

Age-Related Changes in Spatial Navigation Are Evident by Midlife and Differ by Sex

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Introduction

Spatial Navigation

Definition:

how we update our position and orientation in space, learn new location layouts, and plan routes to goal locations in known environments

Spatial navigation serves as a promising behavioral marker for detecting individuals at risk for dementia

Sex Differences



About 2/3 of Alzheimer's disease patients are women, suggesting that sex plays a role in disease risk

Neuroendocrine changes during the midlife transition to menopause may be a sex specific risk factor for Alzheimer's. Previously found: brain regions particularly sensitive to sex steroid hormones changes include key regions within the brain's navigational circuitry

suggests that considering sex differences in age-related changes in navigational ability could be critical for early detection of neurodegenerative disease risk



Aspects of Navigation

Path integration

- updating of one's position and orientation during self-motion without external landmarks and relies on internal senses of self-motion from proprioceptive and vestibular systems, as well as visual information from optic flow
- older adults impaired on path integration
- unknown if these deficits are present earlier in the aging process unclear if sex differences in path integration exist at any point across the life span

Spatial Knowledge Acquisition

- ability to acquire spatial information, such as inferring how paths connect and where items are located in the broader environment
- sex differences in spatial-knowledge acquisition from both route learning and free exploration have been observed in young adults
- effects of aging on the ability to learn a spatial layout from unrestricted exploration are still unknown

Navigational Strategies

- the nature of the paths individuals select to navigate to a goal location in a known environment
- sex differences in navigation strategy have been observed in young adults: women are more likely to follow well-learned routes using cues from landmarks, whereas men more often use knowledge of environment spatial layouts to infer a shortcut to a goal location
- older adults are more likely to follow established routes than take novel shortcuts
- navigational strategies have yet to be examined earlier in the aging process



Materials & Methods



Participants learned environments in desktop and walking VR



Paths that participants took were analyzed

Probed the three essential aspects of spatial navigation to find if behavioral deficits are detectable in early stages of the aging process → analysis of such changes in the healthy aging brain and within sexes would help establish early behavioral signs of memory diseases

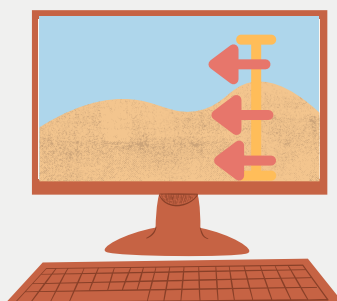


Tasks

1

Loop Closure Task

VR task to test path integration



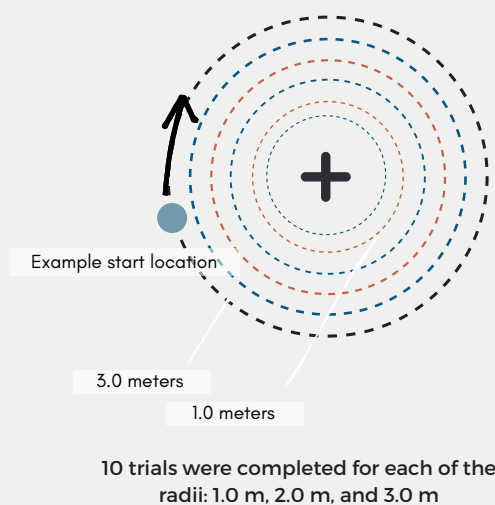
Description:

In a desert VR landscape, participants walked along a circular loop on the circumference of the circle. At the beginning of each trial, an orange pole marked the starting point. Participants clicked a button on a wireless remote to indicate when they thought they returned to the start location after travelling in the circular path.

Primary dependent variables: **position error and variability**

Position error: the straight-line distance between the actual starting location for each trial and the location that the participant indicated was the start. Total degrees traveled represents the number of degrees traveled around the circular path (which can be greater than, less than, or equal to 360°).

