ARTICLE IN PRESS

NEUROBIOLOGY OF AGING

Neurobiology of Aging xx (2010) xxx

www.elsevier.com/locate/neuaging

Effects of age on navigation strategy

M. Kirk Rodgers, Joseph A. Sindone III, Scott D. Moffat*

Institute of Gerontology and Department of Psychology, Wayne State University, Detroit, MI, USA

Received 5 April 2010; received in revised form 20 July 2010; accepted 30 July 2010

Abstract

Age differences in navigation strategies have been demonstrated in animals, with aged animals more likely to prefer an egocentric (route) strategy and younger animals more likely to prefer an allocentric (place) strategy. Using a novel virtual Y-maze strategy assessment (vYSA), the present study demonstrated substantial age differences in strategy preference in humans. Older adults overwhelmingly preferred an egocentric strategy, while younger adults were equally distributed between egocentric and allocentric preference. A preference for allocentric strategy on the Y-maze strategy assessment was found to benefit performance on an independent assessment (virtual Morris water task) only in younger adults. These results establish baseline age differences in spatial strategies and suggest this may impact performance on other spatial navigation assessments. The results are interpreted within the framework of age differences in hippocampal structure and function.

Keywords: Navigation; Strategy; Aging; Age; Egocentric; Allocentric

1. Introduction

Multiple studies have demonstrated reliable age differences in nonhuman species in a wide variety of navigation and spatial learning tasks, including the Morris water maze, a nested T-maze, and the Barnes circular platform maze (Barnes et al., 1980; Ingram, 1988; McLay et al., 1999). Similarly, the observation that young adult humans outperform their older counterparts on spatial navigation measures has now been demonstrated in numerous studies (Driscoll et al., 2005; Moffat et al., 2001; Newman and Kaszniak, 2000; Wilkniss et al., 1997).

In younger adult humans, the hippocampus is part of a neural system involved in spatial navigation, along with the parahippocampal gyrus, cuneus, precuneus, parietal lobe, and posterior cingulate gyrus (Gron et al., 2000; Moffat et al., 2006; Morris et al., 1982; O'Keefe et al., 1975) and it has been suggested that the hippocampus plays a role in allocentric spatial processing whereas other regions, most notably the parietal cortex and caudate nucleus, may play a more prominent role in egocentric spatial processing (Maguire et al., 1998). Several functional neuroimaging studies have now demonstrated that older adult humans show reduced or absent hippocampal activation in performing navigation tasks compared with younger adults (Antonova et al., 2009; Meulenbroek et al., 2004; Moffat et al., 2006) and 1 structural magnetic resonance imaging (MRI) study has shown that hippocampal volume is positively correlated with navigation performance in the young but not in the elderly (Moffat et al., 2007).

The observation of behavioral deficits in navigation among the elderly and reduced hippocampal involvement in elderly navigation has led some researchers to theorize that elderly humans may adopt extrahippocampal strategies in solving navigation tasks (Iaria et al., 2009; Moffat et al., 2006, 2007). Although there are multiple ways to describe navigation strategies, the most common are egocentric and allocentric. An egocentric strategy — sometimes called response or route strategy — is a strategy in which an individual remembers directions or a route based on a frame of reference centered on the individual, independent of absolute position. An allocentric strategy — also known as a cognitive map or place strategy — relies on a frame of

* Corresponding author at: 87 E. Ferry Street, 226 Knapp Building, Detroit, MI 48202, USA. Tel.: +1 313 577 2297; fax: +1 313 875 0127.

E-mail address: moffat@wayne.edu (S.D. Moffat).

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doi:10.1016/j.neurobiolaging.2010.07.021

reference external to the individual, based, for example, on using a cognitive map with external reference points.

There are currently no published studies empirically demonstrating that older human subjects actually do use different strategies than their younger counterparts. However, 2 published studies provide suggestive data. One study retrospectively asked younger and older human participants how they solved a navigation task and found that self-reported allocentric strategy decreased with age (Driscoll et al., 2005). However, it is not ideal to use self report as it requires insight into one's own cognitive processes (i.e., metacognition) which itself decreases with age (Isingrini et al., 2008). In another indirect assessment of strategy in cognitive mapping, it was found that age differences in a cognitive mapping task were maximal when objects were not present on a map and age differences were eliminated whenever proximal objects were present (Moffat and Resnick, 2002). This suggests that older participants may disregard distal geometric information in an environment and focus more on objects to guide navigation.

