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Research report

Age and gender-related differences in a spatial memory task in humans

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HIGHLIGHTS

- Spatial memory decline with age.
- Sixty five-seventy four year-old groups showed the poorer performance.
- Females showed a pronounced decay in comparison with males.
- Gender differences were observed in 65–74 year-old group.

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ABSTRACT

Cognitive skills decline with age. Our ability to keep oriented in our surrounding environment was demonstrated to be influenced by factors like age and gender. Introduction of virtual reality based tasks improved assessment of spatial memory in humans. In this study, spatial orientation was assessed in a virtual memory task in order to determine the effect of aging and gender on navigational skills. Subjects from 45 to 74 years of age were organized in three groups (45–54, 55–64, 65–74 years old). Two levels of difficulty were considered. Results showed that males outperformed females in 65–74 years-old group. In addition to this, females showed a more noticeable poor performance in spatial memory than males, since memory differences appeared between all age groups. On the other hand, 65–74 year-old males showed an impaired performance in comparison with 45–54 year-old group. These results support that spatial memory becomes less accurate as we age and gender is an important factor influencing spatial orientation skills.

1. Introduction

Spatial memory is crucial to orientation and navigation through environments in our daily life. The medial temporal lobe region was demonstrated to be involved in spatial performance, specifically under conditions demanding the use of allocentric reference frames [29,39]. This brain region is also very sensitive to the passage of time. Hippocampal atrophy leads to important functional consequences, including a decline in spatial memory and navigational skills [17].

Several works have assessed spatial memory in old adults using virtual reality-based tasks [12,19,27,33]. Many of these elegant studies described a loss of mnesic abilities as we age. Although groups were representative, studies included wide age-ranges, comparing young-adults with old-adults. This comparison has demonstrated that young subjects perform better than old adults. However, since the age-range is around 20 years, it is difficult to establish at what age the brain suffers changes during maturity and how it happens in males and females. What is more, the high variability in behavioral and cognitive abilities in the old-adult samples as well as the different spatial skills in males and females make this task more complex.

Regarding the dimorphic performance in spatial tasks by males and females, different studies carried out in humans showed that males outperformed females and this can be seen at different ages [8,22] and several spatial tasks [3,5,8].

In recent years, assessment of spatial navigation in humans using virtual reality (VR) tasks, permitted to deeply explore this cognitive function [2,28]. In this line, the Boxes Room is a VR task based on the holeboard maze. This VR task was proved to be sensitive to dimorphic differences in spatial memory [5,22] and hippocampal disturbances, since performance is altered in patients with epilepsy with focus in the medial temporal lobe [6,31]. In addition, the adjustment of the task difficulty-level allowed researchers

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Table 1
Characteristics of the sample.

	Males		Females	
Groups	n	Mean (±SD)	n	Mean (±SD)
45–54-year-old	24	50.67 (2.44)	20	49.05 (2.42)
55–64-year-old	28	59.07 (2.88)	20	59.55 (3.14)
65–74-year-old	23	70.17 (2.42)	20	69.65 (2.23)

to adapt this test to different populations like children and old adults avoiding floor and ceiling effects [9,22,32].

The aim of this study was to examine the evolution of spatial memory in males and females throughout middle- and late-adulthood (from 45 to 74 years old) divided in three age groups (45–54, 55–64, 65–74). We hypothesized that group and gender differences would appear when using the correct level of difficulty of spatial navigation conditions.

2. Materials and methods

2.1. Participants

The sample comprised 135 subjects, 75 males and 60 females, and it was split into three age groups according to the study design: 45–54 year-old, 55–64 year-old and 65–74-year-old subjects (Table 1).

Subjects were recruited from social, entertainment and elderly centers in Almeria, Spain. Exclusion criteria included a history of psychiatric problem, neurological disorder, neurosurgery, intellectual disability, uncorrectable hearing and/or visual impairment or any other circumstance that could potentially interfere with performance. All subjects were volunteers and they provided written consent. This study was conducted in compliance with the European Community Council Directive 2001/20/EC and Helsinki Declaration for biomedical research involving humans.

2.2. Apparatus

A Hewlett Packard 2600-MHz portable computer equipped with 3 GB of RAM, a 15.4 XGA TFT color monitor (1920 × 1200 pixels) and a Logitech joystick were used to administer the Boxes-Room task. The computer provided auditory and visual feedback to the participants.