Variability of position error and degrees traveled: the within subjects standard deviation across the 10 trials at each radius. Variability across trials could indicate how well the participants were able to integrate the cues on a consistent basis; high variability could indicate less certainty in the integration



Maze-Learning Task

VR task to test spatial knowledge acquisition

2

Description:

Each trial began with participants starting at one object and being instructed to navigate to another object within a 45 second time period. A total of 24 trials were completed.

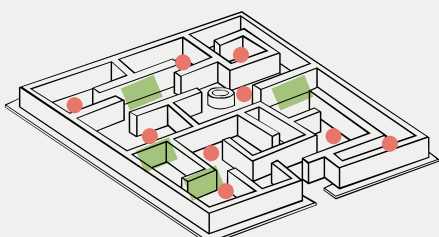
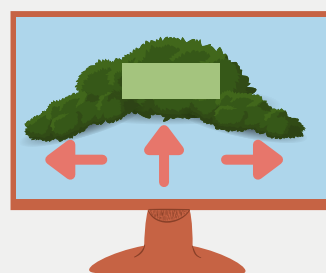


Figure similar, but not equivalent to actual overhead view

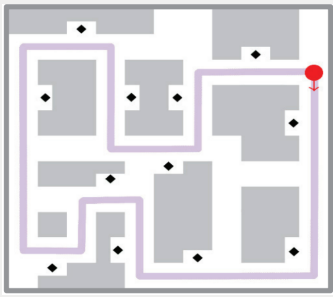
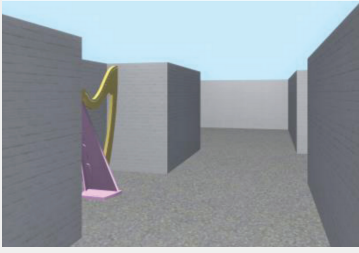
ANOVA and Pearson's correlation were used to analyze sex differences and how the number of moves is related to navigational success, respectively.

3

Dual-Solution Paradigm

VR task to test individual differences in navigational strategy

Description:



(purple line indicates guided fixed route shown to participants during learning phase)

The maze consisted of an environment with 12 landmarks (marked with red stars). All participants in the dual-solution paradigm followed a set route (no free exploration), giving them all the same learning experience (guided along same route through the maze five times, through landmark locations). During testing, they were placed at one object in the maze and instructed to navigate to another. All objects were visible in the test phase. Participants had 40 s to find each target object, with a total of 20 trials. Trials were coded to determine whether participants took the learned route or a novel shortcut when navigating to the target object

Dependent variables:

Wayfinding success (based on route experience) is the proportion of trials on which the participant reached the target object within the time limit. The solution index was also calculated, defined as the number of shortcuts divided by the number of successful trials. A 2 (age group: midlife, young) × 2 (sex: women, men) between-subjects ANOVA was performed on each dependent variable. Heat maps were generated to provide a qualitative assessment of participants' routes in the virtual environment by extracting their location every 100 ms per trial.

Overall Results

Loop Closure Task

In summary, position error was similar across young and middle-aged men and women, whereas the analysis of degrees traveled showed that women tended to overshoot the start location estimate in the task and men tended to undershoot. Overall, performance accuracy for this task suggests insignificant effects of age and sex on path integration ability.

Maze-learning task

Young participants performed significantly above chance in comparison to midlife participants on the measure of wayfinding success. A Pearson's correlation test determined that wayfinding success was related to how much participants explored the maze (measured by # of moves). Younger adults made more moves than midlife adults, indicated by a ANOVA, with the sexes performing similarly. Overall, men showed a steep age-related deficit in wayfinding success. The sex difference favoring men in young adulthood was eliminated by midlife.

Dual-solution Paradigm

Young adults outperformed older adults on wayfinding success, and men outperformed women. Young adults also took more shortcuts than older adults, along with men taking more in comparison to women. Young men were more likely to take shortcuts through the maze center, while women of both age groups and midlife men favored the periphery learned route. In summary, men showed an age-related shift in wayfinding strategies, whereas both young and midlife women tended to take learned routes.