Although there is very little work explicitly investigating age differences in strategy selection in humans, some studies have used creative paradigms to investigate this in non-human species. Barnes and colleagues (1980) performed an elegant strategy assay in middle-aged (14 months) and older (29 months) rats. Using a 3-armed T-maze, rats were trained to go to 1 arm of the maze using water as a reward. An animal could select an arm and maintain set over repeated trials using either a cue strategy (e.g., moving to a specific cue located directly next to the reward), an egocentric strategy (e.g., always turn left), or an allocentric strategy (e.g., go to the same absolute spatial location). Barnes and colleagues measured strategy preferences by starting the rats in a different arm and observing their behavior on a probe trial. This study found that older rats were more likely to use an egocentric strategy to solve the maze than an allocentric strategy, and the reverse was true for middle-aged rats, which preferred an allocentric strategy.

The purpose of the present study was to use a virtual Y-maze strategy assessment task modeled after Barnes and colleagues (1980) to assess age differences in navigation strategy preference. In addition, the present study investigated the effects of strategy preference on an independent measure of spatial navigation, the virtual Morris water task.

2. Methods

2.1. Participants

Ninety-nine community-dwelling older adults ($n = 45$; aged 55 to 85) were recruited using newspaper advertisements and notices posted at older adult community centers, workshops, and events, and 54 younger adults (aged 18 to 35) were recruited from the Wayne State University (WSU) Psychology Department volunteer pool and from the community. All participants were free of psychological, neurological, or severe cardiac disorders as revealed by detailed self-report of medical history, scored 26 or higher on the Mini Mental Status Examination (MMSE), scored better than 20/40 (corrected) on visual acuity tests, and spoke English as their native language. See Table 1 for complete demographic information.

2.2. Procedure

2.2.1. Computer experience

To assess potential between groups differences in computer and virtual environment (VE) experience, a computer experience questionnaire (CEQ) was administered to all participants. The computer experience questionnaire presented a series of questions asking participants to rate their general computer experience, experience with computer games in general, and their experience specifically with

Table 1
Demographics and control measures

	Young			Older		
	Male	Female	Total	Male	Female	Total
n	26	28	54	20	25	45
Age[a]	21.04 (4.18)	21.21 (4.07)	21.13 (4.08)	60.85 (6.88)	63.2 (7.46)	62.16 (7.22)
Education[a]	13.77 (2.01)	13.39 (1.40)	13.57 (1.71)	15.90 (2.65)	15.80 (2.00)	15.84 (2.29)
Systolic BP[a]	115.42 (10.40)	104.75 (11.28)	109.89 (12.04)	133.75 (17.28)	134.24 (25.86)	134.02 (22.22)
Diastolic BP[a]	71.31 (9.24)	69.75 (8.50)	70.50 (8.82)	79.80 (10.14)	81.40 (18.08)	80.69 (14.59)
MMSE	29.38 (0.85)	29.39 (0.63)	29.39 (0.74)	29.25 (1.16)	29.00 (0.96)	29.11 (1.05)
CEQ[a]	15.96 (3.33)	12.63 (2.31)	14.26 (3.28)	10.05 (3.27)	10.40 (3.54)	10.24 (3.39)
Nausea	3.58 (4.0)	5.32 (6.41)	4.48 (5.39)	3.10 (3.23)	5.48 (6.70)	4.42 (5.51)
Speed[a]	58.70 (1.64)	63.39 (7.05)	61.13 (5.67)	64.05 (6.18)	68.80 (6.35)	66.69 (6.65)
High BP	0	1	1	10	11	21
BP medication	N/A	1	1	5	5	10

Data presented as mean (SD), except as indicated: Education, education of participant in years; Nausea, nausea questionnaire; Speed, latency to complete speed assessment task (higher values denote slower speeds); High BP, number of cases classified as having high blood pressure; BP medication, number of cases high blood pressure receiving treatment.

