the same here. So I think there needs to be something on each floor letting you know … it’s a bit hotel-ish to put “floor one” or LG on the wall, (Harry).
- The signage is fine, but again, if your sight is not all that well (Harry).
- When you come out the lift, have the number of the floor or the name of the floor there. It’s a bit too impersonal really (Harry).
- There’s got to be signage anyway, because it is like a hotel, and if people come here you see, I’m not looking at things only as the residents, I’m looking at people who come here for the first time. Like, here we go again, paramedics, traders, carers, visitors, family whatever. So there has to be signage, right opposite the lifts. In the stairwells, most people use the lifts, but in the stairwells, on the backs

of the doors of each floor, there's no sign saying which floor it is. (Harry).

- The exit signs are very good, the fire exit signs are very good, but the exit signs are also for the normal stairs (Harry).
- I would put the exit signs on the fire exit doors … it's got a sign across the top saying exit, but on the door itself, there isn't. And certainly on the outside, (Harry).
- The signage is quite good actually as long as you, you stick to it. No I think the signage is pretty good, it's just if you … when you go out it looks so strange having, or look down in the hall in the by the lift, it looks strange having these numbers mixed up. I think of things being consecutive. And people visiting actually, we've had a few tradesmen, they've been a bit confused. They find it easier going down to meet them (laughs). (Jean).

- And how do you find the signage to the stairs and the lifts? (MOM). I think it's pretty good actually. …. Have got lost but well I think my husband got completely lost once, but he'll tell you that. No it's very good actually and down to the refuse, laundry and everything well signed. (Jean).
- I honestly don't think so. I mean it is well signed. It might just be a , like I said before, a bit confusing that you have the numbers mixed up a little bit, it's only some of the number, you expect to see all the 40s together and you don't! but um, but that's obviously the design of the …. I don't know quite other than renumbering them, they probably …. I don't really think so. It's not bad. (Jean).
- There are signs there which are quite good, and they direct you to number 45, and I went along there, and what I found was that no sort of indication as to which lift one should use to get up to the first floor, so I decided it would be better to go up the stairs, and that was

a big mistake as that was an easier way to get lost, starting to go upstairs, and you can get completely disorientated and the reason is because that all the corridors are the same (Colin).

- I mean every time I've come out of the lift you see a notice which tell you which is that way and which is that way. (Colin).
- Well I think the signs that are there are explicit enough. They're very simple to read. A little bit confusing when people see 40 and 44 which is up here on this level and then they've got to go right to the far end of the building to see 45 and 44 (Colin).
- And how about the signage within the development, how has that helped or not helped with finding your way around? (MOM). Oh it helps a lot. Because if you can look to see which number you want and the number flat, and its pointing either that way or that way, then you have a start to start with so it's not too bad. (Doris).

- Are there any areas within the development that you find more memorable? So along the corridors for example are there any areas that you find more helpful in finding your way around? (MOM). No I don't …at first it was but because when you look at those little placks on the wall, it points to which way you have to go for X numbers so, when you get in the lift you go either up or down, so that's no bother at all. (Doris).
- Think the … errr... with the arrows, without that we would be lost I think. (Doris)
- Sort of helpful I suppose as you've got those things on the wall which tells you which ones to go. But other than that … no you just find… You know you have got those and it give you the numbers of the flats which are say "that way". But if it was that way they'd put the arrows that way so you do get help from that. Once you get used to it, it's alright, it's the …. (Doris).

- Well, when we first moved in, the notices were very poor as to how you got around the place, especially if you live near the front hall, but since then the lady who was the warden before has got much better notices put up which shows whether you go up, or down, or down the corridor, and so it's much easier to find your way around. But some people still get lost… (Joyce).
- All the corridors have got the numbers on of the flats that are to the left and flats that are to the right and it also says the numbers of the flats where you've got to go up a floor and the numbers of the flats where you've got to go down a floor. It's very very well signposted, yeah. (Joyce).
- I think it's all very well signposted – I wouldn't fault any of it, no (Joyce)
- I mean you could find you way looking just at the signs without

speaking to anybody to find somewhere that you’re going to visit y’know. You wouldn’t need somebody to telling you what to do. (Joyce).