2.3. Procedure

Participants were informed about the task and were tested individually by trained psychologists. They were requested to use the joystick to move around the 3-dimensional room with 16 brown boxes symmetrically distributed on the floor (see also Ref. [5]). The aim of the task was finding the position of a number of rewarded boxes in 10 consecutive trials. When the participant was close enough to a box, it turned blue indicating that by pressing a button it was possible to open it. If a rewarded box was opened, it turned green and a pleasant melody sounded. If a wrong box was opened, it turned red and an unpleasant tone sounded. During the same trial, the open boxes remained green or red until the participants found all the rewarded boxes or the maximum trial duration (150 s) was reached. The rewarded boxes remained in the same locations during the experiment; accordingly subjects could improve performance from trial to trial. There were several stimuli in the room that disambiguated spatial locations, including several pictures, a window and a door (see Fig. 1). Individuals were asked to find the rewarded boxes as quickly as possible and avoid opening wrong boxes. There were four different starting positions (North, South, East and West) and they changed between trials. Subjects were not informed about spatial strategies or the position of the rewarded boxes.

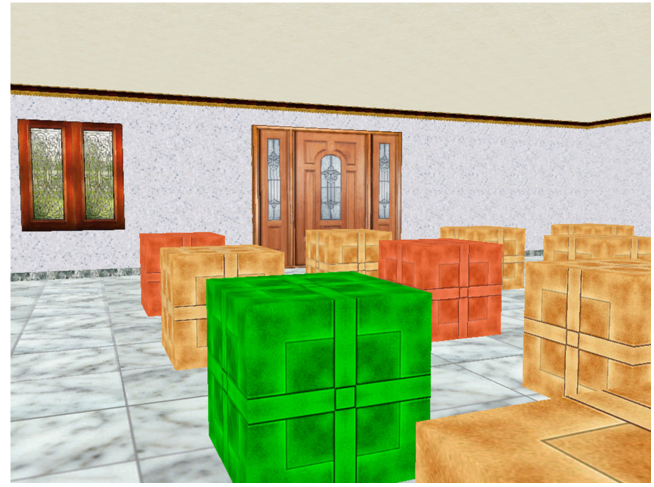

Fig. 1. Representation of the virtual room. Subjects have to search for the green boxes avoiding the red ones. Since the rewarded boxes (green) remained in the same position during ten trials, subjects can use their spatial memory to improve their performance during the experiment. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The evaluation included two conditions of difficulty: low difficulty (one rewarded box) and high difficulty (three rewarded boxes). Each condition consisted of ten trials and the inter-trial interval was 5 s. All subjects completed the two conditions.

2.4. Statistical analyses

The number of errors were analyzed applying a four-way ANOVA (Age × Gender × Difficulty × Trial) with repeated measures in the last two factors. Mauchly's test was considered for ANOVA's sphericity assumption for repeated measures. If the sphericity was not met ($p < 0.05$), Greenhouse-Geisser correction was applied. For post hoc analysis Newman-Keuls test were applied. The interpretation of effect size was done according to Cohen [10].

The first trials of both experimental conditions (low and high) were removed from all analyses because participants opened boxes totally at random. Analyses were carried out with the statistical package IBM-SPSS (version 21). Results with $p < 0.05$ were considered statistically significant.

3. Results

ANOVA revealed a significant main effect of Age $F(2,129) = 25.9$, $p < 0.0001$ partial $\eta^2 = 0.28$, Gender $F(1,129) = 4.92$, $p > 0.05$ partial $\eta^2 = 0.03$, Difficulty $F(1,129) = 112.2$, $p < 0.0001$ partial $\eta^2 = 0.46$ and Trial $F(5.54, 715.13) = 59.4$, $p < 0.0001$ partial $\eta^2 = 0.31$. In addition, Age × Gender interaction was significant $F(2, 129) = 3.46$, $p < 0.05$ partial $\eta^2 = 0.051$, as well as Age × Difficulty $F(2,129) = 7.36$, $p < 0.001$ partial $\eta^2 = 0.1$ and Gender × Trial $F(5.54, 715.13) = 2.65$, $p < 0.05$ partial $\eta^2 = 0.02$. There were no other significant interaction terms. The assumption of sphericity was not met for Difficulty and Trial and Greenhouse-Geisser correction was applied.

Post hoc analysis of the interaction term Age × Gender revealed gender differences in the 65–74 year-old groups with males outperforming females (Fig. 2). Moreover, 65–74 year-old females committed more errors than all the other groups whereas males only made more errors than 45–54 year-old groups ($p < 0.05$) (see Figs. 3 and 4).

Analysis of the interaction term Age x Difficulty showed that the more difficulty the more errors in the task. In addition, 45–54 year-