Key: BP, blood pressure; CEQ, computer experience questionnaire; MMSE, Mini Mental State Examination.

[a] Variables on which there was a significant age difference.

games that feature VEs. Each scale (self-rated from 0 to 7) contributed to an overall computer experience rating for each participant (maximum = 21).

2.2.2. Blood pressure

Blood pressure was collected using a commercially available automated blood pressure cuff (Omron Automatic Blood Pressure Monitor 711X, Omron, Tokyo, Japan). Participants were also asked if they had a hypertensive or high blood pressure diagnosis and if they were taking medications for hypertension. Participants were classified as either high or low blood pressure, with criterion for "high" blood pressure being a systolic blood pressure (BP) ≥140, and/or diastolic BP ≥90 or self-report of high blood pressure diagnosis.

2.2.3. Nausea assessment

One of the risks associated with virtual environments is, in rare cases, nausea. A nausea questionnaire used in multiple studies (e.g., Moffat and Resnick, 2002) was included to determine whether an individual was experiencing severe nausea.

2.2.4. Virtual environments

All VEs were created using Unreal Tournament 2003 modified for use in navigation experiments (Epic Games, Rockville, MD, USA). All environments were run on a personal computer (PC) and presented on a 19″ monitor approximately 20″ away from the face in a dark room. Participants interacted with the virtual environment using a commercially available joystick (Thrustmaster Top Gun Fox 2 Pro, Guillemot Corporation, La Gacilly Cedex, France).

All participants received joystick/VE familiarization training before the test. Additionally, a speed test was administered in which all participants were required to meet a threshold proficiency at moving through a twisting virtual hallway. Participants repeated the task until they completed it in less than 120 seconds (see Table 1).

2.2.5. Protocol

The navigation tasks took place in the following phases: virtual Y-maze strategy assessment (vYSA), virtual Morris water task (vMWT), and cognitive mapping assessment. On the vYSA, virtual environment order, starting location, and training route were counterbalanced within each group to avoid environment order, location, or turn preference effects.

2.2.6. Virtual Y maze strategy assessment

In order to determine pre-existing preferences for allocentric vs. egocentric strategy use, a virtual Y-maze strategy assessment was created. The maze consisted of 3 arms of equal length, connecting in the center, distributed at 120° intervals, and slightly recessed into the floor of a larger virtual room of irregular shape and containing both distal and proximal visual cues. Participants were not able to leave the recessed area, but were easily able to see out of it into the surrounding room. Each arm of the maze terminated with a circular goal area. The vYSA consisted of 5 blocks of 2 parts each: training and probe. Each block was completed in a different vYSA environment. During the training portion of each block, participants completed multiple trials starting at a given location and terminating in 1 of the 3 circular goal areas. See Fig. 1 for the layout of starting points and goal areas in the vYSA. Each trial terminated when the participant reached a goal area. When participants entered the correct goal area, a pleasing tone sounded. A noxious buzzer sounded when participants entered the incorrect goal position. Training continued until participants reached a criterion level of 5 consecutive successful learning trials. See Fig. 1a for a diagram of this procedure.

For the probe trial of each block, participants were placed at a third position that was neither the starting location nor the goal location for preceding training trials (Fig. 1b). Participants were allowed to move to whichever goal position they preferred, at which point neither tone sounded. The vYSA probe trial was designed to determine allocentric or egocentric strategy preference. Participants who, during the probe, followed the same route they learned in training, regardless of absolute location (e.g., turn right), were classified for that block as using an egocentric strategy. Participants who moved to same absolute location as trained in the training trials, even though it required taking a different route were classified as using an allocentric strategy for that trial.

In order to increase the reliability of our vYSA and ensure stability of strategy preferences, participants completed 5 separate blocks of vYSA training and probe trials and were required to choose the same strategy for at least 4 of the 5 blocks in order for that participant to be classified as preferring 1 strategy over another. Participants (n = 8 young adults; 5 older adults) who did not demonstrate the same strategy preference for 4 or 5 of the 5 vYSA assessments were eliminated from analysis.