- It’s excellent, well you only need to look at it. Everything’s listed, all the numbers of all the flats and so on, it’s all on. You get it when you get in the lift so I don‘t think people have a problem. (Joyce).
- You mean the signs on the walls? Yeah they’re useful! I mean if you’re directing someone else, you know you can say when you’ll see, see you’ll find this direction where it is and what ever. (Brenda).
- Well perhaps it’s me but they (the stairs) just look a bit dull when I’ve seen them. And they’re not very well sign-posted. (Betty).
- It’s very clear, it’s easy to understand and it’s put in the right places. When you come out of the lift, it’s in front of you and if you’re coming in the front door, it’s there again for you to read straight

		away. Yes that's good. (Helen). • I suppose by the lift, the first lot of signs. But um, well I suppose people don't need it really. They know the number of their door and that's it. (Helen).
	2.3.Avoiding the corridors - shortcutting	• If I don't want to go out the front door, I've got this door that goes through the garden. At the bottom right here, on the ground floor, there's another door so I can, if I don't want to go through the front, for example tonight there's a little party going on at 5pm. Well I'm not going because I've got guests, and I don't want to go through that beautiful lounge where it will be taking place, because it's embarrassing, but I can go down the ground floor and there's another door there and it takes me through the park! Through the little park here, and I can get out through that door, so it is wonderful, so you're not interfering in anyone's life because we've got a second opening. Wonderful. (Ethel).

- I always use the stairs because I don't want to get … I use the lift for my groceries, but otherwise, all my family, we all use the stairs because we want to keep mobile. (Ethel).
- I use the lift for groceries and if I've got friends coming who are crippled you know. Otherwise I use the stairs all the time. I make a point of it. (Ethel).
- I don't go down there, I don't. I don't visit anybody down there. I have done. Some girl collects stamps or something so I gave some. No I never go down there, never. But I do use the garden gate, I do, if there's something going on here, like the party tonight at 5pm, and I've got people coming for a meeting here, then we will all go that way because we wouldn't be yes. (Ethel).
- The gate which is a boom for this development and I think that's used. And I use that probably more, just as much if not more than I

use the main entrance. Well you've only got to go out this door here, not this one, pardon me the shoppers door and up to the, you know where the gate is? Up to the gate you know, you're there! You don't have to walk along, you don't have to go up in the lift, you don't have to use your fob, no you're out! So that's a boom that gate for people like me on the lower ground. For people on the ground floor and the first floor, they still have to get in the lift and but still you know if people in the annex again as were talking before, on the ground floor, yeah on the ground floor and the first floor in the annex, again they can come down the shoppers entrance and just get in this lift here and go, rather than getting in the other lift, coming in, getting gout on the ground floor on the lower ground floor walking along and getting a … to go, no you just come in and go, so I think quite a few people use that way. (Harry).

- See mainly, from here out the shoppers entrance out the gate or from here, up the stairwell and along to the lounge and the bins and the laundry, or out here, along the corridor, up the following stairwell to the lounge and the bins. So I use the two stairwells if I want to go to the office the lounge … or the lift sometimes if I've got particularly heavy or a lot of baggage. If I want to go to the lounge the bins or the laundry and out there I go out …. So I've … I'm quite fortunate as opposed to some of the people here, (Harry).

- Well it was quite easy actually, I think for one reason the positioning of the flat is very very easy to find. The estate agent took us to one at the back and we walked for miles of corridors up and no I don't … I think were in … you have to go through a lot of corridors a little bit unnerving, I suppose you get used to it, but we both looked at each other and said "ooo we wouldn't like this". But it was, I mean for one thing the estate agent lost us coming out! So that didn't help really! But then we saw this one, a friend told us about it and it's completely different. (Jean).

- I'm not absolutely familiarised with people getting around to the back, I believe they can go through the gate, into the back garden. But this flat we looked at, we thought well can we go through the outside way, but you couldn't lock the patio door so unless someone was in there, you couldn't get in that way. And this was something we considered when we looked at the flat. And we said oh well maybe we could, when we wanted to do shopping or something, we could go to the outside, but you can't do that in less you leave the patio door unlocked. Well it doesn't lock, not from the outside. (Jean).
- The first experience of the long corridors, completely unaware of how long the corridors were to get to some of the properties, and that was one of the reasons because of the long corridors that we decided that we didn't want to go to that flat. Too far from the services, too

far from the entrance exit of the building really normal one. (Colin).