2.2.7. Virtual Morris water task

In the interests of investigating the relationships between initial preferences for a specific navigation strategy and other independent measures of navigation ability, participants were tested on a virtual Morris water task (vMWT). Participants completed 10 learning trials followed by 1 probe trial. For all trials, participants navigated through a circular pool contained in a large, nonsymmetrical virtual room. Four objects were situated close to the edge of the pool, and 2 objects or features were situated more distally in the environment. For learning trials, participants were placed in the environment randomly at 1 of 6 potential starting positions inside the pool area. Participants were instructed that their goal was to find a hidden platform. When located, the platform lifted participants out of the water, accompanied by a pleasing tone. If the participant did not find the platform after 90 seconds, a discordant buzzer tone sounded, the participants were frozen in place, and

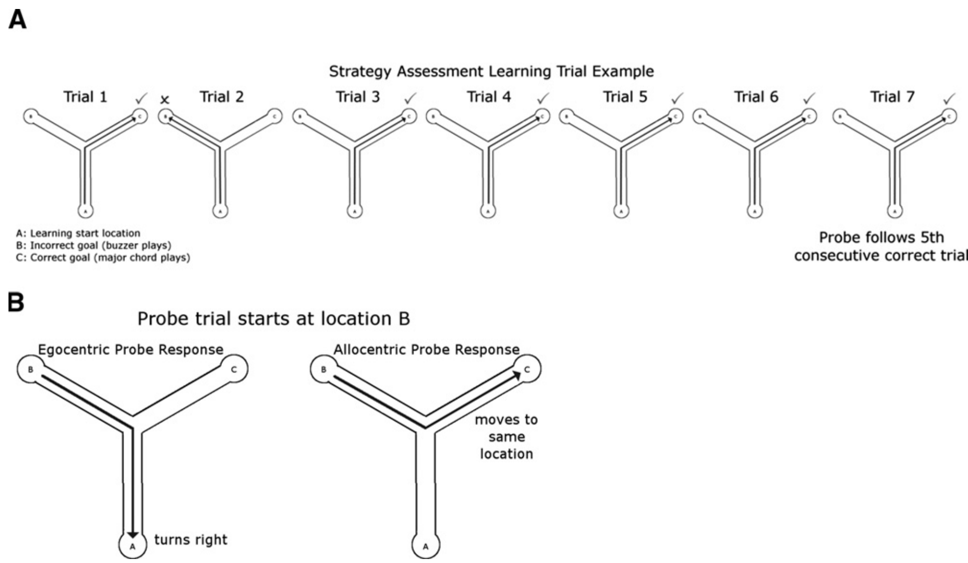

Fig. 1. Experimental sequence of Y-maze tasks including sample training paths and probe start locations. (A) Sample learning block of the Y-maze strategy assessment (vYSA). In this sample, the participant starts at location A with location C being designated as the goal. In trial 1, participant has free choice and chooses correctly (as indicated by the "check mark"). On trial 2, the participant restarts in the same position and makes an incorrect choice (as indicated by "X"). This procedure continues until the participant travels to the reinforced location for 5 consecutive trials, triggering the probe. (B) Probe trial. In the probe trial, participants start in the location that was neither the original starting location nor the reinforced location. Shown are examples of an egocentric and allocentric probe response, respectively.

participants were allowed to look around the environment, followed by the beginning of the next trial. The dependent variable on the learning trials was the latency to reach the platform on each trial.

In the probe trial, the platform was removed and participants began at 1 of the 6 starting locations and were instructed to locate the platform. Unlike training trials, the platform did not rise out of the water when occupied. After 90 seconds the probe trial ended. Dependent variable on the probe trial was the number of platform intersections (number of times the participant crossed over the location that previously contained the platform).

For the visible platform trial, participants started at a random point and were asked to move to the platform location which was marked by flags. The dependent variable was average latency to platform.

Following the completion of the vMWT, participants were presented with 3 overhead maps of the environment: 1 with only the objects surrounding the pool, 1 with only the room geometry present, and 1 with both objects and room geometry. Participants were asked to place the location of the hidden platform, and error (in mm) from the correct location was calculated for each map.

3. Results

3.1. Age differences on control measures

Means and standard deviations for all control measures are reported in Table 1. Due to significant skew and kurtosis, the speed test variable was submitted to a square root transformation. Five outliers (1 each on the speed test, total platform crossings, swim trial latency, diastolic blood pressure, and vYSA average time variables) were found by transforming scores into z-scores. Z-scores > 3.29 were classed as outliers and were preserved in the data set by setting their value to the next highest value in the dataset plus 1 unit of measurement (Tabachnik and Fidell, 2006). Older adults required more time than younger adults to complete the speed task, $t(97) = -4.49$, $p < 0.001$ and reported lower scores on the CEQ compared with younger adults, $t(97) = 5.95$, $p < 0.001$. There was no difference between young and older adults on nausea questionnaire scores, $t(97) = .054$, $p = 0.96$. Both diastolic $t(97) = -6.68$, $p < 0.001$, and systolic, $t(97) = -4.209$, $p < 0.001$ blood pressure were higher in older adults. Using the previously described classification for hypertension status, 2 percent of the young participants were classified as hypertensive. Forty-seven percent of the older adults were classified as hypertensive.

Because there were significant age differences on speed, CEQ, and blood pressure status, these variables were entered as covariates in all of the following analyses. Except where specifically noted, these covariates did not reach statistical significance.

3.2. Age and sex differences in strategy preference on the vYSA

Of the 99 tested subjects, 86 reached criterion (at least 4/5 consistent strategy preferences) required for classifica-

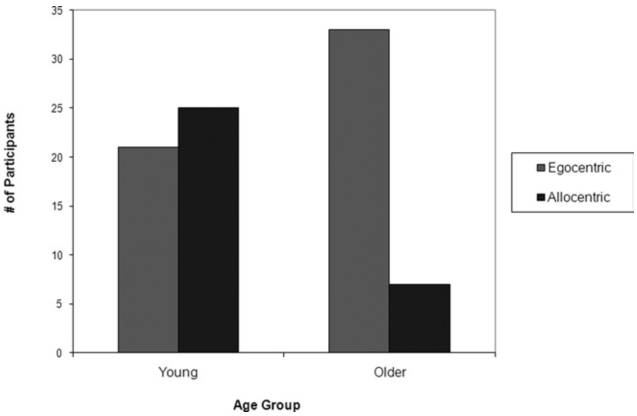

Fig. 2. Frequency plots describing strategy preference by age group on the Y-maze strategy assessment (vYSA). Older adults preferred an egocentric strategy whereas younger adults showed no marked preferences for egocentric or allocentric strategy.

tion into a strategy category.[1] Of the 13 who did not reach criterion, 8 were young (4 male, 4 female) and 5 were older (2 male, 3 female).

To investigate age differences in strategy preference, a χ^2 test was performed on age and strategy selection (Fig. 2). Strategy selection differed as a function of age group (χ^2 = 12.43, $p < 0.001$). Older adults overwhelmingly preferred an egocentric strategy (82% egocentric; 18% allocentric), while younger adults showed a modest preference for allocentric strategy (46% egocentric, 54% allocentric).

To investigate sex differences in strategy preference, a χ^2-test was performed on sex and strategy selection. Strategy selection did not differ as a function of sex ($\chi^2 = 0.003$, $p = 0.96$).

3.3. Effects of age, sex, and strategy on vMWT performance

3.3.1. Visible platform trial

In order to examine performance in the vMWT when the platform was visible, a 2 (young vs. old) by 2 (male vs. female) by 2 (egocentric vs. allocentric) analysis of variance (ANOVA) was computed with vMWT visible platform trial distance as the dependent variable. There was a main effect of age, $F(1,85) = 8.583$, $p < 0.001$, in which older adults (mean = 2930.60 units, SD =1757.76) traveled a longer distance to complete the task than younger adults (mean = 2283.30 units, SD = 582.29). There was no main effect for sex, $F(1,85) = .24$, $p = 0.62$, nor for strategy preference, $F(1,85) = .56$, $p = 0.46$. Due to the significant age difference, visible platform trial performance was entered as a covariate in all analyses of the vMWT, was not found to be a significant covariate, and was therefore excluded from analyses reported here.