- It is difficult with all those corridors and I'm not the only that says that. And I laugh because I'm beginning to know it now but at first you know, you turn right and then "oh gosh" I don't want to come here and then go back again (laughs). Because this is considered the upper lower ground floor, and the ground floor is up there, so it's not quite what it says it is. (Doris).
- Um it's quite easy really because you've got these doors open. This one (patio door), you can sit out there is you want to. And instead of coming out through the front door, you can come out there and walk up there and get to the car park and walk along that way. So there are one or two. And also you can go left up there and go around. But there is a gate there that's locked and it's difficult to unlock it. (Doris)
- But you can't get in, so if I sit there and it's a bit windy, I stack it

open with something or other so that it doesn't shut me out. But other than that it's that way. Or you could as I say. Lock that way and come up into the car park there. There's various ways. But the car park for me is the quickest way out. (Doris)

- If you want to go to the other building you have to gown into the lift, walk the full length of the building under this lawn and then come up in a lift on the other side of the building over there. Over there. Which some people find quite a long way to walk! (Joyce).
- I mean when I go walking I go round the block, the whole way round and right up the grassy bank up the back of the other side. Erm, no problem at all. Mind you some people would never even dream of walking around the site. (Joyce)
- Well I think the first thing that struck me when we moved here was the distances because we're right down, if I want to go out of the building, I have to walk right along the corridor to the other lift, don't

use this lift obviously because it only goes up to …. It's because the buildings built in two halves and were in the garden wing, or whatever they call it, and the other is the main part. It's because it's built on a slope. Um, so there's a long walk from this end up to the lift and then up to get to the laundry and the refuse room. But um. On the other hand, I think of it as exercise now, so (laughs) it doesn't matter so much. (Brenda).

- You can use the on right at the other end of the corridor, that comes down when you come into the building. You come in through the lounge, turn the corner and then there's a lift. And that's the lift that I use, unless I'm going to see someone who lives in one of the flats on this side. (laughs). It can be a bit confusing. If you sort of get up there and you can wander around. (Brenda)
- And how do you find going up to the lounge so from your apartment going up to the lounge? (MOM). I, I find it quite easy I normally go

up on the lift, well I should be going up the stairs but I have had 2 hip replacements so it's the way of least resistance I think to go up on there on the lift and it requires more walking if you go up the stairs (yea) and of course more of a strain on your hips and sometimes knees as well complain (yea) as you do get older (mmhmm) but otherwise I don't find it difficult at all (Lillian).

- The I don't know where the staircase is there, I have never used it to go up the next first and second floor but so I always use the lift and the lift is beyond the turning to the garden door. And that's easy (Lillian).
- Always used to lift. Or you can get out through the garden. (Betty)
- Well it's easy enough, it's all on one level. You just walk along the green bit don't you (laughs). Yes, if I went out here and walked out there, I'd go to the end. Well, you just go out of the door, you know what I mean, it's ever so easy the way they've done it, worked it all

out. (Myra)

- Well, this one. I only live down there so I know that. And its' got the numbers and that goes up in the lift. With all the rest of look these 26-32 I suppose and even more of those. I'm lucky to be on the floor downstairs. (Myra)
- Shopping entrance, the end of the other end of this long corridor down on the lower ground floor there's a door and that takes you out into the garden if you want to go round the garden or to take we have pot plants that we have finished with and there's an area that we can leave them for the gardeners to deal with that good and I do that sometimes or if I want to go out for a walk I would probably go that way to avoid that gate. I would probably go out what they call the shoppers door (Gloria)
- There's a staircase there as well if you wanted or were agile and wanted to use the stairs and then but there's a door out into the

		garden there (Gloria) • But there is a shorter way out, which I sometimes use when I'm coming home, because, these doors don't open from outside and so I use, what they call, the shoppers entrance. I come through the garden and that cuts off a lot of the corridor. (Helen). • Oh yes, well I go out my door here, down the corridor, and then, I do it in three sections really. First to the bend, then the next bit, past the table with the flowers, and then the third bit takes me to the lift. Up in the lift and then it's easy from there because you're right outside the lounge and um, you can see the notices. (Helen).
3. Residents' design suggestions: making spaces meaningful and memorable.	3.1. Moving away from the "hotel-look" for long term living environments	• Um, I have been in quite a lot of these developments and they can differ enormously. The one here, the lounge, as you come in, and when you walk along the corridors, it's like coming into a hotel. (Anne).