3.4. Learning trials

To investigate the role of age, sex, and strategy on vMWT performance, a 2 (young vs. old) by 2 (male vs. female) by 2 (egocentric vs. allocentric vYSA strategy) analysis of variance was conducted using average completion latency of the learning trials as the dependent variable (Fig. 3). There was a main effect of age, $F(1,85) = 6.04$, $p = 0.02$; older adults took more time to complete the water maze than younger adults. There was no significant main effects of sex, $F(1,85) = .66$, $p = 0.42$, or vYSA strategy preference, $F(1,85) = .60$, $p = 0.44$.

There was, however, a significant interaction between age and strategy preference $F(1,85) = 4.78$, $p = 0.03$. *T*-tests were conducted to determine the nature of this interaction. Young adults who preferred an allocentric strategy completed the vMWT maze more quickly than younger adults who preferred an egocentric strategy, $t(44) = 2.66$, $p = 0.011$, whereas, there was no effect of strategy preference in the older adults, $t(38) = -.562$, $p = 0.577$.

An interaction between age group and sex approached significance, $F(1,85) = 3.63$, $p = 0.06$. Although not statistically significant, the nature of the interaction was such that older females took longer to complete the vMWT learning trials than younger females, $t(44) = -3.24$, $p = 0.002$, older males, $t(38) = 2.11$, $p = 0.042$, and younger males, $t(42) = -2.03$, $p = 0.049$. None of the other groups differed in performance (all p's >0.24). There was no strategy preference by sex interaction, $F(1,85) = 1.17$, $p =$

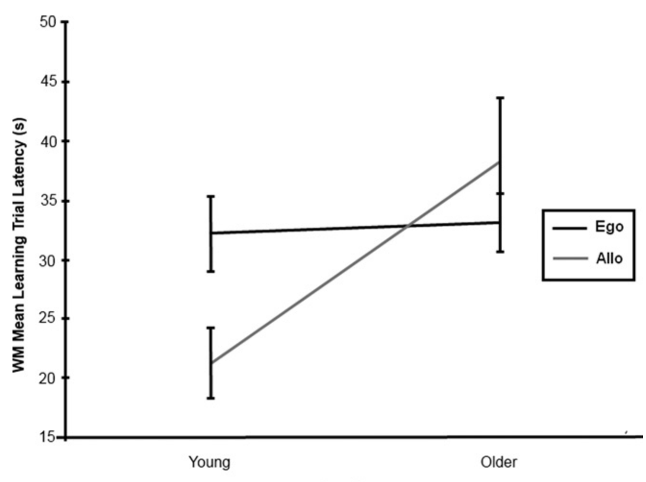

Fig. 3. Mean Morris water task (vMWT) Learning trial latency as a function of age and Y-maze strategy assessment (vYSA) strategy preference. There was a main effect for age, with older adults taking more time to complete the vMWT than younger adults. Younger adults who preferred an allocentric strategy on the vYSA completed the vMWT learning trials faster than all other groups. Older adults who preferred an allocentric strategy performed similarly to older adults who preferred an egocentric strategy.

[1] All analyses were also completed with a less stringent classification of 3 or more consistent strategy choices. As these analyses did not produce different results than the reported analyses, the more conservative classification system was maintained.

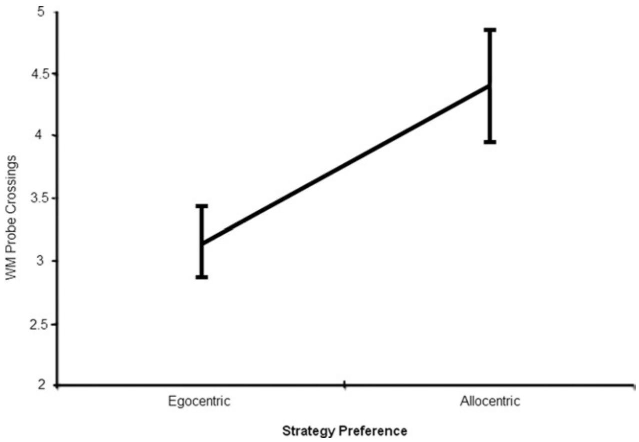

Fig. 4. Morris Water Task (vMWT) Platform Crossings as a function of Strategy Preference. Participants preferring an egocentric strategy on the Y-maze strategy assessment (vYSA) crossed the platform more often on the vMWT.

0.283, nor was there a strategy by age by sex interaction, $F(1,85) = 1.720$, $p = 0.194$.

3.5. Probe trial

In order to examine the effect of age, sex, and strategy on the probe trial of the vMWT, a 2 (young vs. old) by 2 (male vs. female) by 2 (egocentric vs. allocentric) ANOVA was computed with platform crossings during probe trial as the dependent variable. The speed test was a significant covariate, $F(1,85) = 5.76$, $p = 0.02$ and was therefore included in the analysis. There was a main effect of strategy preference, $F(1,85) = 5.42$, $p = 0.02$, with participants who preferred an allocentric strategy crossing the platform more often than those who preferred an egocentric strategy (Fig. 4). There was no main effect for age, $F(1,85) = 1.03$, $p = 0.31$, or sex, $F(1,85) = 2.27$, $p = 0.14$. There was no interaction between age group and strategy preference, $F(1,85) = .69$, $p = 0.97$, sex and strategy preference, $F(1,85) = 3.65$, $p = 0.06$, or age group, sex, and strategy preference, $F(1,85) = .434$, $p = 0.512$.

3.6. Cognitive mapping

In order to examine effects of age, sex, strategy preference, and map type on accuracy of platform placement, a 2 (young vs. old) by 2 (male vs. female) by 2 (egocentric vs. allocentric) repeated measures ANOVA was computed with placement error on the 3 map types as the repeated measure. There was a main effect of map type, $F(2,76) = 21.01$, $p < 0.001$, but not age or sex, p's >0.28. A least significant difference (LSD) posthoc test revealed placement error on the geometry only map to be significantly greater than either the objects only map or the objects + geometry map, p's <0.001. There was a main effect of strategy preference, $F(1,76) = 12.78$, $p = 0.001$ in which participants who preferred an allocentric strategy were more accurate at placing the platform than participants who preferred an egocentric strategy. There were no interactions involving age group or sex, (all p's >0.12) nor were there significant interactions involving map type (all p's >0.20).

4. Discussion

The present study tested age differences in human strategy preference in a new task based on a classic rat model reported by Barnes and colleagues (1980). Like Barnes' model, the test featured a training phase in which the participants had the opportunity to employ either spatial information (allocentric strategy) or route information (egocentric strategy). The probe trial provided an opportunity for participants to reveal to the experimenters which of the 2 types of information was employed to solve the task. Older adults were much more likely to choose an egocentric strategy than an allocentric strategy, while younger adults were more equally distributed between allocentric and egocentric strategy preferences. The difference in strategy in older adults was pronounced: only 7 of the 40 older adults preferred an allocentric to an egocentric strategy. This finding is the clearest empirical demonstration to date that older adults have different strategy preferences or biases in approaching spatial navigation tasks.

In the Barnes task, older rats were more likely to use an egocentric strategy to solve the maze than an allocentric strategy, and the reverse was true for middle aged rats, which preferred an allocentric strategy. The results of the present study are similar to Barnes' results, in that older adults were more likely to choose an egocentric strategy than young adults. In fact, older adults were overwhelmingly more likely to choose an egocentric strategy over an allocentric strategy, which departs somewhat from Barnes' results in which the age differences were more modest. This suggests that to the extent that there are species differences, human aging may be associated with a more marked shift toward egocentric strategy preference than in the rat.

Consistent with previous studies (Driscoll et al., 2005; Moffat and Resnick 2002; Newman and Kaszniak 2000), older adults took longer to solve the water maze than younger adults. The novel contribution of this study to the literature on age differences in vMWT performance is our demonstration that strategy preferences on an independent spatial task (the vYSA) may feed forward and predict behavior on the vMWT. Specifically, we found a significant interaction between age and strategy preference on the vYSA such that allocentric strategy preference on the vYSA was associated with more platform crossings on the probe trial and more accurate cognitive mapping. On the vMWT learning trials allocentric preference was associated with improved performance in the young but did not affect performance in the older group. Although our data indicated that allocentric strategy preference did not benefit performance in the vMWT learning trials in older adults, some caution is warranted in that we had very few older adults who evidenced an allocentric preference (n = 7); thus we may simply not have had the statistical power to detect a positive effect of allocentric spatial processing in older adults. In fact, our data suggest that a large number of older adults would have to be recruited and screened to achieve a sample size large enough to adequately test this hypothesis. Cumulatively, these results suggest that the vYSA is measuring an important preference for a spatial navigation strategy. Importantly, by demonstrating effects of vYSA strategy preference on subsequent vMWT performance our results suggest that the preferences identified on the vYSA feed forward and influence performance on other spatial tasks.