- And funnily enough I had people visiting me without me saying and they all say “oh it’s like coming into a nice a hotel” (Anne).
- But the corridors themselves um, no again, I would say if somebody took you into this building and you were walking along the ground level, I can only speak for where I am, you would actually think you were in a hotel. Um, pleasant, nothing unpleasant. (Anne).
- On each floor, you know if you didn’t have your bearings, it would be difficult to know what was on. And that’s the same here. So I think there needs to be something on each floor letting you know … it’s a bit hotel-ish to put “floor one” or LG on the wall, (Harry).
- There’s got to be signage anyway, because it is like a hotel, and if people come here you see, I’m not looking at things only as the residents, I’m looking at people who come here for the first time. Like, here we go again, paramedics, traders, carers, visitors, family

	whatever. So there has to be signage, right opposite the lifts. (Harry). • All the apartments look the same. And the corridors all look the same, so you knew where you were. Looked a bit like a hotel. (Betty)
3.2. Using colour to make areas distinctive	• You've got to have the pale because the dark colours will crush you in, so whatever happens it's got to be pale, yeah , leave it. (Ethel). • I think each floor, if it was up to me, would have a different coloured carpet. There is a lower ground floor, there is a ground floor and there is a first floor. And … red green and blue, you know? Three easy colours. You would know straight away, if you could manage to put a …. The signage is fine, but again, if you're sight is not all that well, and I don't think the pictures in my other place were put there especially it was just that they were there. So you've got something to mark it by, you get a landmark to mark it by. I don't think it was put in there for that purpose, I … here going back to here, I would

have a different coloured carpet on each floor which would then lend itself to different coloured, well it might lend itself to different coloured walls and um, décor. It might not! But at least with different coloured carpets you would know straight away, if you pressed the wrong button, um "ah I'm on the wrong floor" and yes I do press the wrong button, even though I am, you know 20 years younger than the mean average, so yes you press the wrong button sometimes, and um I haven't here, I did in my last place. (Harry).

- I mean the colours are so relaxing up there and everyone who comes to visit thinks it's a lovely lounge (Lillian).
- I don't need to really I, yes they're they don't hit you as perhaps some colours would do and so which I like in any case so they're calming colours and they are relaxing I mean yes I don't have very far to travel in any case down the corridors normally so when I'm coming back no they're fine (Lillian).

		• Yes, that's non descriptive as well (laughs). But it's mag or something. I don't know what else colour they could have, because it's got to be restful I suppose. You can't have bright colours. (Betty). • Well perhaps every time you come to a right angle bend, the carpet colour could change, yes. But that would cost a lot more of course, and they would not want to do that (laughs). (Helen)
	3.3. Putting up interesting pictures	• Funnily enough I can't remember if there are pictures all along this corr. … can I have a look? (laughs and gets up). There probably are. No there aren't any pictures along the corridors here. I can only speak for this corridor but there are, there's one just outside my door here (Anne). • If somebody was lost and there was sort of one bright picture, it might help. I don't know. (Ethel). • Awful (laughs). Very boring and very repetitive (laughs). Yeah, well

I expect they buy them, you know, a job lot. And that's it! (Helen)

- I know I'm on the first floor or the ground floor because of the louvre windows. The other stairwell I know I'm on the ground floor because of the pictures around the lounge (Harry).
- If you were in these areas I talked of before, the shopping door/shop door area just round the corner here, and there two pictures on the table on the little vase of flowers, you could tell those two and the same with the other two by the louver windows. I've been here two years and if you were to tell me what, or if you were to ask me what pictures were here from the walls, from here to the front lift, I couldn't tell you. Flowers of some description … lilies, water lilies I think. But um, there's nothing that stands out on the walls, but they're nice enough. (Harry).
- If you're walking along whilst you're looking at pictures of, you know impressionist flowers, they would be the same. If you were

walking along looking at pictures "I haven't seen that picture before? I'm on the wrong floor" see. "I haven't seen that" you know, the 19th century pictures like you know. "I haven't seen that one before, where that, hang on a minute, I'm on the wrong floor here" (Harry).

- Just as you come out the lounge by the lift, there's a picture of the Dorchester borough gardens, in the 1880s, and there's a lady with a parasol and there's a chap on the bench, that's the borough gardens so I know that. Now if you were to ask me what photograph is on that corridor down there, I wouldn't be able to tell you or what pictures, sorry. (Laughs) photographs instead of pictures! (Harry).
- I think if there were fewer pictures, and that they were more distinctive, it would help. But they're all much of a muchness. Yes. (Helen).
- You know William Morris said 'have nothing that isn't either useful or beautiful, preferably both' (laughs) I don't think those (the

	pictures) qualify for us! (Brenda). • There is one of the pictures. At the beginning. Because my nan lived in … umm … she lived …(Myra).