The relationship between strategy preference, age, and vMWT performance are consistent with and may help to explain the results from other studies on aging and spatial navigation. For example, Moffat and colleagues (2007) found that HC volume was related to water maze performance in the young, but not in the old. Similarly, functional imaging studies comparing older and younger adults in navigation tasks reliably show reduced or absent hippocampal/medial temporal lobe activation in the older adults (Antonova et al., 2009; Meulenbroek et al., 2004; Moffat et al., 2006). Based on these findings, researchers have speculated that young individuals may solve navigation tasks using an allocentric strategy whereas older individuals may use a response or egocentric strategy, thus minimizing or eliminating HC involvement in navigation performance in the elderly. The present study provides empirical support for this proposition by showing explicitly that older individuals have a marked preference for egocentric solution strategies.

Given that allocentric processing is thought to be dependent on the hippocampus and surrounding areas, (Holdstock et al, 2000; Jordan et al., 2004), and that HC volume declines with age in humans (Raz et al., 2005), it is reasonable to suggest that allocentric processing is especially sensitive to HC atrophy in aging. This is consistent with long standing observations regarding deficits in spatial cognition as an early sign of age-related cognitive impairment, including dementia (Logsdon et al., 1998; Passini et al., 1995). While relying on overlapping neural structures, egocentric navigation does not rely on the hippocampus and is instead primarily reliant on the caudate nucleus (Bohbot et al., 2007; Iaria et al., 2003). The present results suggest that the behavioral manifestation of age-related alterations in medial temporal lobe structure and function may be a reduced reliance on allocentric strategies and, as a result, a much greater reliance on egocentric solution strategies with advancing age. The timing of these changes is not known, and only longitudinal studies would be able to address the timing of these behavioral and brain changes.

While the vYSA found age differences in strategy, no relationship was found between sex and strategy preference. While there is some evidence of a male bias for an allocentric strategy (Levy et al., 2005), other results are not entirely consistent with this (Schmitzer-Torbert, 2007). Further research is needed to determine what, if any, impact sex might have on navigation strategy and how this might be mediated at the neuroanatomical level and how this may be impacted by different environmental characteristics and task demands.

A weakness of the present study was the lack of an egocentric task to parallel the vMWT. It is possible that participants who preferred an egocentric strategy on vYSA might show an advantage when faced with an egocentric task. In addition, self-report of strategy was not collected in our study, making it impossible to compare self-reported strategy with observed strategy on vYSA. Self-reported strategy was deliberately not collected following the vYSA in this study in order to avoid cueing individuals to the nature of the study and possibly influencing their behavior on subsequent tasks. Finally, this study employed a cross-sectional design rather than a longitudinal design, leaving the question open as to whether the age differences observed here would be reflected in within individual changes.

In summary, the present study provided evidence for age-related differences in strategy preference in revealing that older adults are more likely to prefer an egocentric navigation strategy. This overwhelming preference for egocentric strategies in older adults may be a consequence of functional and anatomical changes in the HC and related medial temporal structures. Although this reliance on egocentric processing might negatively impact performance on some navigation tasks, it may also reflect adaptation to a changing brain. Ultimately, results from the present study may lead to specific strategy training interventions that could ameliorate some of the age-related deficits in navigation.

Disclosure statement

The authors have no financial, personal, or other conflicts of interest regarding the material presented in this report.

Ethical oversight: All research and methods described in this report were conducted under the supervision and approval of the Wayne State University Human Investigations Committee.

Acknowledgements

This research was conducted in partial fulfillment of a Master's degree, and was funded in part by the Wayne State University College of Letters, Arts and Sciences via a grant for Master's degree research to MKR.

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